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

Greater Yellowstone Ecosystem

At 3,437.5 square miles (8,903 km^2),Yellowstone National Park forms the core of the Greater Yellowstone Ecosystem—one of the largest nearly intact temperate-zone ecosystems on Earth. Greater Yellowstone's diversity of natural wealth includes the hydrothermal features, wildlife, vegetation, lakes, and geologic wonders like the Grand Canyon of the Yellowstone River.

Heart of an Ecosystem

Yellowstone National Park was established in 1872 primarily to protect geothermal areas that contain about half the world's active geysers. At that time, the natural state of the park was largely taken for granted. As development throughout the West increased, the 2.2 million acres (8,903 km^2) of habitat that now compose Yellowstone National Park became an important sanctuary for the largest concentration of wildlife in the lower 48 states.

The abundance and distribution of these animal species depend on their interactions with each other and on the quality of their habitats, which in turn is the result of thousands of years of volcanic activity, forest fires, changes in climate, and more recent natural and human influences. Most of the park is above 7,500 feet (2,286 m) in elevation and underlain by volcanic bedrock. The terrain is covered with snow for much of the year and supports forests

Quick Facts

Space and Ownership

- 12–22 million acres; 18,750–34,375 square miles (sizes, boundaries, and descriptions of any ecosystem can vary.)
- States: Wyoming, Montana, Idaho
- Encompasses state lands, two national parks, portions of five national forests, three national wildlife refuges, Bureau of Land Management holdings, private and tribal lands.
- Managed by state governments, federal government, tribal governments, and private individuals

Wildlife

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

Management Challenges

- Climate change
- Invasive species
- Managing an ecosystem across political boundaries
- Land use change
- In Yellowstone:
  - Bison management
  - Grizzly bear management
  - Native fish conservation
  - High visitation

dominated by lodgepole pine and interspersed with alpine meadows. Sagebrush steppe and grasslands on the park's lower-elevation ranges provide essential winter forage for elk, bison, and bighorn sheep.

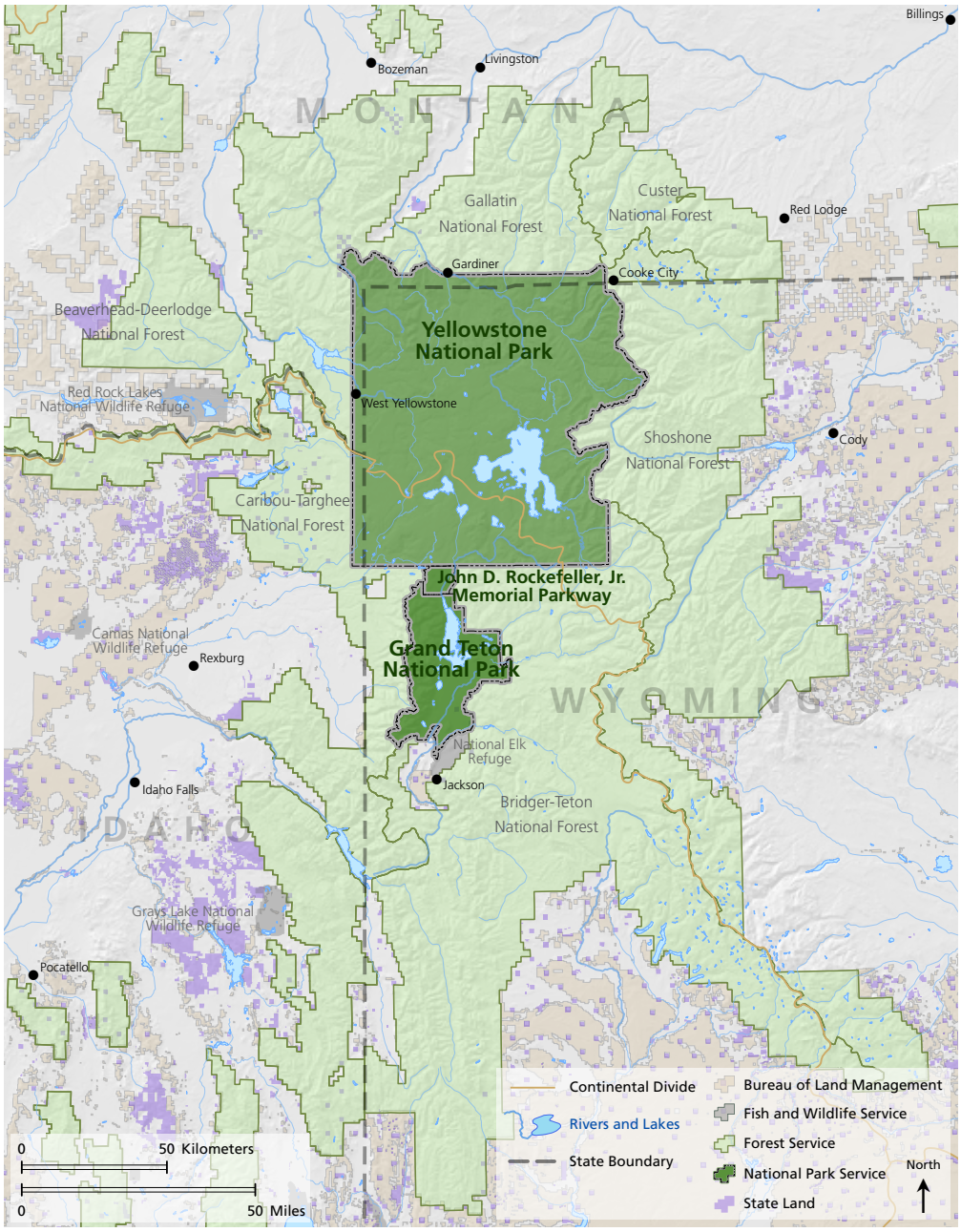
Influence of Geology

Geological characteristics form the foundation of an ecosystem. In Yellowstone, the interplay between volcanic, hydrothermal and glacial processes, and the distribution of flora and fauna, are intricate. The topography of the land from southern Idaho northeast to Yellowstone probably results from millions of years of hot-spot influence. Some scientists believe the Yellowstone Plateau itself is a result of uplift due to hot-spot volcanism. Today's landforms even influence the weather, channeling westerly storm systems onto the plateau where they drop large amounts of snow.

The volcanic rhyolites and tuffs of the Yellowstone Caldera are rich in quartz and potassium feldspar, which form nutrient-poor soils. Thus, areas of the park underlain by rhyolites and tuffs generally are characterized by extensive stands of lodgepole pine, which are drought-tolerant and have shallow roots that take advantage of the nutrients in the soil.

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

Because of the influence rock types, sediments, and topography have on plant distribution, some scientists theorize that geology also influences wildlife



The Greater Yellowstone Ecosystem. Description of an ecosystem's size, boundaries, and characteristics can vary greatly.

distribution and movement. Whitebark pine nuts are an important food source for grizzly bears during autumn. The bears migrate to whitebark pine areas such as the andesitic volcanic terrain of Mount Washburn. Grazing animals such as elk and bison favor the park's grasslands, which grow best in soils formed by sediments in valleys such as Hayden and Lamar. The many hydrothermal areas of the park, where grasses and other food remain uncovered by snow, provide sustenance for animals during winter.

Air Quality

The Clean Air Act Amendments of 1977 designated Yellowstone and Grand Teton among the 156 national parks and wilderness areas as Class I airsheds, requiring the most stringent air-quality protection within and around their boundaries. Yellowstone and Grand Teton are in compliance with federal air quality standards for human health. However, air-quality trends may be affecting other aspects of the ecosystem. Even at relatively low levels, such as those found in the Greater Yellowstone Ecosystem, air pollution and the subsequent deposition of pollutants in water and soil can leach nutrients from the Earth, injure vegetation, and acidify and over-fertilize lakes and streams.

The thin soils, sparse vegetation, short growing seasons, and snow-based water supply of these high elevation areas limit the amount of nitrogen that plants can effectively use. These conditions make the area more vulnerable to the effects of acidification and nutrient enrichment from nitrogen deposition. For example, nitrogen in precipitation has increased at many western sites as a result of fertilizer use and feedlots. Although nitrogen is a nutrient needed for plant growth, too much nitrogen disrupts native plant communities that are adapted to low-nitrogen conditions; high nitrogen levels can advance the spread of nonnative species that increase fire frequency. Acidification of high-alpine lakes from sulfur and nitrogen deposition can cause the loss of macroinvertebrates and fish. Long-term changes in the composition of algae in several alpine lakes in Yellowstone and Grand Teton are correlated with increased nitrogen.

Naturally occurring ozone in the upper atmosphere protects life by absorbing the sun's ultraviolet rays, while ground-level ozone is a pollutant that forms when nitrogen oxides from vehicles, power plants, and other sources combine with volatile organic compounds. Ozone concentrations in Yellowstone typically peak in spring rather than summer, indicating that human influences are less significant than changes in atmospheric circulation and lengthening daylight. Nonetheless, in addition to potentially causing respiratory problems in people, ozone levels during the growing season may be high enough to prevent sensitive species, such as aspen, from reaching full growth potential.

Sources of Particulate Matter

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

Soundscapes

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

The natural soundscape of the Greater Yellowstone Ecosystem delights visitors during the fall elk rut, during birds' spring choruses, along streams, and in the still and profoundly quiet winter days and nights. Natural soundscapes are a resource and are protected by National Park Service policies. Many visitors come to national parks to enjoy serenity and solitude and to hear sounds of nature. Sounds associated with human activity, including road traffic, aircraft, and snowmobiles, often impact these natural soundscapes and are a growing concern. Aircraft noise, the most widespread human-caused sound in the park, is heard on average for less than 10 percent of the day. Yellowstone and Grand Teton initiated a soundscape monitoring program in 2003.

More Information

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National Park Service Air Resources Division: www.nature.nps.gov/air.

Recordings of Yellowstone's Soundscape: https://www.nps.gov/yell/learn/management/yellowstone-soundscapes-program.htm

Yellowstone waters provide essential moisture to much of the American West and water resources provide recreational opportunities, plant and wildlife habitat, and scenic vistas.

Water

The water flowing through Yellowstone and the Greater Yellowstone Ecosystem (GYE) is a vital national resource. The headwaters of seven great rivers located here flow from the Continental Divide across the nation to the Pacific Ocean, and the gulfs of California and Mexico. Rain and snow in the mountains and plateaus of the Northern Rockies flow through stream and river networks to provide essential moisture to much of the American West. Together, Yellowstone's streams and rivers support an abundance of fish and wildlife, provide numerous recreational opportunities, and offer a lifeline for downstream agricultural users and municipalities.

Water also drives the complex geothermal activity in the region and fuels the largest collection of geysers on Earth. Precipitation and groundwater seep down into geothermal "plumbing" over days, and millennia, to be superheated by the Yellowstone Volcano and rise to the surface in the form of hot springs, geysers, mudpots, and fumaroles.

Yellowstone contains some 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. Thousands of small wetlands—habitats that are intermittently wet and dry—make up a small (approximately 3%), fraction of the Yellowstone landscape.

Waters of Yellowstone

Area of Yellowstone National Park	3,472 mi^2 (8,991 km^2)
Water surface area[2,3]	~5% of park area
Number of named lakes[1]	150
Surface area of named lakes[1]	24.7 mi^2 (63.9 km^2)
Number of lakes with fish[2]	~45
Number of named streams[3]	278
Total stream length[3]	2,172.52 mi (3,496,329 m)
Number of streams with fish[2]	~200

[1]Yellowstone Spatial Analysis Center data.
[2]Varley and Schullery 1998.
[3]GRYN Water Quality Report 2009.

Lakes

Yellowstone's inland lakes are essential aquatic habitat for resident species. They are largely protected from many of the environmental stresses to which waters outside the park boundaries may be victim. These lakes maintain freshwater biodiversity, support elaborate food webs, and underpin plant and animal communities. Understanding the complexities of Yellowstone's lake ecosystems allows park managers to successfully conserve Yellowstone's lake resources in the face of nonnative invasive species, climate change, and pollution.

Yellowstone Lake

Yellowstone Lake is the largest high-elevation lake (above 7,000 ft) in North America, covering up to 139 square miles, with an average depth of 138 feet, and just over 12,000,000 acre-feet of water. The lake is covered by ice from mid-December to May or June.

Yellowstone Lake Quick Facts

- Elevation: 7,731 feet (2,357 m)
- Surface area: 131.8–135.9 mi^2 (341–352 km^2)
- Perimeter (Shoreline): 141 miles (227 km)
- Deepest point is due east of Stevenson Island at 430 feet (131 m)

Entering Yellowstone Lake are more than 141 tributaries, but only one river. The Yellowstone River, which enters at the south end of the southeast arm, dominates the inflow of water and sediment flows out. The only outlet of the lake is at Fishing Bridge, where the Yellowstone River flows north and discharges 2,000–9,000 cubic feet per second.

Powerful geologic processes in Yellowstone National Park have contributed to the unusual shape of Yellowstone Lake, which straddles the southeast margin of the Yellowstone caldera. A smaller caldera-forming event about 174,000 years ago, comparable in size to Crater Lake, Oregon, created the West Thumb basin. Several significant glacial advances and recessions continued to shape the lake and overlapped the volcanic events. Glacial scour deepened the central basin of the lake and the faulted south and southeast arms. More recent dynamic processes shaping Yellowstone Lake include currently active fault systems, development of a series of postglacial shoreline terraces, and postglacial hydrothermal-explosion events, which created the Mary Bay crater complex and other craters. (See "Yellowstone Lake Geology" in chapter four, for more information.) Many of the area's 1,000 to 3,000 annual earthquakes occur under Yellowstone Lake, causing uplift and subsidence events which continually reshape the shoreline of the lake.

Yellowstone Lake is also the site of one of the most extensive conservation efforts in the National Park Service. Lake trout (*Salvelinus namaycush*), which were illegally introduced to Yellowstone Lake, have jeopardized the survival of the native population of cutthroat trout (*Oncorhynchus clarkii bouvieri*). See "Native Fish Species" and "Lake Trout" in the wildlife chapter for more information.

Lewis and Shoshone Lakes

Lewis Lake is fed by the Lewis River and other tributaries. Shoshone Lake, the park's second largest lake, is located at the head of the Lewis River southwest of West Thumb. Shoshone Lake is a valuable wilderness resource. Only accessible by foot, or by boat through the Lewis River Channel, one of the park's amazing geyser basins lies near the northwest shore. Shoshone Lake is 205 feet at its maximum depth, has an area of 8,050 acres, and contains lake trout, brown trout (*Salmo trutta*), and Utah chub (*Gila atraria*). Originally, Shoshone Lake was barren of fish owing to waterfalls on the Lewis River. The two types of

trout were planted beginning in 1890, and the Utah chub was apparently introduced by bait fishermen. This large lake is the source of the Lewis River, which flows to the Pacific Ocean via the Snake River system. The US Fish and Wildlife Service believes that Shoshone Lake may be the largest lake in the lower 48 states that cannot be reached by road.

Heart Lake

Heart Lake is located at the south end of the park near the base of Mt. Sheridan. It sits in prime bear habitat, and there are several thermal areas along the northwest shore.

Rivers

Watersheds, or drainage basins, represent the surface area that contributes runoff to a particular river. The boundaries of a watershed are ridges or elevated areas which determine the direction surface water will flow. Any rain or snow that falls within the watershed will flow downstream to the basin's mouth, unless it is removed from the flow by evaporation, freezing, absorption as groundwater, or diversion for human use.

Yellowstone River

The Yellowstone River is 671 miles long. It is the longest undammed river in the lower 48 states. The headwaters of the Yellowstone are outside the

Yellowstone River delta

southeast park boundary on Younts Peak (Wyoming) and flow 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 across the North Dakota state line. Its watershed drains one-third of the state of Montana. It carves out the Grand Canyon of the Yellowstone in the middle of the park and runs over the Upper and Lower Falls and is home to Yellowstone cutthroat trout.

The Yellowstone River is among the top recreational river destinations in the US and provides opportunities for boating and fishing enthusiasts, birders, and for other forms of recreation. Additionally, the Yellowstone River serves many downstream communities (e.g., Billings, Montana) and is recognized regionally and nationally for economic importance to agriculture, industry, and municipalities.

Lamar River

The Lamar River originates on the east side of the park. Park boundaries were adjusted in 1929 to include the entire Lamar watershed in order to protect this major tributary of the Yellowstone River. The Lamar River is joined by Soda Butte Creek as it flows across the northern range to the outflow of Yellowstone Lake. The Lamar River Valley is home to wild pronghorn, bison rutting, bear habitat, the most consistent viewing of wild wolves in the world, and first-rate fly fishing.

Gardner River

The Gardner River originates in the northwest corner of the park and flows to the Missouri River. The Gardner flows into the Yellowstone first, joining near Rattlesnake Butte at the north entrance to the park.

Snake River

The Snake River—a major tributary of the Columbia River—originates in Yellowstone National Park, and then turns south, passing through the John D. Rockefeller, Jr., Memorial Parkway into Grand Teton National Park. The river flows through Idaho and joins the Columbia River in Washington.

The Snake River is 1,040 miles long (1,674 km); 42 miles (68 km) of it are in Yellowstone National Park. The river feeds Jackson Lake—a natural lake augmented by a dam, resulting in regulated downstream flows since 1907.

