

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

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

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

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

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

GYE BASICS

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

- One of two grizzly populations in contiguous U.S.
- Home to the rare wolverine and lynx

In Yellowstone National Park:

- 67 mammals
- 322 bird species; 148 species nest here
- 16 fish species: 11 native, 5 non-native
- 10 reptiles and amphibians
- 12,000+ insect species, including 128 species of butterflies
- 1,500+ species of native vascular plants



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

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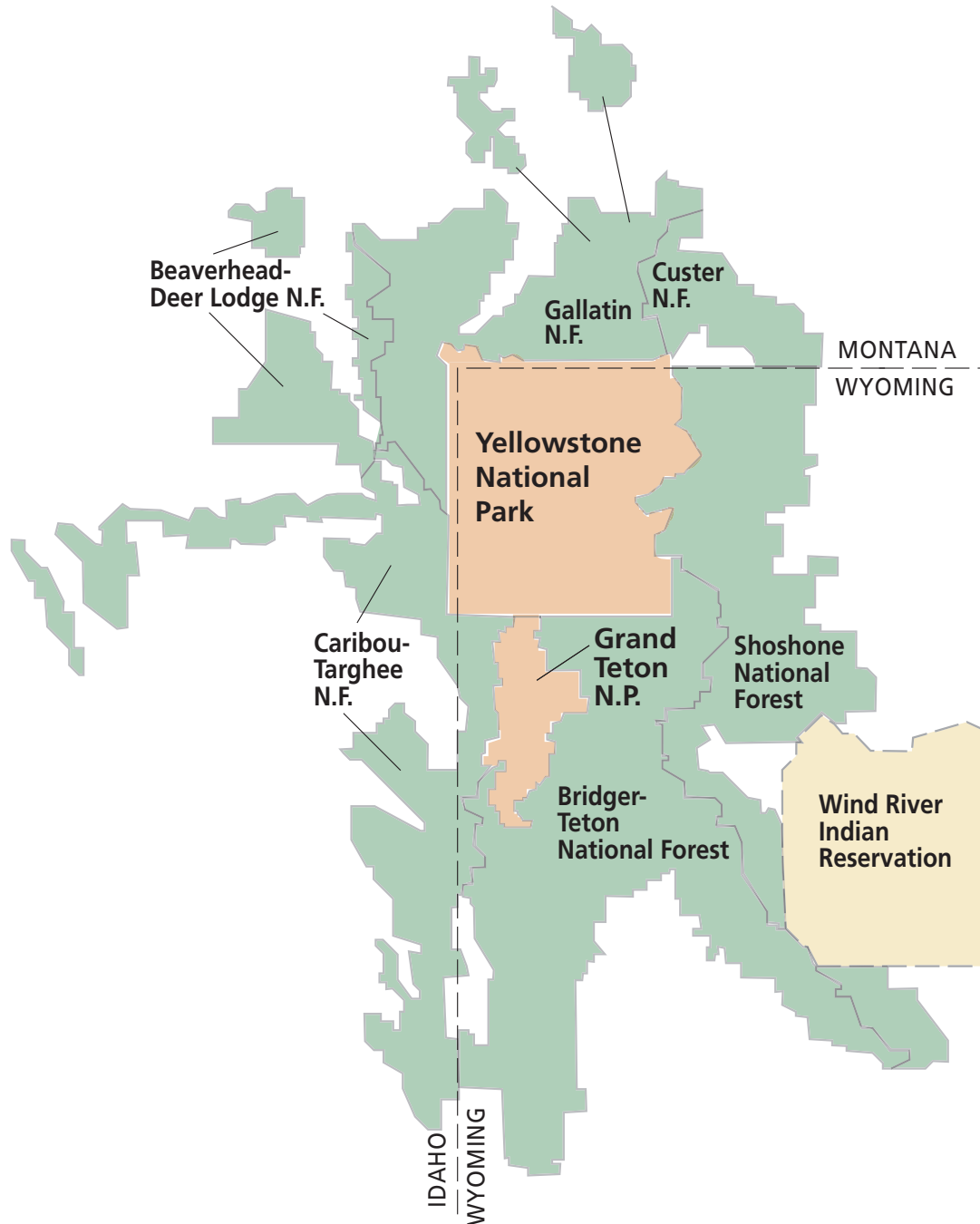
Greater Yellowstone Ecosystem

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

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

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

The Greater Yellowstone Ecosystem



Biological Diversity

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

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

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

Other unique life forms are protected here, too. Various species of microorganisms are the living representatives of the primitive life forms now recognized as the beginnings of life on this planet. Cyanobacteria found in Yellowstone's hot springs are similar to the cyanobacteria that were among the first organisms capable of photosynthesis (the process by which plants use sunlight to convert carbon dioxide to oxygen and other byproducts). (*See Chapter 4.*) Because Earth's original atmosphere was anoxic (without oxygen), cyanobacteria's photosynthesis began to create an atmosphere on Earth that would eventually support plants and animals.



Cycles and Processes

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

and processes are the essential connections within the ecosystem.

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

The ecosystem is constantly changing and evolving. A forest fire is one example of such an integral, dynamic process. Fires rejuvenate forests on a grand scale. Some species of plants survive the intense burning to resprout. Some cones of lodgepole pines pop open only in heat generated by fires, spreading millions of seeds on the forest floor. After fire sweeps through an area, mammals, birds, and insects quickly take advantage of the newly created habitats. Fires recycle and release nutrients and create dead trees or snags that serve a number of ecological functions, such as the addition of organic matter to the soil when the trees decompose. (*See chapters 5 & 6.*)

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

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Complexity

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

—Paul Schullery

Increasing Community Complexity

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

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

Intricate Layers

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

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

Trophic Cascades

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

indirectly increasing riparian bird habitat and improving fish habitat.

It is too soon to know for sure if this trophic cascade is actually happening, and how extensive it might be—or if it is one of many factors at work. For example, ecologists have documented a substantial rise in temperature in the northern range: From 1995 to 2005, the number of days above freezing has increased from 90 to 110 days. Changes in precipitation and effects of global climate change are also affecting vegetation growth. Ongoing, long-term scientific research will continue to examine these complicated interweavings of the Greater Yellowstone Ecosystem. (See chapters 5 and 8.)

Balancing Nature?

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

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

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

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



Winter in Yellowstone

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

Animal Behavioral Adaptations

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

Animal Morphological/Physical Adaptations

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

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

Biochemical/Physiological Adaptations

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

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Winter Challenges

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

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

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

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

Research in the Park

Additional information

Yellowstone as a Laboratory

Before and after its inception, Yellowstone has attracted scientists as a unique outdoor laboratory for research. For example, dozens of comprehensive studies were completed in the twenty years following the 1988 fires—something that could have