Visitors enjoy a multitude of recreational opportunities on the river such as rafting, fishing, and photography. The river is home to a wide variety of riparian and aquatic species, including the native Yellowstone cutthroat trout and an endemic variety, the Snake River fine-spotted cutthroat trout (*Oncorhynchus clarkii behnkei*). The 2009 Snake River Headwaters Legacy Act designated the river above Jackson Lake as a Wild and Scenic River. The Lewis River is a tributary of the Snake River.

Firehole River

Home to several species of trout, the Firehole River is a favored fly fishing spot. Most of the outflow from the park's geyser basins empties into the Firehole River causing it to be warmer with larger concentrations of

FREQUENTLY ASKED QUESTION

Does the Missouri River begin here?

No, but its three tributaries begin in the greater Yellowstone area. The Jefferson River 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.

Fishing on the Firehole River.

dissolved minerals (chemically richer) than other watersheds. The Gibbon and Firehole rivers join to form the Madison River. The Madison flows to Hebgen Lake, joins the Jefferson River and eventually the Missouri River on its way to the Gulf of Mexico.

Water Quality

The quality of the nation's waters is protected by laws and policy at local, state, and federal levels. To understand and maintain or improve water quality and aquatic ecosystems, resource managers take inventory and actively monitor water resources throughout the region. Water quality in a national park may reflect activities taking place upstream of the park's surface waters as well as within the park. The water quality in Grand Teton and Yellowstone national parks, where most of the watersheds originate on federally protected land, is generally very high. However, it is vulnerable to impacts such as road construction, recreational activities, and deposition from atmospheric pollutants.

A volunteer collects a water sample at Soda Butte Creek. Collection of water quality data has continued at fixed sites since 2002.

All Yellowstone waters are classified as Outstanding National Resource Waters, which receive the highest level of protection for surface waters under the Clean Water Act. Because of the relatively pristine nature of the park's surface waters, they are often used to establish reference conditions for the northern Rocky Mountain region. Although most of the park's watersheds originate within its boundaries and are minimally affected by human activities, they are vulnerable to impacts such as road construction, dewatering, atmospheric deposition, sewage spills, climate change, and runoff from mining activities outside park boundaries.

Long-term Water Quality Monitoring

Monitoring water quality continues to be a high priority for Yellowstone, with standardized data collected at fixed sites since 2002. This long-term data is used to evaluate overall ecosystem health, ascertain impacts of potential stressors (e.g., upstream impacts from legacy mines), identify changes that may be associated with water quality degradation, and guide resource management decisions related to water quality.

The characteristics of Yellowstone's surface waters are influenced by season, elevation, precipitation, surrounding vegetation, and wildfire. Some waters are also affected by the park's geothermal features, generally resulting in warmer temperatures and higher dissolved ion concentrations.

Most waters in Yellowstone meet or surpass national and state water quality standards. Geothermal influence on some park waters can result in failure to meet state drinking or recreational water quality standards. For example, arsenic levels in the Madison River at West Yellowstone exceeded the State of Montana's criteria on most sampling occasions. Arsenic in the Madison River is likely naturally occurring from geothermal geology in the watershed.

Park staff also monitor three sites on the park boundary where stream segments in the Yellowstone River drainage have been listed as impaired by the State of Montana.

Reese Creek

Irrigation by landowners north of the park has often reduced the lowermost reach of the stream during

mid-summer and fall. The water flow becomes unsuitable for sustaining native trout and overall biological integrity. The adjudicated water rights stipulate that the creek is to have a minimum flow of 1.306 ft^3/sec from April 15 to October 15. A stakeholder group of federal agencies, private citizens, and conservation organizations are working together on projects to maintain the flows in the main channel.

Soda Butte Creek

Soda Butte Creek is located near the park boundary, approximately 5 miles (8 km) downstream of the former location of the McLaren Mill and Tailings site. As a result of metal contamination from previous mining activity, dissolved and total metals (arsenic, copper, iron, and lead) persist in the floodplain. State and federal agencies completed a three-year effort to relocate mine tailings away from the floodplain and to reconstruct the former channel in 2014. Results from 2015 and 2016 monitoring activities in Soda Butte Creek downstream of the reclamation work show that iron levels associated with the former tailing site have been dramatically reduced.

The resulting data from recent monitoring also led to a determination in November 2017 by the Montana Department of Environmental Quality (DEQ) that metals conditions in Soda Butte Creek support designated beneficial uses. On November 27, 2018, the Montana DEQ officially removed Soda Butte Creek from the state's impaired waters [303(d)] list. The reclamation of McLaren Mill and Tailings site and subsequent removal from the 303(d) list represent important milestones in the restoration of Soda Butte Creek.

Yellowstone River at Corwin Springs

Similar to prior years, water samples were collected on the Yellowstone River from mid-April to mid-November 2019 and indicated that samples reqularly exceeded the EPA drinking water standard of 0.01 mg/L total arsenic but not the aquatic life criterion (0.15 mg/L). The higher total arsenic values in this drainage may be due to natural geological or geothermal influences on water chemistry.

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Staff Reviewer

Andrew Ray, Ecologist, Greater Yellowstone Network.

The ecological diversity of the Greater Yellowstone Ecosystem contributes to its value, and its controversy. Yellowstone's northern range has been the focus of debate since the 1930s.

Cycles and Processes

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

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

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

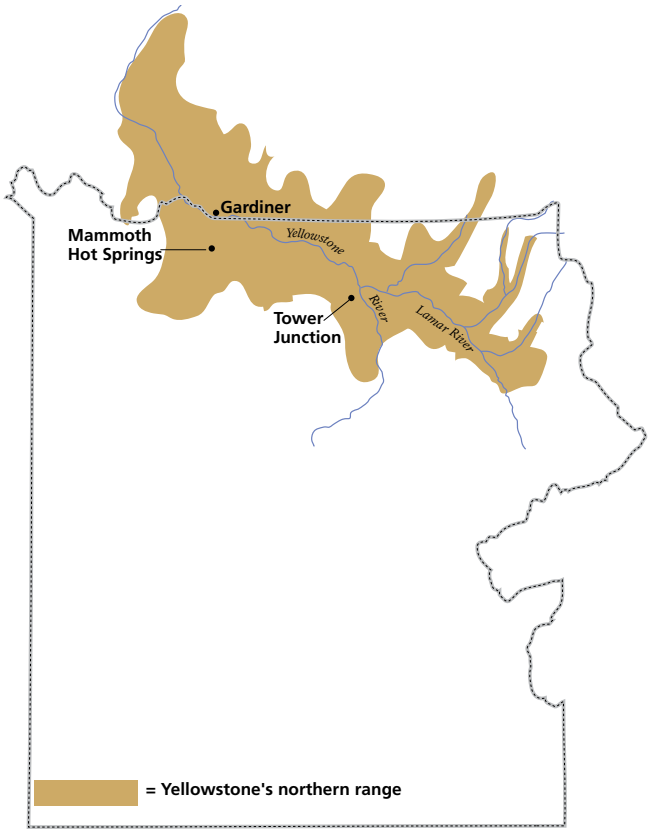
These cycles and processes are easily and frequently observed on Yellowstone's northern range, which refers to the broad grassland that borders the Yellowstone and Lamar rivers in the northern portion of the park and into Montana. This area sustains one of the largest and most diverse communities of 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 easier access to forage.

As a result of its incredible biodiversity, relatively complete ecosystem integrity, and year-round access, research conducted on the northern range has informed much of our current scientific understanding of native species and the ecological processes that sustain them.

Biodiversity

Each species—no matter how small—has an important role to play in a functioning ecosystem. They all participate in various ecosystem processes like transferring energy, providing nutrient storage, or breaking down pollutants. That is why biological diversity, or biodiversity, is a benchmark for measuring the health of an ecosystem. Biodiversity can be measured in many ways, including the number of different species (also called richness) and the abundance of each species (also called evenness).

The biodiversity and ecological processes that are protected in the park support a healthy ecosystem. Significantly, Greater Yellowstone's natural diversity is essentially intact. The region appears to have retained or restored its full historical complement of vertebrate wildlife species—a condition 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, from hydrothermal areas, to forests, meadows, and other habitat types. All of these are connected, by landforms, through links provided by streams and rivers that course through the changing elevations, and by the air that circulates between them.



The northern range is a broad grassland that borders the Yellowstone and Lamar rivers in the northern portion of Yellowstone and into Montana.

Biodiversity also supports the resilience of an ecosystem. When a variety of organisms contributes to ecosystem processes, an ecosystem can be more flexible through dynamic events like floods or fire. Knowledge of the park's biodiversity expanded in 2009 with Yellowstone's first bioblitz.

Intricate Layers

The reintroduction of the wolf to Yellowstone restored an important element 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, though not necessarily in the same numbers or distribution. But the wolf is only one factor in the extremely complex and dynamic community of wild Yellowstone. Since wolves were restored, scientists have discovered layers of complexity reaching far beyond the large mammals. For example, the carcasses of elk, bison, and other large mammals each become ecosystems of their own. Researchers have identified at least 57 species of beetle associated with these ungulate carcasses on the northern range. Only one of those species eats ungulate meat. The rest prey on other small scavengers, especially the larvae of flies and beetles. Others consume carcass by-products such as microscopic fungal spores. In this very busy neighborhood, thousands of appetites interact until the carcass melts away and everybody moves on.

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

Trophic Cascade

Wolf reintroduction created the chance to observe how a top predator influences its plant-eating prey and how changes in those prey influence plants. By reducing the abundance of herbivores or changing their feeding behavior, predators free plants from being eaten. This series of effects is called a "trophic cascade."

Accumulated studies show that the loss of wolves from the food web on the northern range in the 1930s led to a loss of willows and other woody plants due to excessive grazing by elk. Most researchers agree that reintroduced wolves have contributed to fewer elk and changes in elk behavior. Some studies have shown a correlation between the presence of wolves and increased growth in willows. However, not all scientists agree that this relationship is causal. For example, some researchers say elk don't linger in willow or aspen areas where visibility is poor and that this behavioral change prevents them from eating as much willow or aspen. Other scientists argue that fluctuations in the availability of ground water explain much of the growth patterns in woody vegetation. 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. Changes in precipitation and effects of global climate change are also affecting vegetation growth.

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 just one of many factors at work. Ongoing, long-term scientific research will continue to examine the complex fabric of the Greater Yellowstone Ecosystem.

Predators and Prey

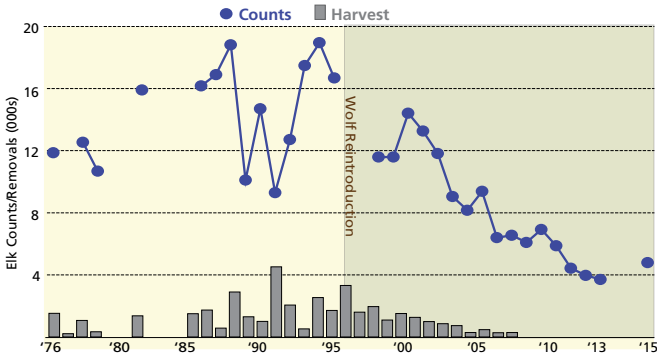
For the visitor, this community's complexity has been highlighted primarily through the large predators and

The processes of predation, scavenging, and eventual decomposition are just some of the ways that nutrients cycle in a dynamic ecosystem.

their prey species. This ecological "suite" of species provides a rare display of the dramatic pre-European conditions of wildlife in North America.

Consider the northern Yellowstone elk herd, which decreased in numbers from 1994–2010. Computer models prior to wolf recovery predicted a decline in elk and the decline has exceeded those predictions. However, prey populations that share their habitat with more species of predators are now thought to fluctuate around lower equilibria, and wolf recovery occurred simultaneously with increased grizzly bear and mountain lion populations, sustained human hunting of elk (especially female or "antlerless") north of the park, and an extended drought.

Elk are subject to predation by many 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, Montana, 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 migrated outside the park during winter and limit grazing of crops on private lands. During 1996–2002, approximately 5–19% (mean approximately 11%) of the adult female portion of counted elk were harvested each year during the late hunt. However, the hunt has not been held since 2009 due to decreased elk numbers.



Winter counts and hunting harvests of the northern elk herd in Yellowstone National Park and adjacent areas of Montana, 1976–2015. Counts were not adjusted for factors that may decrease the detection of elk.

Animal populations are not static and do not always stay at levels pleasing to humans. Instead, a more dynamic variability is present, which probably characterized this region's wildlife populations for millennia. 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 (elk calf survival). Nature does have balances, but they are fluid rather than static, flexible rather than rigid, and experience dynamic fluctuation as opposed to a steady state.

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.

Grazing and Migration

Grasses are an important part of the diet of most ungulates (hoofed animals) in Yellowstone. Bighorn sheep, bison, and elk rely on grasses for 50–80% of their food. Ungulates in this temperate mountain environment migrate seasonally and move selectively across the landscape following the new growth of grasses, when forage is at its most nutritious.

These ungulates eat green plants in the spring at lower-elevation winter ranges, before migrating higher in elevation with the wave of young, nutritious vegetation later in the growing season. Ungulates then return to the winter range in late autumn to access mostly dead, low-quality foods when deep snow covers the higher-elevation areas.

Intense grazing can degrade plant communities by removing vegetation, compacting soils, and reducing

the diversity of plants. Dense ungulate populations can also shift the composition and structure of plant communities. Studies of the northern range began to address the issue of overgrazing in the 1960s and have continued to the present. Early studies identified some over-browsing of riparian plants, but found no clear evidence of overgrazing.

The results of years of research and analysis, 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." The northern range is healthy and elk do 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.

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 resulted in less forage consumed and less intense feedbacks by elk on soil and plant processes, which likely 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.

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.

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

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

Seasons and Weather

A warming climate could influence the diet, nutrition, and condition of Yellowstone wildlife. Likely scenarios suggest a 1–3 degrees Celsius increase in average temperature during the 21st century, with a corresponding increase in annual rainfall—though it is unknown precisely how precipitation patterns will change and how those changes will affect the Yellowstone system.

"Too Many" or "Too Few"

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 overgrazing and overbrowsing, park managers removed ungulates—including elk, bison, and pronghorn—from the northern range by shooting or trapping from 1935 to the late 1960s. More than 26,000 elk were culled or shipped out of the park to control their numbers and to repopulate areas where over-harvesting or poaching had eliminated elk. Hunting outside the park removed another 45,000 elk during this period. These removals reduced the annual elk counts from approximately 12,000 to fewer than 4,000 animals.

As the result of public pressure and changing National Park Service conservation philosophy, park managers ended elk removals in the late 1960s and let a combination of weather, predators, range conditions, and outside-the-park hunting and land uses influence elk abundance. Without any direct controls inside the park, annual 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 ungulate on the northern range and composed more than 89% of documented wolf kills during winters from 1997 to 2008. Also, from 2002 to 2008, elk-calf survival (recruitment) and total number of the northern elk herd declined. Many factors (e.g., other predators, drought, winterkill, hunting) contributed to the low recruitment and decreased elk numbers. These trends 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.

Opinions about "too many" or "too few" assume there is an ideal, static ecosystem state to which we compare current conditions. Scientifically, no such condition exists. But in the scope of human values, everyone has an idea about how things "ought to be." Controversy arises when those different experiences and values conflict. For example, 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, on the other hand, tend to view the landscape in terms of the number of animals that a unit of land can optimally sustain. Range science has developed techniques that allow intensive human manipulation of the landscape for this goal, which is often economically based. Furthermore, many ecologists and wilderness managers 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.

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

Winter Ecology

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

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

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

Animal Adaptations

Deep snow, cold temperatures, and short days characterize winter in the Greater Yellowstone Ecosystem. Resident plants and animals are adapted to these conditions. 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.

Behavioral

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

FREQUENTLY ASKED QUESTIONS:

Is Yellowstone open in winter?

Yes, though not all roads are open to cars. 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 oversnow tours to Norris Geyser Basin, Old Faithful, and the Grand Canyon of the Yellowstone River.

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

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

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

How cold is Yellowstone in winter?

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

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.

- Grouse roost overnight by burrowing into snow for insulation.
- Bison, elk, geese, and other animals find food and warmth in hydrothermal areas.

Morphological and Physical

- Mammals molt their fur in late spring to early summer. Incoming guard hairs are longer and protect the underfur. Additional underfur grows each fall and consists of short, thick, often wavy hairs designed to trap air. A sebaceous (oil) gland, adjacent to each hair canal, secretes oil to waterproof the fur. Mammals have muscular control of their fur, fluffing it up to trap air when they are cold and sleeking it down to remove air when they are warm.
- River otters' fur has long guard hairs with interlocking spikes that protect the underfur, which is extremely wavy and dense to trap insulating air. Oil secreted from sebaceous glands prevents water from contacting the otters' skin. After emerging from water, they replace air in their fur by rolling in the snow and shaking their wet fur.
- Snowshoe hares, white-tailed jackrabbits, long-tailed weasels, and short-tailed weasels turn white for winter. White provides camouflage but may have evolved primarily to keep these animals insulated as hollow white hairs contain air instead of pigment.
- Snowshoe hares have large feet to spread their weight over the snow; martens and lynx grow additional fur between their toes to give them effectively larger feet.
- Moose have special joints that allow them to swing their legs over snow rather than push through snow as elk do.
- Chickadees' half-inch-thick layer of feathers keeps them up to 100 degrees warmer than the ambient temperature.

Biochemical and Physiological

- Mammals and waterfowl exhibit counter-current heat exchange in their limbs that enables them to stand in cold water: cold temperatures cause surface blood vessels to constrict, shunting blood into deeper veins that lie close to arteries. Cooled blood returning from extremities is warmed by arterial blood traveling towards the extremities, conserving heat.
- At night, chickadees' body temperature drops from 108°F to 88°F (42–31°C), which lessens the sharp gradient between the temperature of their bodies and the external temperature. This leads to a 23% decrease in the amount of fat burned each night.
- Chorus frogs tolerate freezing by becoming severely diabetic in response to cold temperatures and the formation of ice within their bodies. The liver quickly converts glycogen to glucose, which enters the blood stream and serves as an antifreeze. Within eight hours, blood sugar rises 200-fold. When a frog's internal ice content reaches 60–65%, the frog's heart and breathing stop. Within one hour of thawing, the frog's heart resumes beating.

Oversnow vehicles have become much cleaner and quieter under the park's new winter-use regulations. Here, a snowmobile guide checks in at the West Entrance in 2015.

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

Winter Soundscapes

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

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

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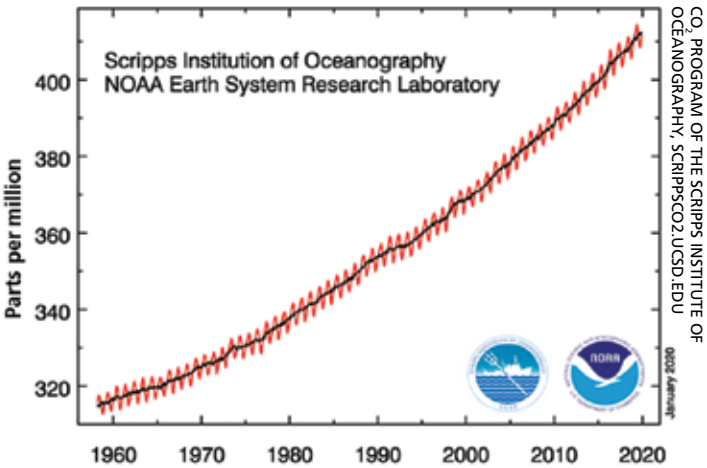
The global climate is changing, and is already affecting the Greater Yellowstone Ecosystem. Scientists predict wolverine, lynx, and pikas (shown here) may lose habitat in the park.

Climate Change

Today, climate change is no longer a vague threat in our future; it is the changing reality we live with, and it requires continuous planning and adaptation. Climate change presents significant risks to our nation's natural and cultural resources. Though natural evolution and change are an integral part of our national parks, climate change jeopardizes their physical infrastructure, natural and cultural resources, visitor experience, and intrinsic values. Climate change is fundamentally transforming protected lands and will continue to do so for many years to come. Climate change will affect everyone's experience of our national parks.

Some effects are already measurable. Warmer temperatures are accelerating the melting of mountain glaciers, reducing snowpack, and changing the timing, temperature, and amount of streamflow. These changes are expected to result in the loss or relocation of native species, altered vegetation patterns, and reduced water availability in some regions. Wildfire seasons have expanded, and fires have increased in severity, frequency, and size. More acres burned in the fire season of 2016 than in any year in the last century, except for 1988. Conditions that favor outbreaks of pests, pathogens, disease, and nonnative species invasion occur more frequently than in the recent past. In Alaska, melting sea ice threatens marine mammals as well as coastal communities, while thawing permafrost disrupts the structural basis of large regions, jeopardizing the physical stability of natural systems as well as buildings, roads, and facilities. Rising sea levels, ocean warming, and acidification affect wildlife habitat, cultural and historic features, coastal archeological sites, and park infrastructure, resulting in damage to and the loss of some coastal resources. Some studies suggest that extreme weather events such as thunderstorms, hurricanes, and windstorms that damage park infrastructure and habitat are increasing in frequency and intensity. Climate change will manifest itself not only as changes in average conditions, creating a "new normal," but also as changes in particular climate events (e.g., more intense storms, floods, or drought). These extreme climate events may cause widespread and fundamental shifts in conditions of park resources.

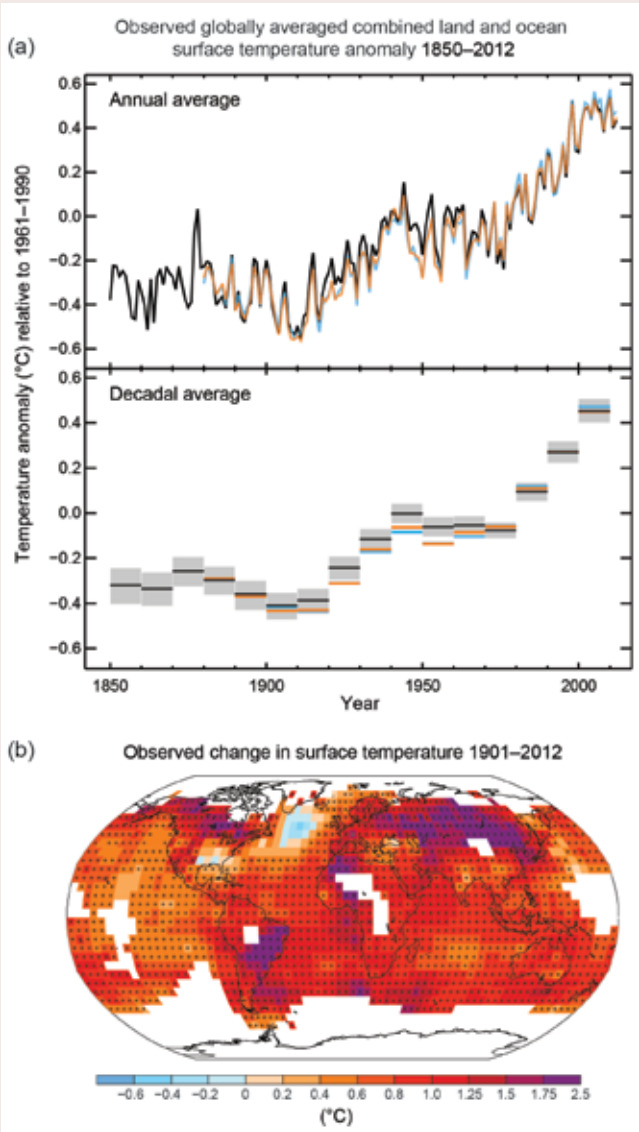
A 2014 assessment of the magnitude and direction of ongoing climate changes in Yellowstone National Park showed that recent climatic conditions are already shifting beyond the historical range of variability. Ongoing and future climate change will likely affect all aspects of park management, including natural and cultural resource protection as well as park operations and visitor experience. In order to deal with the predicted impacts, effective planning and management must be grounded in concrete information about past dynamics, present conditions, and projected future change.



Atmospheric concentrations of CO_2 began a marked increase that coincides with the Industrial Revolution. CO_2 levels rose by more than 20% from 1958 to 2019.

A History of Climate Change Awareness, Science, and Policy

- ~1760–1840: The Industrial Revolution (IR) begins a period in which greenhouse gases produced by human activities are added to the atmosphere in increasing amounts. Since the IR, global climate has changed faster than at any other time in Earth's history.
- 1827: Jean-Baptiste Joseph Fourier describes what is later termed the "greenhouse effect."
- 1896: Savre Arrehnius calculates that increasing atmospheric greenhouse gases will cause global warming.
- 1958: Charles David Keeling measures atmospheric carbon dioxide from Mauna Loa, Hawaii. Five years later he warns of 10.8°F temperature rise in next century.
- 1965: First Global Climate Models (GCM) developed.
- 1969: Weather satellites begin providing atmospheric data.
- 1988: The Intergovernmental Panel on Climate Change (IPCC) is established.
- 1997: Kyoto Protocol sets targets for greenhouse gas emissions for most industrialized nations (US does not sign).
- 2007: 4th IPCC report states, "Warming of the climate system is unequivocal."
- 2009: The Copenhagen Summit is held; an accord is reached for nonbinding actions to address climate change.
- 2010: The Greater Yellowstone Coordinating Committee (GYCC) forms the Climate Change Adaptation subcommittee to explore adaptation strategies for climate change impacts to the Greater Yellowstone Ecosystem resources.
- 2014: The 5th IPCC Synthesis Report details the current state of scientific knowledge about global warming trends.
- 2015: Yellowstone Science publishes a special issue (23-1) dedicated to the effects of climate change on park resources.
- 2015: The annual average of atmospheric carbon dioxide measured at Mauna Loa, Hawaii, was above 400 ppm for the first time in several million years.
- 2015: The Paris Agreement, a global agreement dealing with greenhouse-gas-emissions mitigation, adaptation, and finance, is adapted by consensus by 196 countries, including the US. The agreement's long-term temperature goal is to keep the increase in global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the increase to 1.5 °C (US withdraws in 2020).
- 2016: NASA, NOAA, and other international organizations identify 2016 as the hottest year on record (since 1880); the average global temperature was about 1.1 degrees C (2°F) warmer than pre-industrial levels.
- 2017: The Montana Climate Assessment (https://montanaclimate.org/) is completed and provides credible scientific information about climate change in Montana. This is the template for the on-going Greater Yellowstone Area Climate Assessment that will be available in 2021.
- 2018: The IPCC releases a special report, *Global Warming of 1.5 °C*, on the impacts of global warming of 1.5 °C above pre-industrial levels.



(a) Observed global mean combined land and ocean surface temperature anomalies from 1850 to 2012 from three data sets. Top panel: annual mean values. Bottom panel: decadal mean values including the estimate of uncertainty for one dataset (black). Anomalies are relative to the mean of 1961–1990. (b) Map of the observed surface temperature change from 1901 to 2012 derived from temperature trends determined by linear regression from one dataset (orange line in panel a). (From http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf Summary for Policy makers, IPCC report 5th, 2013.)

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

Changes in Yellowstone Climate

The Greater Yellowstone Ecosystem is a complex region, encompassing approximately 58,000 square miles and 14 mountain ranges. Weather varies greatly across steep elevational changes, bringing snowfall to some areas and warm, dry conditions to others. This dynamic system has provoked the curiosity of researchers for a long time.

Across Space and Time

Space and time are critical to the evaluation of real-world data, and every study defines their parameters differently. This can make it difficult to get a sense of what is actually occurring. Climate summaries over longer periods of time and across larger areas tend to mask local extremes. Conversely, a continuously changing set of short-term reference averages (weather "normals") could obscure the long-term magnitude of change. It is important to look at climate information across many scales and to use available data and models to arrive at reasonable answers to our questions about how climate has changed, how those changes will affect the park, and what impacts we may be able to anticipate in the future.

Analyzing smaller areas within the Greater Yellowstone Ecosystem (GYE), in Yellowstone National Park or on the Northern Range for example, poses specific challenges. Small regions have fewer actual monitoring stations to feed data to computer models, and gridded weather data are often used to fill in the gaps. As a consequence, small-area analyses may not be as accurate. Local field observations from stream gauge and weather stations can be used to verify some of the observed trends, as well as to describe local conditions to which the ecological system may be responding. This "ground-truthing" allows researchers to arrive at reasonable conclusions about ecological activity.

Temperature and Precipitation

Global temperature is the master force affecting climate. Everything else that climate affects—sea-level rise, growing season, drought, glacial melt, extreme storms—is driven by changes in temperature. Weather stations have been maintained within the GYE since 1894, resulting in some of the longest running records of temperature and precipitation anywhere in the United States. Increasingly sophisticated satellite technology and data yielded by climate models help climate experts and park managers assess the current situation in the GYE across several scales.

There is evidence that climate has changed in the past century and will continue to change in the future. Researchers looking at annual average temperatures report an increase of 0.31°F/decade within the GYE, consistent with the continuing upward trend in global temperatures. Recent studies show mean annual minimum and maximum temperatures have been increasing at the same rate of 0.3°F/decade for the GYE. Conditions are becoming significantly drier at elevations below 6,500 ft. In fact, the rise in minimum temperatures in the last decade exceeds those of the 1930s Dust Bowl.

Future Temperature and Precipitation

All global climate models predict that temperatures in the GYE will continue to increase. Projections of future precipitation vary based on differing scenarios that account for future levels of greenhouse gas emissions, which depend upon economic, policy, and institutional improvements, or lack thereof. Any potential increases in precipitation that may or may not occur will be overwhelmed by temperature increases. Considering the most recent trends in which warmer temperatures have been exacerbating drought conditions during the summers, a warmer, drier future for

the GYE appears likely in the coming decades. By the latter part of the 21st century, the hot, dry conditions that led to the fires of 1988 will likely be the norm, representing a significant shift from past norms in the GYE toward the type of climate conditions we currently see in the southwestern United States.

Snowpack and Snow Cover

Snowmelt in the alpine areas of the Rocky Mountains is critical to both the quality and quantity of water throughout the region, providing 60–80 percent of streamflow in the West. Throughout the GYE, snow often lingers into early summer at high elevations. Each year, a large spike in water flow occurs when snow starts to melt at lower elevations, usually in late February and early March. Peak flow is reached when the deep snow fields at mid and high elevations begin to melt more quickly, typically in June. Minimum flow occurs during winter when all the previous year's snow has melted, temperatures have dropped, and precipitation comes down as snow instead of rain so only water flowing from underground sources can supply the streams. By contrast, the proportion of stream flow due to rain storms is significantly lower than the contributions of snow melt.

Climate change is expected to affect both snow accumulation and rate of spring melt. In some places, warmer temperatures will mean more moisture falling as rain during the cooler months and the snowpack melting earlier in the year. The reduction in snowpack is most pronounced in spring and summer, with an overall continued decline in snowfall projected for Yellowstone over the coming decades. The Yellowstone, Snake, and Green rivers all have their headwaters in Yellowstone. As major tributaries for the Missouri, Columbia, and Colorado rivers, they are important sources of water for drinking, agriculture, recreation, and energy production throughout the region. A decrease in Yellowstone's snow will affect millions of people beyond the boundaries of the GYE who depend on this critical source of water (see *Water*, p. 60).

Future Snowpack and Snow Cover

The interactions of snowpack, temperature, and precipitation involve a complex interchange between heat and light. Warming temperatures increase evaporation; increased moisture in the air could lead to more snowfall and cloud cover. The increased cloud cover could block additional heat from reaching the surface of the Earth resulting in cooler temperatures

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

FREQUENTLY ASKED QUESTIONS:

Why do you say climate change now, instead of global warming?

Though the overall global temperature is increasing, the term "climate change" includes more of the actual impacts that we see as a result of this increase. Changing amounts of greenhouse gases in the atmosphere also lead to severe storms, drought, sea-level rise, insect infestations, and other consequences that can be different anywhere on Earth.

What is causing climate change?

Changes in climate are due primarily to human-caused emission of heat-trapping gases such as carbon dioxide (CO^2). These greenhouse gases have been on the rise since the 1800s, and their effect on climate will persist for many more decades. Levels of carbon dioxide and methane (another greenhouse gas) in the atmosphere are higher now than in the last 800,000 years. Scientists believe that as humans continue burning more and more fossil fuels, the impacts of global warming will accelerate.

Has global climate warmed before?

Yes, but never this fast. Prehistoric fossil records show us that Earth's climate is warming 40 times faster than during any other period in the planet's history.

Can you tell about climate from changes in the weather?

Weather is the temperature and precipitation patterns that occur over days or weeks. Climate is a trend in weather conditions over decades or centuries. While weather does play a part in our experience of climate, it is just one small corner of a much bigger picture.

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

> One of the most precious values of the national parks is their ability to teach us about ourselves and how we relate to the natural world. This important role may prove invaluable in the near future as we strive to understand and adapt to a changing climate.
>
> — Jon Jarvis, Former Director, National Park Service

below. However, increased temperature could possibly limit snowfall instead—by converting it to rain or by melting snow rapidly once it falls, thereby driving snowlines farther up the mountains. Recent modeling work indicates that snowpack will almost certainly decline in the long term.

Changes in the area covered by snow are especially important as snow reflects more solar radiation out to space (albedo) than bare ground and tends to keep the surface cool. When land is exposed, sunlight is absorbed by the surface of the Earth. This raises the overall surface temperature, which leads to more melting and less snowcover.

Stream Flow and Water Temperature

Glaciers, snowpack, and rainfall produce water that flows through streams, lakes, and rivers, and these waterways are critical to life. Analyses of streams from 1950–2010 in the Central Rocky Mountains, including those in the GYE, show an 89% decline in stream discharge. Reduced flows were most pronounced during the summer months, especially in the Yellowstone River. In addition, stream temperatures have changed across the range of the Yellowstone, with a warming of 1.8°F (-16.8°C) over the past century. Continued warming could have major implications for the management and preservation of the many aquatic resources we have today.

ECOSYSTEM

Climate Change and the Greater Yellowstone Ecosystem

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

- Average temperatures in the park are higher now than they were 50 years ago, especially during springtime. Nighttime temperatures seem to be increasing more rapidly than daytime temperatures.
- Over the past 50 years, the growing season (the time between the last freeze of spring and the first freeze of fall) has increased by roughly 30 days in some areas of the park.
- At the Northeast Entrance, there are now 80 more days per year above freezing than there were in the 1960s.
- There are approximately 30 fewer days per year with snow on the ground than there were in the 1960s.

The Ecosystem Elements
Climate change impacts are detected by studying the following:

- Vegetation
- Snowpack
- Phenology (timing of biological events like the budding of trees or arrival of migratory birds)
- Alpine habitats
- Wildlife movement patterns
- Water
- Fire
- Insect infestations
- Wetlands

The Impacts
The continued rise in temperature will fundamentally alter Yellowstone's ecosystem:

- Composition of plants and animals throughout the park will likely be affected.
- Amount and timing of spring snowmelt, affecting water levels, vegetation growth, and movement of wildlife—from migrating bison, to spawning trout, and arrival of pollinators —will be altered. Any change in the rivers flowing out of Yellowstone will affect downstream users like ranchers, farmers, towns, and cities.
- Fire frequency and season length could increase.

Words to Know

Albedo: the fraction of solar energy (shortwave radiation) reflected from the Earth back into space. It is a measure of the reflectivity of Earth's surface. Ice, especially with snow on top of it, has a high albedo: most sunlight hitting the surface bounces back towards space.

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

Gridded climate data: In order to consistently compare historic climate trends from one area to another, scientists estimate weather data in places and during time periods not covered by weather stations using computer models. The models use a combination of existing and corrected weather records, temperature change based on elevation, knowledge of local climate anomalies, and satellite data to estimate temperature and precipitation values. Daily or monthly weather values are calculated for every square in a regular grid pattern and analyzed to define the climate over time. The three most commonly used data sets are PRISM, DAYMET, and TopoWx. As useful as these data sets are, it is important to remember that they are approximations or best estimates. Ultimately, they are confirmed only when different people, using different data types and analysis techniques, reach the same conclusions.

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.

Snow-water equivalent: the amount of water in the snow, usually expressed as inches. If you melted all the snow from one location, the depth of the resulting water is the snow-water equivalent (SWE). When comparing the amount of snow at different locations, it is easier to think in terms of SWE rather than snow depth, because there are no complications from snow being fluffy in one place and dense and compacted somewhere else.

Weather "Normals": 30-year averages of temperature or precipitation. If a daily or monthly measurement is said to be "above normal," it means, by convention, the measurement exceeds the most recent set of 30-year averages. Every 10 years, the time period used to calculate the official "normal" values is calculated and updated by the agencies that run the weather stations (e.g., NOAA, NRCS). Continuously updating the reference period to the most recent 30 years made sense when climate data were used primarily for short-term forecasting and agricultural applications because the goal was to compare the current year to what most people had experienced recently and were "used to." In contrast, in the era of anthropogenic climate change, it often makes sense to choose an older, historic reference period. Because of this, scientists sometimes choose a different reference period than the current "normal" when they compare conditions from the past to current conditions. It is important to be aware of this subtle but significant difference in reference conditions.

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

Changes in volume and timing of spring runoff may disrupt native fish spawning and increase nonnative aquatic species expansion.

Growing Season

The Intergovernmental Panel on Climate Change (IPCC) predicts that overall forest growth in North America will likely increase 10–20% as a result of extended growing seasons and elevated CO_2 during the next century but with important spatial and temporal variations. Forests in the Rocky Mountain/Columbia Basin region are expected to have less snow on the ground, a shorter snow season, a longer growing season due to an earlier spring start, earlier peak snowmelt, and about two months of additional drought. Despite a longer growing season, Yellowstone forests will likely be less dense, more patchy, and have more diverse age structure. In fact, experts project less tree cover in much of the park as well as potential migration of new species like Ponderosa pine. Complicating matters, increased drought stress and higher temperatures may increase the likelihood of widespread die-offs of some vegetation.

The integrated runoff response from the Yellowstone River has been toward earlier spring runoff peaks, suggesting that the majority of the park is experiencing shorter winters and longer summers as a result of snowpack changes. Changes in these seasonal patterns will likely disrupt vegetation growth and development, causing plants to bud, flower, fruit, and die at different times of the year than they do now. Those changes, in turn, would alter or seriously disrupt wildlife migrations, one of the key resources for which Yellowstone is globally treasured.

Extreme Events: Insect Activity

Although outbreak dynamics differ among species and forests, climate change appears to be driving current insect outbreaks. Outbreaks of western spruce budworm, the most destructive defoliator in Western North America, were more widespread and lasted longer in the 20th century than in the 19th primarily because of fire suppression and increasing fir populations. However, patterns of spruce budworm outbreaks have been tied to climate nationwide.

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

> The management implications for protecting species, biological communities, and physical resources within finite land management boundaries in a rapidly changing climate are complex and without precedent.
>
> — Jon Jarvis, Former Director, National Park Service

Summer and spring precipitation are positively correlated with increased frequency of outbreaks over regional scales and long time frames, but experimental evidence suggests that drought may promote infestations. Although bark beetle infestations are a force of natural change in forested ecosystems, several concurrent outbreaks across western North America are the largest and most severe in recorded history. From 2004 to 2008, the area of mountain pine beetle outbreaks increased across Wyoming from 1,000 to 100,000 acres. At the end of 2016, 26% of whitebark pine trees in the GYE had been killed as a result of mountain pine beetle, whitepine blister rust, wildland fire, and other factors. Since 1999, an eruption of mountain pine beetle events has been observed that exceed the frequencies, impacts, and ranges documented during the past 125 years. Aerial assessment of whitebark pine species populations within the GYE has indicated a 79% mortality rate of mature trees. These changes may be early indicators of how GYE vegetation communities will shift due to climate change.

These outbreaks of bark beetles in the West have coincided with increased temperatures and changes in precipitation patterns, suggesting a response to a changing climate. Warming temperatures and the loss of extreme cold days reduce winter overkills of insects, speed up life cycles, modify damage rates, and lead to range expansions, particularly in the north.

Future Insect Activity

Climate change, and particularly warming, will have a dramatic impact on pest insects, and the recent trends of increasing outbreaks are expected to worsen. The greatest increase in mountain pine beetle outbreaks is expected to occur at high elevations, where models predict warmer temperatures will increase winter survival. At low elevations, however, mountain pine beetle populations may decrease as warmer temperatures disrupt the insects' seasonality. Climate change will also alter host susceptibility to infestation. Over the short-term, trees will likely increase in susceptibility to pests due to stress from fires, drought, and high temperatures; over the long-term, these stresses will cause tree ranges and distributions to change. Moreover, climate change and changes in CO_2 and ozone may alter the conifers' defensive mechanisms and susceptibility to beetles through their effects on the production of plant secondary compounds.

Insect infestations are damaging millions of acres of western forests, and there is clear evidence that damage is increasing. Nonetheless, future predictions of the extent of infestations remain uncertain because our understanding of insect infestations is incomplete. Key uncertainties include the influence of drought and precipitation changes, how altered forest/host composition will alter outbreaks, the biochemical response of trees and evolution of defensive mechanisms, regional differences, and the interactive effects of fire, plant disease, and insect outbreaks.

Extreme Events: Fire Activity

The increasing frequency of warm spring and summer temperatures, reduced winter precipitation, and earlier snowmelt in the West during the past 20 years has led to an increase in the frequency of very large wildfires and total acres burned annually. The relative influence of climate on fire behavior varies regionally and by ecosystem type, but generally current-year

drought, low winter precipitation, wind conditions, and high summer temperature are determining factors for area burned in the Rockies.

Fire dynamics have been altered by climate indirectly through its effects on insect infestations and forest health. By changing the forest environment, bark beetles can influence the probability, extent, and behavior of fire events, but despite the widely held belief that bark beetle outbreaks set the stage for severe wildfires, few scientifically and statistically sound studies have been published on this topic. That fire promotes beetle infestations is clearer; the fire-caused injury changes conifers' volatile emissions, thereby increasing their susceptibility to bark beetles.

Future Fires

Most evidence suggests that climate change will bring increases in the frequency, intensity, severity, and average annual extent of wildland fires. Models project that numerous aspects of fire behavior will change, including longer fire seasons, more days with high fire danger, increased natural ignition frequency and fire severity, more frequent large fires, and more episodes of extreme fire behavior. The best evidence is for increases in the average annual area burned. 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.

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

Projecting the influences of climate change on future patterns of fire is extremely difficult. 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. Other factors, such as increases in annual, non-native grass invasions, may alter fire dynamics, making predictions based on climate alone difficult.

Examining the Evidence

Insights from Paleoecology

As we think about and prepare for the future, it is important to learn what we can from past episodes of climate change. The study of paleoecology has provided insight into prehistoric changes in the ecosystem, including evidence of ancient plant and animal movements that have been preserved in fossil records. Studies conducted in the past 20 years have provided critical insights into past climate change and its ecological consequences in the GYE.

During the transition from glacial to Holocene conditions (ca. 14,000–9,000 years ago), temperatures rose at least 9°F–12°F (-13°C–11°C). As a result of rising temperatures, plant species expanded their ranges into newly available habitats, forming new plant communities. Throughout the Holocene, climate variation of a lesser magnitude continued to occur, resulting in smaller shifts in species distributions and increased fire frequency during hotter and drier periods.

Though the changes documented in the paleo record occurred over longer periods of time, drawing from the past of this region can help to gauge the potential for future changes. If future climate change is of similar magnitude to the changes that occurred in the past 9,000 years, it is likely that Yellowstone's ecosystems will change to some extent, but probably not to any great degree. However, if the magnitude of future change is comparable to that of the glacial to Holocene transition, then enormous changes are possible—even likely.

Whitebark pine trees, living on the edge in high elevations, are vulnerable to climate change.

Heeding the signs of change

Aspen

Findings from research focusing on aspen forests indicate that a possible shift in the distribution of this important species may already be underway. By comparing documentation of aspen regeneration before and after the 1988 fires, experts found evidence suggesting that the sexual reproduction of aspen in the Rocky Mountains occurs primarily after large severe fires. Prior to 1988, aspen regeneration was understood to occur primarily via vegetative root sprouting. Aspen seedlings, rarely documented prior to the fires, were observed in 1988 burn areas, including areas where aspen had not been present before the fires, often many kilometers from pre-fire aspen stands. Aspen seedlings have persisted in many areas, and in some instances expanded into higher elevations since 1988. Meanwhile, aspen forests at the lowest elevations and on the driest sites have declined throughout much of the western US in response to severe drought in the early 2000s. Research is ongoing to fully understand the processes at work, but the pattern is consistent with expectations of shifts in species ranges from a warming climate.

Whitebark pine

Five-needle pine trees are foundational species in high-elevation ecosystems across the West. For the sub-alpine species whitebark pine (*Pinus albicaulis*), warming temperatures may indirectly result in loss of suitable habitat, reducing its distribution within its historic range over the next century. Whitebark pine is associated with lower summer maximum temperatures and adequate springtime snowpack for survival.

Modeling of whitebark pine habitat in the greater Yellowstone area predicts that suitable habitat will decrease over time and the species may only be able to survive at the highest elevations, although it is likely that there will remain microrefugia (small areas with suitable climates) of whitebark pine throughout the region.

Given the ecological importance of whitebark pine, and that 98% of the species occurs on public lands, an interagency whitebark pine monitoring group, including the National Park Service, US Forest Service, Bureau of Land Management, and US Geological Survey, has been monitoring the status and trend of whitebark pine stands since 2004.

Sagebrush Steppe

Sagebrush steppe is one of the most altered ecosystems in the intermountain West. Substantial sagebrush areas have been converted to agriculture, heavily grazed, and degraded through altered fire regimes and the invasion of nonnative plants. Changes in climate are expected to further alter fire regimes and increase invasive species in sagebrush steppe and low-elevation woodlands. Yellowstone National Park also has upland vegetation data that may be useful in addressing climate change responses in sagebrush-steppe and grassland systems. In 2015, vegetation specialists initiated a long-term monitoring program of sagebrush steppe habitats across the park.

Alpine Vegetation and Soils

The cold and relatively little-studied alpine ecosystems are among those where climate-change impacts are expected to be pronounced and detectable early on. The Greater Yellowstone and Rocky Mountain networks collaborated to implement alpine vegetation and soils monitoring in high-elevation parks. National parks including Glacier, Yellowstone, Rocky Mountain, and Great Sand Dunes are now participants in the Global Observation Research Initiative in Alpine Environments (GLORIA) monitoring

network. Monitoring includes sampling of vascular plants, soil temperature, air, and temperature at a set of four alpine summits along an elevation gradient. This set of sites spans alpine environments from northwest Montana to southern Colorado. Information is available through the GLORIA website at http://www.gloria.ac.at/

Wetlands

Wetlands in Yellowstone are few and far between, and include small lakes and kettle ponds, which are already drying up. Scientists don't know how much ground-water recharge they will need to recover. However, precipitation and snowpack will likely continue to decrease, which will continue to decrease surface and ground water—and thus the lakes and ponds may not recover. Recognizing that many of these small water basins are already drying, the park began to monitor groundwater hydrology in 2012 to understand the drivers and variability in groundwater flow patterns. The baseline information obtained from these select sites further informs the anticipated consequences under changing climatic conditions. As wetlands diminish, sedges, rushes, and other mesic (water-loving) plants will likely decline. In turn, amphibians and some birds will also lose habitat.

Annual monitoring data suggest chronic repetition of dry, warm years could lead to a decline in upwards of 40% of the region's wetlands. This decline could ultimately reduce the distribution and abundance of wetland-dependent species, like boreal chorus frogs.

JENNIFER WHIPPLE

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

Chorus frogs prefer shallow, ephemeral wetland habitats, making them especially vulnerable to climate change. Boreal chorus frog breeding habitat responded negatively to dry, warm years. Some sites where breeding was documented dried up prior to completion of amphibian metamorphosis, which can cause reproductive failure. The strong relationship between annual runoff, wetland inundation, and chorus frog breeding occurrence suggests increasingly difficult conditions for amphibians if projected drought increases occur.

Declines in water levels and drying conditions could affect other species, such as moose, beaver, trumpeter swans, and sandhill cranes, which are dependent on inundated wetlands for survival. In addition, wetland loss is expected to reduce plant productivity, which in turn impacts the carbon sequestration potential of landscapes, affects hydrologic flow paths and water storage within floodplains and uplands, alters soundscapes, affects wildlife viewing opportunities, and potentially removes natural fire breaks important for managing low- to moderate-intensity wildfires.

Wildlife

Understanding how climate change will influence wildlife requires a comprehensive understanding of the park's climate system and how it interacts with both plants and animals. Clear predictions are difficult to make, but many current and potential impacts have been identified.

- Wolverines require deep snow to build the dens to breed and raise their young. Decrease in annual snowpack may cause a decline in wolverine populations.
- Wolves take advantage of deep snow to prey upon long-legged, small-footed ungulates who are less agile in extreme winter conditions. Decrease in annual snowpack may decrease wolf hunting success.
- Elk and pronghorn migration is triggered by a number of factors, including hours of daylight—a factor unaffected by climate change. However, early spring green-up could leave them migrating after their forage has lost much of its initial nutritional value, or earlier peak stream-water flow could force them to change their migration routes.
- The tiny pika tolerates a very narrow habitat range. As the climate zone they live in shifts to higher elevation, pika must move with it.

- Due to extended warm temperatures in fall, male grizzly bears are tending to den later, which exposes them to risks associated with hunting of elk outside of the park boundary.
- Foxes have to adapt to harder snow surfaces. Harder snow surfaces decrease access to rodents but increase access to carcasses.
- Increased water levels over extended periods on Yellowstone Lake have interfered with pelican reproduction. Extended periods of high water caused by snowmelt in early summer not only flood existing nests, but prevent pelicans from re-nesting. High lake levels also reduce foraging success.

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

Climate change is anticipated to cause changes in the distribution and abundance of many species in Yellowstone. Thanks to the growing library of field studies and the availability of increasingly fine-tuned global climate models, ecologists are in a good position to deepen our understanding of how plants, animals, ecosystems, and whole landscapes respond to climate change, and, consequently, to think about how the GYE is likely to change in the coming century.

Management and monitoring

Many national parks and other protected areas were set up to safeguard a wide range of plant and animal life assuming a certain set of climate conditions. As the climate drivers change, the natural ecosystem and human use of that landscape are bound to change. Even subtle shifts in climate can create substantial changes—nature will begin to rearrange itself, and our ability to protect and manage national parks will be challenged.

In 2010, the National Park Service released its Climate Change Response Strategy. The Climate Change Response Strategy provides direction to our agency and employees to address the impacts of climate change. It describes goals and objectives to guide our actions under four integrated components:

Science

Park scientists conduct research to help us understand the effects of climate change on national parks. The National Park Service also collaborates with other scientific agencies and institutions to discover the best available climate science. This information is then applied to address the specific needs of park managers and park partners as they confront the challenges of climate change.

The Greater Yellowstone Network (GRYN) conducts high-quality, natural-resource monitoring and collects robust inventory data to track changes in resources as they occur. In support of this reporting the interactive web site www.climateanalyzer.org provides climate data for many locations across the country. GRYN is part of the National Park Service High Elevation Climate Change Response Monitoring Program, along with the Rocky Mountain Network and the Upper Columbia Basin Network, created to measure changes in resources as a result of climate change.

Mitigation

The most effective way to lessen the long-term effects of climate change is to reduce greenhouse gas emissions. The National Park Service aims to be a leader in reducing its carbon footprint through energy efficient practices and integrating climate-friendly practices into administration, planning, and workforce culture.

The Green Parks Plan defines a collective vision and a strategic plan for sustainable operations in the National Park Service. The plan is framed around nine categories and sets ambitious goals to make the National Park Service a worldwide leader in sustainability:

- Continuously Improve Environmental Performance
- Be Climate Friendly and Climate Ready
- Be Energy Smart
- Be Water Wise
- Green Our Rides
- Buy Green and Reduce, Reuse, Recycle

- Preserve Outdoor Values
- Adopt Best Practices
- Foster Sustainability Beyond Our Boundaries

The Climate Friendly Parks (CFP) Program, of which Yellowstone is a member, is one component of the NPS Green Parks Plan. The program supports parks in developing an integrated approach to address climate change through implementing sustainable practices throughout their operations. Since 2003, the program has assisted parks with:

- Measuring park-based greenhouse gas (GHG) emissions
- Educating staff, partners, stakeholders, and the public about climate change and demonstrating ways individuals and groups can take action to address the issue
- Developing strategies and specific actions to address sustainability challenges, reduce GHG emissions, and anticipate the impacts of climate change on park resources.

The CFP Program includes more than 120 member parks dedicated to reducing resource consumption, decreasing GHG emissions, and educating park staff and the public about climate change and sustainable initiatives taking place across the agency.

Adaptation

Climate change will alter park ecosystems in fundamental ways. The National Park Service must remain flexible amidst this changing landscape and uncertain future. In some cases we must take bold and immediate actions, while in others we may be methodical and cautious. Many techniques will be used and refined as new science becomes available and the future of climate change unfolds.

Communication

National parks are visible examples of how climate change can affect natural and cultural resources. Park rangers engage visitors about climate change by sharing information concerning the impacts to parks and steps the agency is taking to preserve our heritage.

Outlook

The complexity of the global climate system means that there is no one, "best" model for predicting the future climate everywhere on the Earth. Instead, scientists use a group of different models that are all good at predicting some part of the answer. Usually, the greatest differences among predictions are not caused by the mathematical methods used to model the climate system. Most uncertainty is due to the difficulty in predicting what people will do. If climate scientists knew what choices humans were going to make about limiting greenhouse gas emissions, then their predictions about climate change would be much more certain.

Climate change is generally not an easy conversation piece. However, it is a conversation that we need to have, and a process we must continue to study. Humans need to adapt to changing climate, as will wildlife and ecosystems. Through better understanding, we may arrive at more informed decisions to help conserve and adapt to our changing environment.

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

Beyond Boundaries

Managing Resources and Impacts Across Political Lines

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. A healthy Yellowstone is important for meeting the park's mandate to preserve resources and values in a manner that provides for their enjoyment by people. At the same time, a healthy Yellowstone enhances the lives of people living outside the park, by providing sustainable resources such as clean water, wildlife populations, and vegetation communities.

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

- The Greater Yellowstone Ecosystem spans different climate regimes and vegetation zones, crosses multiple jurisdictional boundaries, and is the last remaining large, intact native ecosystem in the contiguous United States.
- The park's geographic location also attracts humans who want to occupy increasing amounts of space in the ecosystem. This leads to habitat modification, which poses a serious threat to both biodiversity and to ecosystem processes. For example, when homes are built close to wilderness boundaries, they fragment habitats and isolate populations of plants and animals, cutting them off from processes necessary for survival.
- Yellowstone National Park was created before the surrounding states existed, which makes its relationship to its neighbors different from those of many national parks. This park has exclusive jurisdiction over managing wildlife within the park boundary; wildlife management is driven by National Park Service mission and federal mandates, rather than by state wildlife management objectives. However, the National Park Service recognizes ecological boundaries do not match the social and political boundaries established in the ecosystem. Thus, most managers in the park have established relationships with neighboring agencies to coordinate actions that, in some cases, are quite different on each side of the park boundary. The park works with the states on most issues, including wolf and bison management.
- Time also affects how this ecosystem changes and at what pace. What are the intervals between volcanic eruptions? Between fires? How has forest composition changed in the past 100 years? How will climate change alter these patterns? These are the types of "time" questions that influence management of Yellowstone.

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

Partners

Effective management also requires strong partnerships. Several management and research partnerships exist among state, federal, and tribal agencies to help focus resources and provide collaborative problem-solving on regional issues. Many of these partnerships include academic and non-profit institutions as well.

Greater Yellowstone Network

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

Rocky Mountains Cooperative Ecosystem Studies Unit

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

Greater Yellowstone Coordinating Committee

In 1964, the managers of the national parks and national forests in the Greater Yellowstone Ecosystem formed the Greater Yellowstone Coordinating Committee (GYCC) to seek solutions to common issues. One of the nation's earliest land-management partnerships, the GYCC reportedly first signed a Memorandum of Understanding in 1964. The GYCC now includes managers from two national parks, five national forests, two national wildlife refuges, and the Bureau of Land Management in Montana, Idaho, and Wyoming. During its five decades, the GYCC has provided guidance and decisions for managing the Greater Yellowstone Ecosystem. The GYCC managers set priorities for interagency coordination, and allocate staff and funding to advance these priorities. Interagency staff and partners collaborate on topic-specific committees to address priority issues and to coordinate operations such as wildfire management. Current GYCC priorities are:

- Ecosystem health: air and water quality, invasive species management, species on the brink (bears, cutthroat trout, whitebark pine) and climate-change adaptation.
- Connecting people to the land.

More Information

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Staff Reviewer

Tom Olliff, NPS IMR Chief, Landscape Conservation and Climate Change

Yellowstone National Park issues and manages between 130 and 180 research permits annually—one of the highest volumes in the National Park Service.

Research in the Park

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

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

A Long History of Scientific Study

As a research location, Yellowstone has long attracted scientists. In any given year, 115–150 scientific researchers are permitted to use study sites in the park, and many more conduct research at the park's Heritage and Research Center. Yellowstone is one of the most high-profile research locations in the National Park Service and has one of the most active research programs. Researchers from universities, other agencies, and the National Park Service come to Yellowstone to conduct scientific studies. In 2019, permitted researchers came from more than 30 states and 11 foreign countries.

Some of the first written accounts about the wildlife and thermal features of the greater Yellowstone area were in journals and letters from settlers,

Research in Yellowstone

Number in Yellowstone
2019: 145 permits were issued.

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

Types of Research
In 2019, permitted research included

- Physical Sciences: 27%
- Biology (wildlife, vegetation): 31%
- Microbiology: 23%
- Ecology: 15%
- Other: 4%

Conducting Research

- Research permits are required for studies and collections (except for archival research conducted at the Heritage and Research Center facility). The Research Permit Office (in the Yellowstone Center for Resources) is responsible for issuing and tracking research permits. It also provides support to permitted researchers in the park.
- Each permit application undergoes a formal, standard process for research permit review and issuance.
- All researchers are required to submit an annual report of their study progress and results. These annual reports are available online at https://irma.nps.gov/rprs.
- Publications resulting from research may be on file in the Yellowstone Heritage and Research Center Library.

trappers, Indian scouts, and the military. These early accounts brought about expeditions to explore Yellowstone in the 1860s and 1870s (see also: *History*). It is in these explorations that the history of science in Yellowstone formally began with the expeditions of geologist Ferdinand V. Hayden, who led official government expeditions to the Yellowstone area in the 1870s.

WILLIAM H. JACKSON

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

Modern Research

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

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History of Science in Yellowstone

- 1871–1878: Expeditions of US Geological Survey Geologist Ferdinand Hayden to the Yellowstone area.
- 1877–1882: Park Superintendent Philetus Norris establishes scientific inquiry as an important aspect of park management and argues for employing a resident scientist in the park.
- 1935: Eugene Thomas Allen and Arthur Lewis Day publish *Hot Springs of the Yellowstone National Park* (Carnegie Institution), the definitive literature on the park's thermal environment for many decades.
- 1959–1971: A team of researchers led by John and Frank Craighead use the park to pioneer the field of radio telemetry in their ground-breaking studies of Yellowstone's grizzly bears. The Craigheads are also at the forefront of technological innovation in other methods of identifying and classifying grizzly bears.
- 1967–1971: Park managers differ with the Craigheads over some of their scientific conclusions and are disinclined to implement most of their recommendations. The Craigheads conclude their work in the park. The disagreements were so well-publicized in the news media that a widespread, enduring mythology developed that the National Park Service was generally anti-research, especially when it came to outside researchers.
- 1960s: The National Park Service changes its research permitting policy, only permitting projects that are of direct benefit to park managers and would help make important decisions.
- 1966: Park researcher Dr. Thomas Brock discovers *Thermus aquaticus* in a Yellowstone hot spring. An enzyme discovered in the microorganism is eventually used to rapidly replicate DNA.
- 1968: Yellowstone begins "natural regulation" management. The resource management philosophy has been highly controversial over the years, and has itself become a major focus of scientific study in Yellowstone.
- 1970s and 1980s: Evolving management priorities—in which the need for scientific research becomes progressively more compelling both politically and practically—combined with increasing attention and interest in Yellowstone by the scientific community is reflected in an increase in the volume of research.
- 1984: Total research permits exceed 100 for the first time.
- 1987: Total research permits exceed 200.
- 1990s–2000s: Total research permits average about 250 annually.
- 1993: The Yellowstone Center for Resources is established as a separate operational division, further elevating the formal recognition of research as an essential element of management.
- 2001: The Yellowstone Volcano Observatory forms to strengthen the long-term monitoring of volcanic and earthquake unrest in the Yellowstone region. Member organizations include the USGS, Yellowstone National Park, Montana State University, the University of Utah, the University of Wyoming, UNAVCO, and the geological surveys of ID, MT, and WY.
- 2017: The National Ecological Observatory Network (NEON) constructs a monitoring tower as part of a 30-year national effort to monitor ecological changes.
- 2009–2018: Total research permits are approximately 150 annually.

the National Park Service also adopted a goal to host mission-oriented research, and managers sometimes felt free to suggest researchers adjust their proposals accordingly to meet that goal.

As important as wildlife science has been in Yellowstone's history, the park's hot springs have demonstrated immeasurable scientific value. In 1966, researcher Thomas Brock discovered *Thermus aquaticus*, a microorganism capable of surviving in temperatures extreme enough to kill most other living organisms, in a Yellowstone hot spring. In 1985, the Cetus Corporation obtained a sample of *T. aquaticus* for use in developing the Polymerase Chain Reaction (PCR) process for rapidly replicating DNA.

Aerial surveillance of moose on the northern range.

Amplifying a segment of DNA to a billion exact copies in a few hours gives a scientist enough material to study seriously. The use of an enzyme discovered in *T. aquaticus*, called Taq polymerase (which does not break down at the high temperatures required in the PCR process), made PCR practical and is seen as the biggest advance in PCR. Today, PCR is still the main process used to study nucleic acids, and DNA sequencing is a multibillion-dollar business. More than 53 patents involve research from Yellowstone.

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

Research Projects in Yellowstone

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

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

NEON–National Ecological Observatory Network

From floods and wildfires to land use and invasive species, our ecosystems are constantly changing. The National Science Foundation's National Ecological Observatory Network (NEON), is designed to collect standardized scientific data at field sites across the United States to help us better understand how these ecosystems are changing over time. Field sites

are strategically located in terrestrial and freshwater aquatic ecosystems including two field sites in Yellowstone National Park's northern range. NEON's aquatic site in Yellowstone is located in Blacktail Deer Creek while NEON's terrestrial sampling locations are distributed throughout the northern range with an instrument tower on Blacktail Plateau. At each field site, NEON uses a combination of automated instruments, observational sampling and airborne remote sensing technologies to collect data on plants, animals, soils, nutrients, freshwater and atmosphere. The NEON project, operated by Battelle, will help scientists study our nation's ecosystems by providing a wealth of open data and a continental-scale infrastructure for research studies. Learn more at neonscience.org.

Bioprospecting: Innovation Through Science

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

Today, several scientific research projects sponsored by universities, federal agencies, 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

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Bioprospecting and Benefits-sharing in Yellowstone

The Issue

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

Researchers who study material obtained under a Yellowstone National Park research permit are required to enter into benefits-sharing agreements with the National Park Service before using their research results for any commercial purpose.

Definitions

- **Bioprospecting** is the discovery of useful scientific information from genetic or biochemical resources. It does not require large-scale resource consumption typical of extractive industries associated with the term "prospecting," such as logging and mining.
- **Benefits-sharing** is an agreement between researchers, their institutions, and the National Park Service that returns benefits to the parks when results of research have potential for commercial development.
- **Extremophile:** A microorganism living in extreme conditions such as heat and acid, and cannot survive without these conditions.
- **Thermophile:** Heat-loving extremophile.

History in Yellowstone

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

grand-scale resource consumption required by the kinds of extractive industries typically associated with the term "prospecting," such as logging and mining. In this case, the "prospecting" is for new knowledge. Research is encouraged in Yellowstone if it does not adversely impact park resources and visitor use and enjoyment. Importantly, only research results, i.e., information and know-how gained during research on park specimens, may be commercialized—not the specimens themselves.

Park Science Informs 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 by-products. 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.

Biggest Innovation from Yellowstone, So Far

Until the 1980s, our ability to study DNA was limited. Things we take for granted today such as DNA fingerprinting to identify criminals, DNA medical diagnoses, DNA-based studies of nature, and genetic engineering did not exist. But in 1985, the polymerase chain reaction (PCR) was invented. PCR is an artificial way to do something that living things do every day—replicate DNA. PCR is the rocket ship of replication, because it allows scientists to make billions of copies of a piece of DNA in a few hours.

Without PCR, scientists could not make enough copies of DNA quickly enough to perform their analyses. However, the heat necessary to do the PCR process inactivated the enzymes, making the process extremely slow and expensive. They found the solution to this problem in one of the hot spring organisms, *Thermus aquaticus*, isolated from Yellowstone by park researcher Thomas Brock in the 1960s. An enzyme discovered in *T. aquaticus*—called Taq polymerase—made PCR practical. Because it came from an extremophile, Taq polymerase can withstand the heat of the PCR process without breaking down like ordinary polymerase enzymes. Many laboratory-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. Servicewide procedures for benefits sharing have been developed and can be viewed in the Benefits-Sharing Handbook at https://parkplanning.nps.gov/.

More Information

www.nature.nps.gov/benefitssharing

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Staff Reviewer

Sue Mills, Natural Resource Management Specialist
Annie Carlson, Research Permit Coordinator
Jake White, Assistant NEON Domain Manager

Exurban development (top right) and forest dieback (bottom left) in the Gallatin Valley of Montana, in the Greater Yellowstone Ecosystem.

Land Use

How land is used outside the park can disrupt ecological processes within the park. Though still sparse in the early 2000s, the population in Greater Yellowstone has grown steadily since 1970. Data compiled by the Greater Yellowstone Inventory and Monitoring Network show that from 1990 to 2010, the population in and near the Greater Yellowstone Ecosystem increased nearly 50% (approximately 220,000 to 323,000). About 27% of land in the counties that compose the Greater Yellowstone Ecosystem is privately owned. Much of the growth occurred in rural residential areas. Development density is expected to increase, but with rural residential development continuing to dominate. The distribution of population growth on private land in recent decades is having a larger impact on the ecosystem than the population increase itself.

Private land in the Greater Yellowstone Ecosystem is primarily located in valley bottoms and flood plains, which generally have longer growing seasons and higher plant productivity than the higher-elevation areas that are protected as public land. In addition, new homes have been disproportionately located in areas that are important for biodiversity, particularly grizzly bear habitat, bird hot spots, and riparian zones. The percentage of the Greater Yellowstone Ecosystem used for agriculture remained relatively constant from 1920 to 1990 but has declined slightly since then, to about 18%. Agriculture is still a significant use of the land. In 2007, the percentage of agricultural crop land in the counties in and near the Greater Yellowstone Ecosystem ranged from less than 5% to more than 50%.

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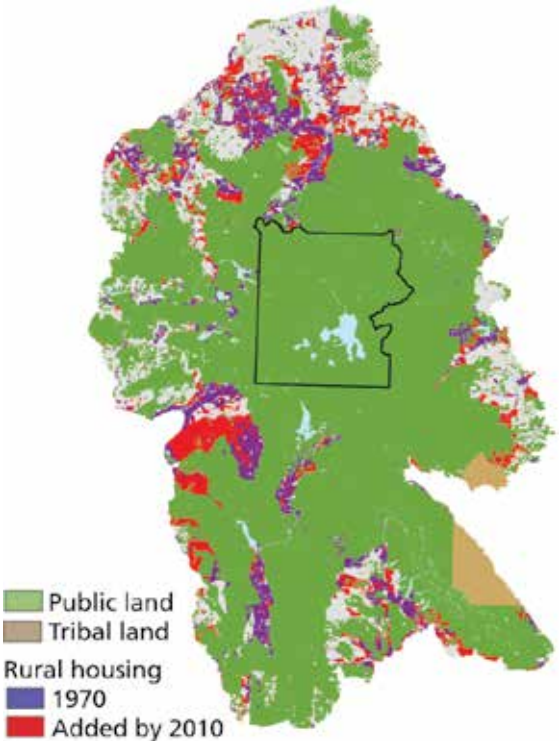

Rural housing and land ownership in the Greater Yellowstone Ecosystem.

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

Wilderness

Yellowstone National Park has always managed its backcountry to protect natural and cultural resources and to provide visitors with the opportunity to enjoy a pristine environment within a setting of solitude. Yet none of the park is designated as federal wilderness under the Wilderness Act of 1964.

In 1972, in accordance with that law, the Secretary of the Interior recommended 2,016,181 acres of Yellowstone's backcountry be designated as wilderness. Although Congress has not acted on this recommendation, all lands that fall within Yellowstone's Recommended Wilderness are managed to maintain their natural wilderness character so as not to preclude wilderness designation in the future. The last Yellowstone wilderness recommendation sent to Congress was for 2,032,721 acres.

Wilderness in the National Park System

Congress specifically included the National Park Service in the Wilderness Act and directed the National Park Service to evaluate all its lands for suitability as wilderness. Lands evaluated and categorized as "designated," "recommended," "proposed," "suitable," or "study area" in the Wilderness Preservation System must be managed in such a way as to (1) not diminish their suitability as wilderness, and (2) apply the concepts of "minimum requirements" to all management decisions affecting those lands, regardless of the wilderness category. Some activities that are typically prohibited under the Wilderness Act are motorized or mechanized equipment use and the installation of structures.

Director's Order 41

In 1999, Director's Order 41 was issued to guide National Park Service efforts to meet the 1964 Wilderness Act, directing that recommended wilderness must be managed to protect wilderness resources and values.

Revised in 2013, Director's Order 41 provides clearer guidance on contemporary issues in wilderness stewardship and management . It provides accountability, consistency, and continuity to the National Park Service's Wilderness Stewardship Program, and guides the National Park Service efforts to meet the letter and spirit of the 1964 Wilderness Act. Instructions include:

- "The NPS will apply the guidance contained in [Director's Order 41] to all of its wilderness stewardship activities. For the purpose of

Quick Facts

The Issue
In 1972, 90% of Yellowstone National Park was recommended for federal wilderness designation. Congress has not acted on this recommendation.

Backcountry Statistics
- Approximately 1,000 miles of trail.
- 72 trailheads within the park; 20 trailheads on the boundary.
- 301 designated campsites.
- Approximately 13% of users travel with boats, 6% with stock.
- In 2016, 20,783 visitors camped in the backcountry.

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

Current Status
Yellowstone does not have an approved wilderness management plan.

FREQUENTLY ASKED QUESTION:

Does Yellowstone include a federally designated wilderness?

No. Most of the park was recommended for this designation in 1972, but Congress has not acted on the recommendation.

applying guidance, unless specifically noted, the term "wilderness" includes the categories of eligible, proposed, recommended, and designated. Potential wilderness may be identified within the proposed, recommended, or designated categories."

- "For every designated wilderness, a Wilderness Stewardship Plan will guide management actions to preserve wilderness character . . . Parks with lands determined eligible, proposed, or recommended should also develop plans to preserve wilderness character ... Preservation of wilderness character will be incorporated into appropriate sections of park planning and management documents."

Minimum Requirement Analysis

National Park Service Management Policies (6.3.5) requires park superintendents to implement a Minimum Requirement Policy to evaluate proposed management actions within recommended wilderness areas, stating "all management decisions affecting wilderness must be consistent with the minimum requirement concept." This concept allows managers to assess:

1. If the proposed management action is appropriate or necessary for administering the area as wilderness and does not impact wilderness

Proposed wilderness (light gray) in Yellowstone National Park. Ninety percent of the park is recommended as federally designated wilderness. Areas near roads, around major visitor areas, around backcountry ranger cabins, and in previously disturbed areas are not included.

significantly. (Why must the activity occur in recommended wilderness?)

2. Which techniques and types of equipment are needed to minimize impacts to the wilderness resource. (If the project is necessary to conduct in wilderness, what is the appropriate means to conduct it that will cause the minimum impact to the wilderness resource, character, and experience that will still get the job done?)

Superintendents apply the minimum requirement concept to all administrative practices, proposed special uses, scientific activities, and equipment use in wilderness. They must consider potential disruption of wilderness character and resources before, and give significantly more weight than, economic efficiency and convenience. If the 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

Yellowstone's Backcountry Management Plan and environmental assessment were drafted in 1994 but were never signed. Though unofficial, both began to provide management guidance to park managers. As managers consider wilderness in Yellowstone today, they must determine how current practices in the park will be handled within areas that are managed as wilderness:

- Protecting natural and cultural resources while also maintaining the wilderness character of the park's lands managed as wilderness.
- Managing administrative and scientific use to provide the greatest contribution with the minimum amount of intrusion on lands managed as wilderness.
- Monitoring wilderness character to develop and enact long-range strategies to better protect wilderness resources and enhance visitor experiences.
- Minimizing visitor wilderness recreation impacts by educating users in Leave No Trace outdoor skills and ethics that promote responsible outdoor recreation and stewardship.
- Evaluating the impacts to wilderness resources among other parameters for all research projects that will take place on lands managed as wilderness in Yellowstone.

Outlook

Yellowstone managers will continue to steward lands managed as wilderness in such a way that sustains the wilderness resource and wilderness character while providing wilderness recreational opportunities for park visitors. If or when Congress acts upon the recommendation to designate much of Yellowstone as wilderness, park managers will continue to manage those areas accordingly.

More Information

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Staff Reviewer

Ivan Kowski, Backcountry Program Manager

Visitor Use

The history of human presence in the Greater Yellowstone Area is long and varied. The land now defined as Yellowstone National Park has been visited, traversed, and enjoyed for millennia. Archeological evidence documents the lives and activities of people in Yellowstone going back more than 11,000 years. Each wave of human tenure in the park has been accompanied by changes in subsistence, habitation, transportation, communication, and significance. Archeological sites and historic objects inform us about past human activities in the region, illuminating the stories of people in Yellowstone.

Park managers use archeological and historical studies to help us understand how people lived and travelled here in the past. However, research is also conducted to learn how people continue to affect and be affected by this place, many parts of which have been relatively protected from human impacts. Some alterations to the landscape, such as the construction of roads and other facilities, are generally accepted as necessary to accommodate the needs of visitors today. Information on the possible consequences of modern human activities, both inside and outside the parks, is used to determine how best to preserve Yellowstone's natural and cultural resources, and the quality of the visitors' experience.

Game Changer: The Automobile

In 1905, the masterpiece of engineering known as the Belt Line (Grand Loop Road), and its accompanying bridges and approach roads, was completed under Captain Hiram Chittenden of the Army Corps of Engineers.

However, transportation patterns and methods were beginning to change. During that year only 78,000 automobiles existed in the United States, and nearly all of them were in the cities. Most of the country's roads were traversed by steel-wheeled, horse-drawn wagons. Over the following decade, the production of safer, cheaper automobiles led to a dramatic increase in their range and appeal. By 1915, there were 2.33 million automobiles on American roads, (nearly double that by 1918) and private vehicles were finally authorized to enter national parks on August 1, 1915. It soon became evident that the roads in Yellowstone were unsafe for combined stock and automobile travel. Severe injuries to animals, passengers, and motorists prompted park managers and concessioners to act decisively. By just two years later, concessions companies had completely replaced their horse-drawn stages with autos.

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Tourism and Visitation

Yellowstone National Park was designated in 1872 as the world's first national park. The explicit mission of Yellowstone, is "…to provide for the benefit and enjoyment of the people." Yet, at the time of this designation, Idaho, Montana, and Wyoming were not yet states. The total population of US Territories was only 720,000 . To fulfill this mandate and truly serve the nation, Yellowstone had to develop with tourism and visitors in mind.

Infrastructure

Since its designation as a national park, infrastructure development in Yellowstone has continued to evolve. From Superintendent Philetus Norris and the first stretches of the historic Grand Loop Road, to the recently constructed Canyon lodges, approximately two percent of the park area has been developed and devoted to the accommodation and service of visitors. This infrastructure both facilitates and limits the number of visitors that the park can hold. Currently, lodging and campgrounds in the park can accommodate only about 14,300 overnight visitors during the summer. However, daily visitation during July averages around 30,200. Most of those visitors concentrate at the park's points of interest along 466 miles of paved road—mostly the same historic Grand Loop Road built more than a century ago for wagons and stage coaches, rather than RVs and tour busses.

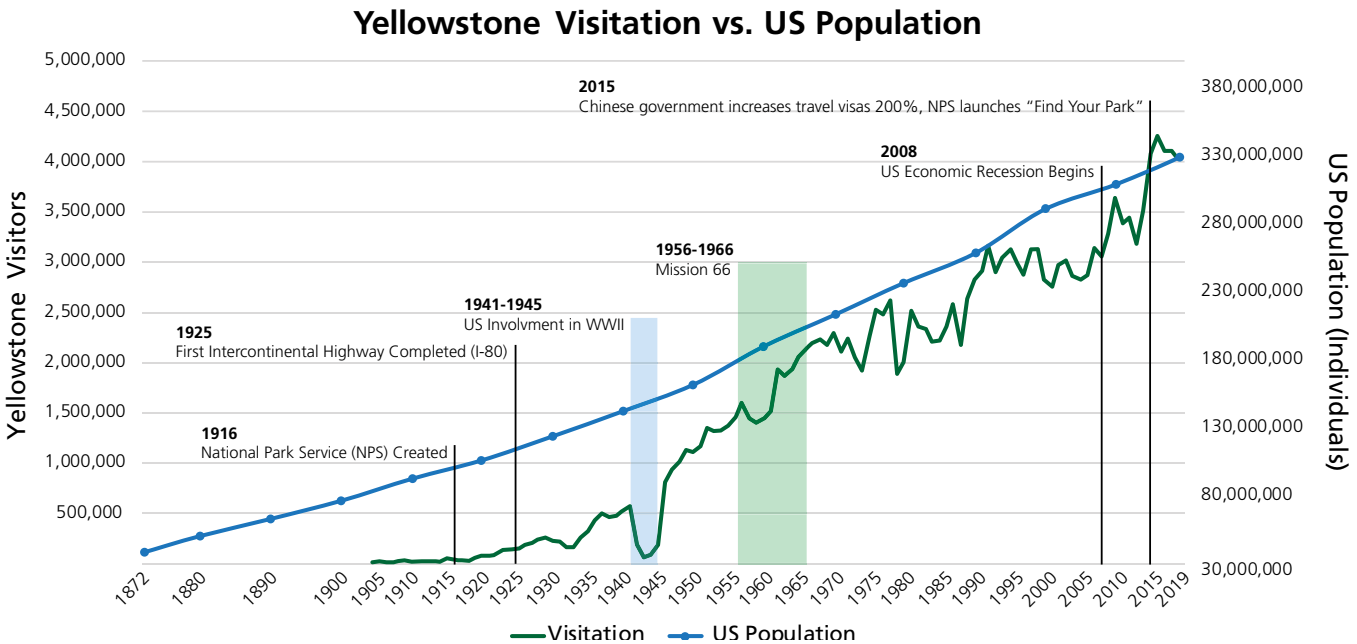
Population

Yellowstone provides a place where people can glimpse primitive America. A place where humans get the increasingly rare experience of sharing an open landscape with thousands of wild animals, including bison, bears, elk, and wolves. A precious place where a volcano's hidden power rises up in colorful hot springs, mudpots, and geysers. A place where people can see all of these things with relative ease thanks to a road system that connects five entrances with many popular destinations.

There are more people on Earth than ever before, and more and more of them want to experience Yellowstone. Visitors come to the park throughout the year but not in equal distribution. About 70% of the visitation occurs from June through August. Fall visitation has increased since the 1980s and now comprises about 21% of annual use; winter visitation has always been minimal and has never accounted for more than 6% of the annual total.

Changing Types and Timing of Visitation

In 1992, visits to Yellowstone National Park exceeded 3 million for the first time. After that, annual visitation at Yellowstone fluctuated between 2.8 and 3.1 million until new records were set in 2009 (3.3 million) and 2015 (more than 4 million). Visitation peaked in 2016 at 4,257,177. Since 2008, annual visitation to Yellowstone increased by more than



There are more people on Earth than ever before, and more and more of them want to experience Yellowstone.

40% over the previous decade. The shoulder seasons have seen the most dramatic increase in visitation on a percentage basis. From 2014 to 2016, visitation increased 44% in May, 25% in June, 16% in July, 9% in August, and 24% in October.

- Similar to trends at other western parks, overnight backcountry use in Yellowstone peaked in 1977 at more than 55,000 nights spent in the backcountry. Since the mid-1990s backcountry use has remained fairly steady, ranging between 37,000 and 46,000 person use nights annually.
- Yellowstone has seen a 130% increase in tour buses between 2012–2017 and a 267% increase in tour buses at the West Entrance since 2008.
- A 2018 study showed that approximately 30% of visitors to Yellowstone National Park are international visitors. North American visitors to Yellowstone make up 77% of all visitors followed by visitors from Europe at 13% (Germany, France, Switzerland, and UK make up the top 4) and Asia at 8% of all visitors (89% of Asian visitors are from China).

Cultural differences and language barriers can lead to communication challenges about critical park information, and even conflicts among visitors. Yellowstone has added additional Mandarin-speaking rangers and publications in Mandarin to accommodate this growing user group.

Use Impact

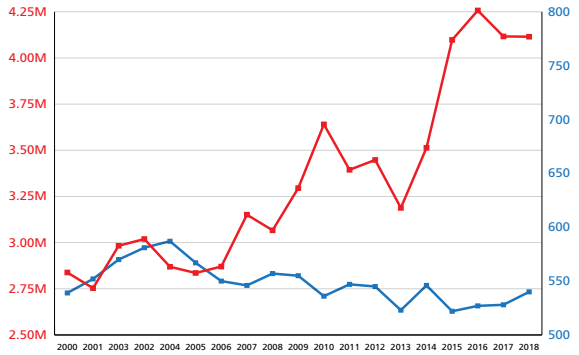
The impact of human beings on any landscape is complex, and our values and priorities color much of how we interpret that impact. In 2018, 4.1 million visitors to Yellowstone National Park generated $43.9 million in funding for park operations. Just a portion of this revenue funded educational programs for more than 260,000 people in the park, and more than 27,500 school children and teachers. Money collected through fees was also used to monitor (or remove) some of our 225 species of invasive plants; to study the 285 species of birds and watch them for impacts of climate change; and to provide opportunities for hundreds of thousands of visitors to view wild wolves in their natural habitat.

In 2018, 4.1 million park visitors spent an estimated $513 million in local gateway regions while visiting Yellowstone National Park. That spending supported 7,090 jobs in the local area (for a cumulative benefit to the local economy of $647.1 million). Park supporters donated an additional $1.7 million for research internships, historic preservation, and projects to protect and learn about native species like Yellowstone cutthroat trout, golden eagles, black bears, and cougars.

Use by visitors is both a primary reason for the establishment of national parks and a factor in the condition of many of the natural and cultural resources that the parks are intended to protect. Visitors do much to support the preservation and operation of parks but not all impacts are positive. While activities like poaching and road collisions have immediate negative consequences for wildlife, most visitor impacts are less obvious. The long-term consequences of some previous park policies carried out for the presumed benefit of visitors—such as predator control and the introduction of nonnative fish—continue to be problems in the parks today. In addition, ongoing visitor activities and associated infrastructure affect many park resources, including:

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

Increased annual visitation to Yellowstone is causing overflowing parking lots, a rise in traffic jams, roadside soil erosion and vegetation trampling, and unsanitary conditions around busy bathrooms. In just two years (2014 to 2016) Yellowstone saw a twenty percent increase in visitation over the previous decade. This arrived coupled with an even



While visitation has climbed dramatically, the number of full-time National Park Service employees has not changed significantly.

greater rise in motor vehicle accidents (+90%), ambulance use (+60%), and search and rescue efforts (+130%). Meanwhile, staffing levels and funding have remained flat over the last ten years.

Visitor Use Management

Yellowstone has not begun a formal planning process for visitor use management. The park has been working to understand the impacts of increasing visitation. Below are details about past and current work.

Upcoming Work

- Pilot Projects—The park continues to test a range of pilot projects around the park, such as altering traffic, parking, and visitor flow configurations and adding staff to highly congested areas to improve resource protection, safety, operations, and the visitor experience.

Past Work

Visitor Use Studies

- Visitor Use Study (2016): The park commissioned a survey of summer visitors to better understand who comes to Yellowstone, how they plan their trips, what they come to see, their perceptions of the park (including attitudes about access and transportation), and level of satisfaction with park services and facilities.
- Visitor Use Study (2018): Researchers conducted a study to explore how people experience and move through the park in real-time and how their experiences vary across the season (May–September).
- Visitor Use and Behavior at Attraction Sites: In 2017, the park began an on-going monitoring project in partnership with Oregon State University and the Youth Conservation Corp (YCC) to better understand visitor volumes and behaviors at high-use attraction sites. YCC Crews monitor numbers and density of people, how they use the area, and instances of resource impacts. This monitoring occurs at Old Faithful, Midway Geyser Basin, the Fairy Falls trail to the Grand Prismatic Overlook, and Norris.

Transportation Studies

- Transportation and Vehicle Mobility Study, Phase I (2016): Researchers collected data in 2016 to describe traffic, parking, capacity, and visitor flow patterns throughout the park.
- Transportation and Vehicle Mobility Study, Phase 2 (2018): Researchers used the 2016 data to model traffic conditions and demand specifically on the West Yellowstone to Old Faithful Corridor.
- In 2018, a graduate student conducted a study to explore the feasibility of a shuttle system between West Yellowstone and Old Faithful.

Wildlife Jams (2018)

Employees worked with University of Montana students to examine how humans and animals interact with one another at wildlife jams.

Visitor and Employee Safety (2018)

Two graduate students from the NPS Business Plan Internship program worked with the park to study the relationship between increasing visitation, human safety, and impacts on employees and operations in the Resource and Visitor Protection Division.

Resource Impacts

Employees monitored the creation and expansion of social trails, which are unwanted and unofficial trails made by visitors that damage soil and plants.

More Information

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Staff reviewer

Christina White, Outdoor Recreation Planner

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

Winter Use

The National Park Service (NPS) mission is a dual mandate: preserve Yellowstone's resources and make the park available and accessible for enjoyment and appreciation. The ways in which visitors access Yellowstone in winter can affect the park's plants, animals, and wild character in ways more profound—and potentially more damaging—than at other times of the year. To meet its mission, the NPS has worked carefully to develop a long-term plan for winter use in Yellowstone that both protects the park's resources and provides outstanding opportunities "for the benefit and enjoyment of the people."

For years, the National Park Service managed the park in winter with interim management plans in the face of repeated courtroom challenges over snowmobiles and other winter operations. The final rule, published in October 2013, established long-term management of winter use in Yellowstone and concluded more than 15 years of planning efforts and litigation.

History of the Debate

The popularity of visiting the park in winter, coupled with concerns over impacts to resources from visitation, has made winter use planning for Yellowstone one of the most contentious issues for park managers and visitors. The debate spans more than 80 years, with each participant asking: should the park be accessible in winter? If so, what type of transportation has the least harmful impact on resources, while providing for meaningful visitor experiences?

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 these requests, 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 vehicles into Yellowstone. These snowplanes consisted of

Quick Facts

The Issue

National Park Service Regulation 36 CFR 2.18 prohibits snowmobile use in national parks when there is no specific rule authorizing their use. This is known as the "closed unless open rule"—without a specific rule, oversnow vehicles would be prohibited from entering Yellowstone.

Winter Use Management Goals

- Provide a high-quality, safe, and educational winter experience
- Provide for visitor and employee health and safety
- Protect wilderness character and values
- Preserve pristine air quality
- Preserve natural soundscapes
- Mitigate impacts to wildlife
- Coordinate with partners and gateway communities

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
- Importance of winter visitation to the local and regional economy
- Wildlife using groomed roads
- Displacing wildlife
- Health and human safety

Updates: www.nps.gov/yell/learn/management/winter-use-management.htm

passenger cabs set on skis and blown about (without becoming airborne) with a rear-mounted airplane propeller and engine. In 1955, visitors began touring the park on snowcoaches (then called snowmobiles), enclosed oversnow vehicles (OSV) capable of carrying about 10 people. Finally, in 1963, the first visitors on modern snowmobiles entered Yellowstone. Not long after, snowmobiling became the dominant way to tour the park in winter.

Still, pressure to plow park roads persisted, and Yellowstone authorities knew that they could not accommodate both snowmobiles and automobiles. The matter culminated in a congressional hearing in Jackson, Wyoming, in 1967. By this time, park managers felt plowing would dramatically alter the look and feel of the park's winter wilderness. They thought snowmobiles offered a way to accommodate visitors while preserving the wintertime experience. By 1968, an OSV program was formalized. In 1971, park managers began grooming snowmobile routes to provide smoother, more comfortable touring, and also opened Old Faithful Snow Lodge so visitors could stay overnight at the famous geyser.

Plowing the high mountain roads in Yellowstone is both costly and dangerous.

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. Meanwhile, in 1972, President Nixon signed Executive Order 11644, which described how off-road vehicles, including snowmobiles, should be managed. This Executive Order requires each agency to establish policies and provide for procedures that will ensure that the use of off-road vehicles on public lands will be controlled and directed so as to protect the resources of those lands; to promote the safety of all users of those lands; and to minimize conflicts among the various uses of those lands.

In 1990, park managers completed the Winter Use Plan Environmental Assessment for Yellowstone and Grand Teton national parks and the John D. Rockefeller, Jr. Memorial Parkway to address known and developing problems with snowmobile use. This plan formalized the park's existing winter use program and included a commitment to examine the issue further if winter visitation exceeded the threshold of 140,000 visitors. That threshold was exceeded in the winter of 1992–1993, eight years earlier than the plan predicted.

In accordance with the 1990 plan, the NPS began an analysis of all types of winter recreation on all

Visitor Use in National Parks

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

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

After exceeding 3 million visits for the first time in 1992, annual visitation at Yellowstone fluctuated between 2.8 and 3.1 million until new records were set in 2009 (3.3 million) and 2016 (more than 4 million). About 70% of the visitation occurs from June through August. Although there are no day-use quotas, lodging and campgrounds in the park can accommodate only about 14,300 overnight visitors during the summer, while daily visitation during July averages around 30,200. Fall visitation has increased since the 1980s and now comprises about 21% of annual use; winter visitation has never been more than 6% of the annual total.

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

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 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 AirAct's standards at the West Entrance in one event. Air particulate and some hydrocarbon levels were also high. Two-stroke machines were also loud, making it difficult on many days to experience natural silence in the Firehole Valley. Moreover many visitors traveling by snowmobile lacked the experience necessary to pass bison and other wildlife without causing harassment.

Planning and Litigation

The winter of 1996–1997 was one of the harshest winters of the 1990s, with abundant snow, cold temperatures, and a thick ice layer in the snowpack. Unable to access the forage under the ice, more than 1,000 bison left the park and were shot or shipped to slaughter amid concerns they could transmit brucellosis to cattle in Montana (see also: *Brucellosis p. 193*). Concerned that groomed roads increased the number of bison leaving the park and being killed, the Fund for Animals and other groups filed suit in the US District Court for the District of Columbia

Litigation and Planning 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 six snowmobiles enter the park.
- 1967: Congressional hearing on plowing park roads year-round.
- 1968: Yellowstone managers formalize oversnow use instead of plowing.
- 1971: Managers begin grooming roads; Yellowstone Park Co. opens Old Faithful Snow Lodge.
- 1990: NPS issues first winter-use environmental assessment (EA) for Yellowstone and Grand Teton.
- 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: NPS develops a new winter use plan and environmental impact statement (EIS) in response to a lawsuit alleging bison use groomed roads to leave the park, leading to their slaughter.
- 1999: Draft EIS released; 46,000 public comments received. Organizations petition to prohibit trail grooming and snowmobile use in all national parks.
- 2000: Final EIS released and Record of Decision signed, banning snowmobiles and converting to snowcoach-only transportation. Snowmobile enthusiasts sue to challenge the ban.
- 2001: NPS settles with snowmobilers' group, agrees to prepare a supplemental EIS (SEIS).
- 2002: Draft SEIS released; 357,000 comments received.
- 2003: Dec. 11: Final rule published in Federal Register to allow 950 Best Available Technology (BAT), guided snowmobiles daily.
  - Dec. 16: Federal judge directs park to begin phasing out snowmobiles.
- 2004: February: Another federal judge stops phase-out; requires temporary rules for rest of winter.
  - August: NPS releases a new EA, allowing 720 BAT, guided snowmobiles daily; 95,000 comments received.
  - Nov: Plan approved. Winter use proceeds per 2004 EA.
- 2007: March: Draft Final EIS released; it allows 540 BAT, guided snowmobiles in the park daily; 122,000 comments received.
  - December: final rule published in Federal Register.
- 2008: September–December: Federal court decisions cancel the new winter plan.
  - December 15: Winter season opens with a modified version of the winter plan followed in 2004–2007, allowing 720 BAT, guided snowmobiles daily.
- 2009: Winter season opens under interim plan during EIS process, allows 318 BAT, guided snowmobiles and 78 snowcoaches daily for the next two winters.
- 2010: The National Park Service begins preparing a next long-term plan.
- 2013: February: Final Winter Use Plan/SEIS released, proposing to manage oversnow vehicles based on "transportation events" rather than the number of snowmobiles and snowcoaches allowed in the park each day.
- 2013: October: Final Rule for winter use released, authorizing OSV use based on Transportation Events.

against the NPS in May 1997. The groups alleged that the NPS had failed to examine the environmental impacts of winter use. In 1999, the 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.

As part of a court-mediated settlement, the NPS produced a draft EIS (in 1999) that 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 published in fall of 2000. At the time, snowmobiles which used new technology to dramatically reduce emissions and somewhat reduce noise (what we now refer to as "Best Available Technology," or BAT) were not widely available commercially.

Since that initial EIS, other environmental compliance documents have proposed addressing winter-use impacts using a combination of new technologies, limits on vehicle numbers, mandatory guiding, and monitoring winter-use impacts on park resources. All of these environmental compliance planning documents have proposed allowing a combination of snowmobiles and snowcoaches, with the snowmobile numbers decreasing from plan to plan and snowcoach numbers remaining relatively consistent. By 2002, BAT snowmobiles were commercially available. 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 aimed to eliminate the problems of the past.

Snowcoaches first entered the park in 1955.

Each of the subsequent winter use plans was litigated. The Fund for Animals, the Greater Yellowstone Coalition, and other environmental groups consistently sued in the US District Court for the District of Columbia. The International Snowmobile Manufacturers' Association, the State of Wyoming, the BlueRibbon Coalition, and others consistently file their lawsuits in the US District Court for the District of Wyoming. Litigants have found some traction in each of their courts, with varying degrees of success on any given environmental document. Certainly, the litigation is one of the factors accounting for the protracted nature of the winter use debate. In each decision against it, the National Park Service has responded by addressing the concerns of the courts.

Beginning in 2009, winter use was managed with an interim plan. In 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. Nearly 60,000 comments were filed during a more than 60-day public comment period that followed the draft document's release. After months of public comment and review, the NPS decided additional study was needed before putting a long-term plan in place, and the planning process was extended for another year. Among the subjects identified for further study were requirements for entry into the park by 10:30 AM daily, sound- and air-quality computer modeling assumptions, "best available technology" standards for snowcoaches, the impacts of Sylvan Pass avalanche-hazard mitigation, and opportunities for park access by non-commercially guided snowmobile groups.

Management by "Transportation Events"

In 2012, the NPS released a draft Supplemental EIS, the seventh environmental document since 2000. This document introduced the idea of managing oversnow vehicles by "transportation events." Recognizing that a group of snowmobiles traveling together is comparable to a snowcoach in terms of impacts, a transportation event is defined as a group of up to 10 snowmobiles, averaging 7 seasonally, or 1 snowcoach. As OSVs meet stricter air and noise emission standards, group size can increase from a

seasonal average of 7 to 8 snowmobiles and from 1 snowcoach to an average of 1.5 across the season. Previous management alternatives were based on managing by absolute numbers of OSVs. Through analysis of monitoring data and computer simulations, the park discovered that by packaging traffic into transportation events (i.e., groups) and limiting the total number of transportation events allowed into the park each day, the park would be able to lessen disturbances to wildlife and improve natural soundscape conditions, in addition to allowing more visitors to see the park in winter. Based on monitoring data, the NPS demonstrated that snowmobile and snowcoach transportation events have comparable impacts on Yellowstone's resources and values.

In February 2013, the NPS published a final Winter Use Plan/Supplemental EIS to guide the future of winter use in Yellowstone National Park with management by transportation events as the preferred alternative. A proposed rule was published in the Federal Register in April 2013, and the Record of Decision, which officially concludes the SEIS process by selecting management by transportation events as the final alternative, was signed in August 2013.

Visitor Survey Results

The University of Montana conducted a survey of winter visitors in 2007–2008:

- Almost 90% of those surveyed agreed that Yellowstone is a place for natural quiet and to hear natural sounds.
- 83% were somewhat or very satisfied with their experience of natural sounds.
- 71% indicated that they found the level of natural sound they desired for half or more of the time they desired it.
- 87% were "very satisfied" with their overall experience. The remaining 13% were "satisfied."
- 71% considered the opportunity to view bison to be extremely important.
- 87% reported that the wildlife-viewing aspect of their Yellowstone winter experience was very satisfying.
- 99% who saw bison in winter were able to see them behaving naturally.
- 21% witnessed an encounter where the bison were hurried, took flight, or acted defensively.
- More than 72% largely considered the bison-human interactions they witnessed and the park setting as a whole as "very" appropriate and/or acceptable.

A Final Rule for Winter Use in Yellowstone

National Park Service Regulation 36 CFR 2.18 prohibits snowmobile use in national parks when there is no specific rule authorizing their use. This is known as the "closed unless open rule"—without a specific rule, oversnow vehicles would be prohibited from entering Yellowstone

The final Rule authorizing OSV use in Yellowstone was published in the Federal Register on October 23, 2013, and was based upon the environmental analyses contained within the 2013 SEIS and Record of Decision. The final Rule provides mechanisms to make the park cleaner and quieter than previously authorized; provides greater flexibility for OSV commercial tour operators; rewards new oversnow technologies; and allows for increases in public visitation. The specific parameters established by the final Rule for winter use in Yellowstone are

- Up to 110 daily transportation events.
- 46 events reserved for commercially guided snowmobiles,
- 4 reserved for non-commercially guided snowmobiles.
- No fewer than 60 events reserved for snowcoaches.
- New "best available technology" (New BAT) is required for snowmobiles. Under New BAT, snowmobile transportation events can be up to 10 snowmobiles in a group, with group size averaging 7 each winter.
- BAT is required for all snowcoaches.
- Voluntary "Enhanced BAT" (E-BAT) certification will allow commercial tour operators to increase the average numbers of snowmobiles

Research indicates that disturbance by winter visitors is not a primary influence on the distribution, movements, or vital rates (how fast vital statistics change within a population) of bison, trumpeter swans, elk, coyotes, and bald eagles.

in their groups from 7 to 8 and snowcoaches from 1 to 1.5 across the season.

- One non-commercially guided group of up to five snowmobiles is permitted to enter through each of the four park entrances every day.
- OSVs may continue to use Sylvan Pass; however, the pass may be closed at any time due to avalanche danger or mitigation efforts.
- Park managers are collaborating with the public by implementing an Adaptive Management Program, which will combine science with public input to ensure that OSV-use impacts stay within limits predicted in the final Plan/SEIS.

Under the final Rule, OSVs are permitted on Sylvan Pass unless it is closed for safety reasons.

Adaptive Management Program

The final Rule authorizes an adaptive management program to inform and improve winter-use management. Adaptive management is a three-step process: management, monitoring, and evaluation improve resource protection by blending science and public engagement. It enables natural-resource managers to acknowledge uncertainties in the management of natural systems and to respond to changing conditions while working with the public and interested stakeholders. Collaborative adaptive management, the approach Yellowstone is taking, emphasizes joint learning and an active partnership among managers, scientists, and other stakeholders, including the public. The objectives of the program are to

- Evaluate the impacts of OSV use and help managers implement actions that keep impacts within the range predicted under the final Plan/SEIS.
- Gather additional data to compare impacts from a group of snowmobiles versus a snowcoach.
- Reduce impacts on park resources after implementation of the final Rule by gathering additional data on the overall social and ecological impacts of winter use.

To meet these objectives, the NPS has collaborated with the public and other partners to develop a long-term, sustainable adaptive management plan for winter use in Yellowstone National Park, released in December 2016. Members of the public participate in working groups around six topics: wildlife, soundscapes and acoustic resources, air quality, human dimensions, operations and technology, and the Non-Commercially Guided Snowmobile Access Program. The NPS leads for each of these working groups publish monitoring and study data, and working group members provide public feedback.

Improvements to winter use management are made through the adaptive management process. For example, input from commercial snowcoach operators suggested that low-pressure tires should be explored as an alternative to traditional mattracks. Following a study to assess the impacts of low-pressure tires on safety, the park, and visitor experience, coupled with a pilot program, low-pressure tires are now widely used. The implementation of low-pressure tires has led to snowcoaches that are significantly quieter, more fuel efficient, less part and labor intensive, and provide a smoother ride for visitors.

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FREQUENTLY ASKED QUESTION:

Do winter use regulations effectively protect park resources?

Recent studies on winter use indicate park resources are in very good condition. Research shows that snowmobiles and snowcoaches contribute similarly to the impacts of winter use. The perception that snowmobiles contribute to the vast majority of observed effects, and that those effects would greatly diminish by limiting travel to snowcoaches only, is not supported. When managed, both modes of transportation provide opportunities for visitors to enjoy the park offering different winter experiences for visitors.

Wildlife

The impact of oversnow vehicles (OSV) on wildlife is a key issue in winter use policies. OSVs are required to stay on groomed roads, but the roads are often situated where wildlife may concentrate in winter. Research indicates that disturbance by winter visitors is not a primary influence on the distribution, movements, or population size and composition of bison, trumpeter swans, elk, coyotes, and bald eagles.

Monitoring OSV use in Yellowstone shows that nearly all OSV users remain on groomed roads and behave appropriately toward wildlife, rarely approaching unless animals are on or adjacent to the road. In most encounters observed between people on OSVs and wildlife, the animals either had no apparent response or looked and then resumed what they were previously doing.

Road grooming does not increase bison migration out of the park. Data on bison road use and off-road travel collected from 1997 to 2005 found bison on the road less often from December to April when the roads were groomed than during the rest of the year, and found no evidence that bison preferentially used groomed roads during winter.

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

Making all visitors use a 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.

Air Quality

Winter air quality in Yellowstone depends primarily on proximity to roads, parking areas, employee housing, and visitor lodging. Although visitation is far lower in the winter than in the summer, OSVs produce more emissions than autos. Levels of carbon monoxide and particulates fell dramatically after 2002 with conversion to BAT snowmobiles and reduced OSV numbers. Hydrocarbon and air toxin concentrations are also no longer a concern. Carbon monoxide, nitrogen dioxide, and particulate matter are monitored at the West Entrance and Old Faithful, where OSVs are most concentrated.

In general, the requirements of the managed use era (the 2004-2005 season and beyond) have had a very positive affect on winter air quality. This includes BAT requirements, a reduction in time OSVs spend idling, and the requirement that guides accompany groups when they tour the park. Analysis of the data shows that levels of carbon monoxide, particulate matter, and hydrocarbons have all been reduced since 2002. When the older values are compared to current values, the improvement is even more dramatic. Monitoring of nitrogen dioxide has only occurred since 2009, but the data indicates that ambient levels are well below those of the National Ambient Air Quality Standards. BAT snowmobiles and snowcoaches produce a similar amount of air pollution on a per passenger basis. Under the Clean Air Act Amendments of 1977, Yellowstone is designated as Class I airsheds, a classification that requires the most stringent protection.

Soundscapes

Noise levels have also fallen somewhat with the conversion to BAT OSVs, mandatory commercial guiding, and limited numbers of snowmobiles. 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.

During the day, OSVs can be heard, on average, about half the time at Madison Junction and approximately 62% of the time at Old Faithful, but much less often in areas of the park with lower OSV activity. The maximum sound levels of groups of snowmobiles measured at 100 feet are generally in the 60s dBA and occasionally reach into the 70s dBA for some individual snowcoaches. Most operators have since reached enhanced BAT and new low pressure tires introduced more recently have made snowcoaches 5-6 times quieter.

Incidents

With guiding has come a 50% 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.

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Staff Reviewer

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

Sustainable and Greening Practices

The National Park Service (NPS) mission articulates a clear ethic for environmental stewardship and Yellowstone's sustainability program extends this commitment to minimizing the environmental impacts from its own operations. Though Yellowstone has been working toward becoming a greener park for many years, sustainability is made more urgent by a changing climate resulting in impacts to natural resources both locally and globally.

Increases in visitation as well as aging facilities and infrastructure create an additional challenge and a need for the park to continue to improve and expand sustainability efforts. The Green Parks Plan provides guidance for reductions in energy, water, waste, and greenhouse gas emissions for all National Park units in the US.

Yellowstone's size and complexity create challenges that require collaboration among park managers and partners. The Yellowstone Environmental Coordinating Committee (YECC) works to ensure a comprehensive approach to sustainability. This team consists of representatives from the National Park Service, Xanterra, Delaware North, Medcor, Yellowstone Park Service Stations, and Yellowstone Forever. The YECC team is constantly working to identify projects that reduce energy and water use and improve waste management throughout the park.

Sustainable and Greening Practices in Yellowstone

The Issue
Demonstrating and promoting sound environmental stewardship through regional and national partnerships.

History

- 1997: Park celebrates 125th anniversary and "greening" efforts increase.
- 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 vehicles.
- 2004: Park employees begin using hybrid vehicles; Xanterra employee housing receives LEED designation.
- 2005: The Energy Policy Act addresses U.S. energy production.
- 2007: Park completes a greenhouse gas inventory, leading to initiatives to reduce greenhouse gas emissions.
- 2011: Corporate partners participate in "Greening Yellowstone Symposium."
- 2012: Green Park's Plan articulates the overarching vision for NPS sustainability.
- 2013: Yellowstone becomes a Climate Friendly Park.
- 2015: Executive Order 13693, Planning for Federal Sustainability in the Next Decade, signed.
- 2017: 44 KW solar and 2.5 kilowatt micro-hydro system online at Lamar Buffalo Ranch.
- 2018: Executive Order 13834, Efficient Federal Operations, signed revoking E.O. 13693 of 2015.

Park Waste Diverted from Landfills
Latest data from 2018: 51.6% of waste diverted (34% recycled, 18% compost).

- newspapers, magazines, office paper: 61 tons
- aluminum and steel: 36.5 tons
- glass: 133 tons
- plastics: 58 tons
- cardboard: 363 tons
- food waste and other garbage composted: 722 tons
- manure: 257 tons

Energy Conservation

Yellowstone is the largest consumer of energy in the NPS. Though most of Yellowstone's energy comes from electricity generated at coal-fueled power plants and other fossil fuels used directly, the park is reducing energy use by making facilities more energy efficient and increasing the use of renewable energy where possible.

Electricity is used for lighting, appliances, computers, tools and some heating and cooling. Improving the efficiency of these applications is one of the most productive steps we can take toward energy conservation. North-Western Energy (Yellowstone's electricity provider) is also increasing its renewable energy portfolio further reducing the emissions from electricity production.

Most of Yellowstone's building heating and cooling systems rely on fuel: either diesel (fuel oil) or propane. Other common users of fuel for direct heat and power are water heaters, kitchen appliances and generators. Renovating Yellowstone's buildings presents opportunities for reducing fuel use. Heating systems are being updated where possible and efforts are being made throughout the park to improve building envelopes such as adding insulation and installing better storm windows. Yellowstone's housing initiative is also focused on installing energy efficient appliances and using best building practices for energy smart housing.

Approximately 2.2 billion dollars in global energy consumption is wasted annually from artificial lighting at night. Yellowstone has more than 5,000 outdoor lights throughout developed areas of the park, ranging from historic lampposts to garage flood lights. Each of these lights must adhere to the strict lighting guidelines which reduce energy use and light pollution. Unfortunately, most lights were installed before these guidelines existed and even before negative effects of artificial light were considered. Yellowstone's staff is working retroactively to identify and remove any unnecessary or excess lights, replace all bulbs with high-efficiency LEDs, and install fully shielded fixtures that direct light only where needed allowing for a lower wattage bulb.

New construction and major renovations provide opportunities to implement energy efficient designs. Many buildings in Yellowstone now have LEED (Leadership in Energy and Environmental Design) certification including the Old Faithful Visitor Education Center, Old Faithful Haynes Photoshop, Canyon Lodges, and several employee housing dormitories.

Photovoltaic (PV) solar energy systems have been a great success, particularly at locations that do not have main line electric power. At Bechler, a portable trailer with a 9 kW solar panel array meets 90% of the electrical needs in the summer season and several arrays now exist on newer buildings that are tied into the electrical grid.

The Buffalo Ranch in Lamar Valley has the largest solar array in Yellowstone. The off-grid ranch has a 44 kW solar panel system and microhydro turbine that together meet over 90% of electrical needs averaged throughout the year. Each building's energy

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

The irrigation system used to water the historic lawns of Fort Yellowstone and Mammoth Hot Springs, pictured here in 1916, was upgraded to include smart controllers which measure moisture levels.

use is monitored so that occupants can see their use and energy savings can be tracked which can be used to make better informed efficiency decisions in the future.

In 2012, a microhydro generator was installed on an existing piped water supply in Mammoth Hot Springs, providing renewable electric power to the grid. The generator produces about 1.4 million KW-hours for the park annually, saving approximately $95,000 in electricity costs and 900 metric tons of greenhouse gas emissions each year. Solar hot water systems on concession buildings have also been successful at Old Faithful and Grant. Using thermal energy from the ground or from natural hot water is not being considered by park managers as the effects could be detrimental to the park's hydrothermal features and other sensitive resources.

Water Conservation

As the Rocky Mountain West becomes warmer and drier with the effects of climate change, and with more than four million annual visitors, it is important that Yellowstone minimizes water use and our impact on natural water resources.

Currently, over 250 million gallons are used for hydrating, flushing, and washing each year. Continued education of our visitors and staff is important, but changing people's habits is one of the toughest challenges for lessening water (and energy) use.

Updating old infrastructure and installing water-smart technology and design is the best way to keep our water use and impact down. Small, hidden leaks in underground pipes can release thousands of gallons of drinking water a day. To identify unseen weaknesses, we perform leak detection surveys on potable water pipes in some developed areas using acoustic sensor technology. Other water saving initiatives include updating water fixtures to low flow and installing smart controllers on irrigation systems.

Yellowstone has seen a slight decrease in overall water use in recent years. Continued vigilance in updating our water infrastructure should keep this trend going.

Fleet and Transportation

The NPS is working toward reducing fossil fuel consumption from fleet vehicles by decreasing the size of our fleet, replacing the existing fleet with more fuel-efficient vehicles, and choosing the most efficient vehicles for each job. Approximately 19% of the vehicles used for work in Yellowstone are hybrid vehicles.

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

The set speed limit throughout most of the park is 45 mph, which is also the speed range vehicles have the highest gas mileage. However, traffic jams are all too common and increase greenhouse gas (GHG) emissions if engines are not turned off. Studies show that idling for just 10 seconds in modern vehicles uses more fuel than restarting the engine. Yellowstone has partnered with Yellowstone–Teton Clean Cities on several fuel-reduction projects including an idle-reduction campaign and the installation of electric vehicle (EV) charging stations for both fleet and visitors. Level 2 EV charging is now available free to the public at all the major developed areas through Xanterra Travel Collection.

Yellowstone also operates a ride-share program for employees who live north of the park with a single 45-seater bus. Not only does this reduce fuel and emissions by taking many cars off the road but it is a safer solution for staff working ten hour days and traveling 50 miles each way.

Environmental Purchasing and Waste Reduction

Yellowstone is striving to divert 75% of the solid waste produced in the park from landfills. The YECC, We Recycle Montana (Yellowstone's recycling contractor), and the West Yellowstone Compost Facility aggregate solid waste statistics to determine the total amount diverted annually. In 2018, park employees, visitors, and partners diverted 51.6% through recycling and composting initiatives, as well as by purchasing environmentally preferred products. Items with minimal packaging, biodegradable

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

In 2018, park employees, visitors, and partners diverted approximately 52% of waste from the landfill through recycling and compost initiatives.

and recovered materials, and without toxic chemicals as well as those requiring minimal energy to produce and transport are preferred. For example single-use plastic water bottles are being reduced by providing water bottle filling stations throughout the park and alternate containers such as cans for water. The recycling program in Yellowstone accepts glass, 1 and 2 plastic, paper, aluminum, steel and cardboard as well as bear spray and 1 pound or smaller camping gas cylinders.

A Commitment from Yellowstone Concessions

Yellowstone National Park's major concessioners have more interaction with visitors through food service, lodging, fuel and automotive services, and retail operations than any National Park Service facilities.

Concession partners have made corporate commitments to use environmental management systems that meet international business standards for sustainability and further the success of Yellowstone's sustainable operation goals. They work hard to minimize waste from the services they provide to visitors and make it a priority for their operations. Both Xanterra Parks and Resorts and Delaware North Services have won awards for their green initiatives.

Xanterra Travel Collection

Xanterra Travel Collection provides lodging and other guest services in the park is a huge proponent of sustainability in Yellowstone. Their environmental commitment includes solid waste diversion, energy and water conservation, and environmental purchasing. Xanterra has several new and longstanding green initiatives and awards including:

- The green housekeeping program "Our Softer Stay" gives guests the opportunity to opt out of housekeeping services, offering a $5 incentive to participate.
- The "Choose to be Straw Free" campaign made a commitment in 2018 to purchase only compostable straws, eliminating hundreds of thousands of plastic straws each year.
- Continuing to discourage the use of plastic water bottles by partnering with Phillipsburg Brewing Company and Montana Silver Springs for locally-sourced canned water.
- Installing a sanitizing system that creates environmentally friendly, safe, and affordable sanitizing products by electrochemically activating water.
- NPS Environmental Achievement Award for the sustainable design and construction of the Canyon Area Lodging Development.
- Near-Zero Waste Award by the Green Restaurant Association for Mammoth Hotel Dining Room.

Delaware North

Delaware North operates twelve general stores in the park and practices an award winning sustainability system focused on environmental management, community involvement, facilities and asset protection, healthy living, and interpretation and education. Successful programs and initiatives include:

- The "Last Straw" campaign where straws are no longer provided with drinks and compostable straws are available upon request, resulting in 25,000 less straws used in 2018 than previous years.

- GBCI's TRUE Zero Waste certification for the West Yellowstone warehouse—the first and only within the NPS to obtain this award. In 2018, the warehouse diverted over 97% of waste through composting and recycling.
- Installing free water-filling stations to reduce the production, shipping, and use of approximately 35,000 plastic water bottles.
- Using renewable energy at Grant Village dormitory for water heating.

Sustainability Challenges

Even though Yellowstone strives to constantly reduce energy and water use as well as decrease unnecessary waste, reaching goals made twenty years ago has been challenging. Exponential increases in visitation and an extended busy season puts stress on Yellowstone's infrastructure and energy use has only continued to increase. Challenges with composting and recycling facilities have also caused waste diversion to decrease since 2017. Education is a top priority but convincing people to change their habits is often difficult. The YECC staff is vigilant in pursuing new ideas and technology to incorporate green practices into everyday activities, making Yellowstone sustainable from the ground up.

Sustainability and You

Though sustainable practices face many challenges, it is really easy to get involved and help make positive changes towards Yellowstone's energy, water, and waste conservation efforts. Reduce, reuse, recycle, refuse, and rethink are strategies staff and visitors should keep in mind.

- Reduce: Turn off the lights, limit shower times, and unplug appliances. These are simple ways to reduce energy use. Turning off the car while in a traffic jam or pull-off reduces gas consumption and air pollution.
- Reuse: Carrying a refillable water bottle and coffee tumbler eliminates plastic waste. Reusing hotel towels minimizes water and energy use from washing and drying.
- Recycle: Yellowstone is home to countless recycling centers and waste stations where glass, plastic, metal, and cardboard are recycled and compost is collected. There are also recycling centers for bear spray and propane canisters.
- Refuse: Saying no can be difficult, but consider if you're really going to read that pamphlet or drink that last refill with your meal. Yellowstone says yes to recycled products and green packaging.
- Rethink: Technology is constantly improving and new ideas come about daily. Rethinking how we go about everyday tasks and incorporate sustainable practices in daily activities is key to creating a more sustainable Yellowstone and preserving this unique ecosystem.

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

More Information

National Park Service Green Parks Plan: www.nps.gov/greenparksplan

Yellowstone's sustainable practices: http://www.nps.gov/yell/getinvolved/sustainability.htm

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GreenPath at Delaware North: http://www.delawarenorth.com/about/values/greenpath

Staff Reviewers

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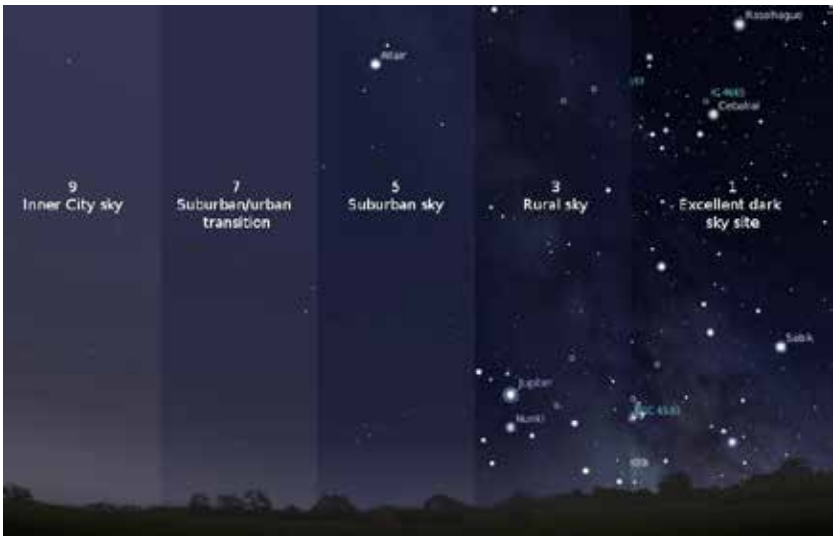
Dark Skies

Light pollution, the inappropriate or excess use of artificial light, is eliminating dark night skies as *skyglow* increases. Skyglow is the brightening of the night sky from artificial light and creates a glow that diminishes visibility of the natural night sky. Inefficient use of technology and the resulting light pollution is a growing concern. Limiting artificial light is crucial to protecting the dark night sky and the health of Yellowstone's wilderness environment.



The Bortle scale is a nine-level numeric scale that measures the night sky's brightness of a particular location. It quantifies the astronomical observability of celestial objects and the interference caused by light pollution.

Effects on Human Health and Wildlife

Daily light-dark cycles are necessary for maintaining human health and wildlife activity. Artificially lit areas create light pollution which masks these cycles. Artificially lighted areas disrupt behavior, reproduction, nourishment cycles, and predator-prey relationships in wildlife. In Yellowstone, this manifests in negative impacts particularly to insects, bats, amphibians, and birds. In humans, excessive light levels are known to impact behavior, melatonin production, sleep patterns, anxiety, and may contribute to the development of various types of cancer.

Yellowstone by Night

Most of Yellowstone is free of artificial light. This allows the viewing of cosmic events like meteor showers, comets, and even the Aurora Borealis. However, in developed areas throughout the park there are more than 5,000 light fixtures. Visitors often encounter bright light fixtures illuminating parking areas and access to buildings making it difficult to view the natural night sky. Often these lights create glare and are too bright making it difficult to see. Yellowstone is addressing this false sense that more light is safer with better lighting design, incorporating fully shielded lights that direct light only downward and are also low wattage, energy saving LEDs. Currently, only 46% of light fixtures are on at night and 75% those are fully shielded; helping to further preserve nighttime wilderness.

Quick Facts

Good Lighting Design Should:

- Avoid all upward light, glare, and sideways light.
- Be no brighter than necessary and light only areas where light is needed.
- Use uniform lighting so eyes can adjust easily and create smooth, gentle transitions from light to dark.
- Use lights in the yellow end of the spectrum (less than 3000K), not blue light which replicates daylight.
- Be energy efficient.

More Information

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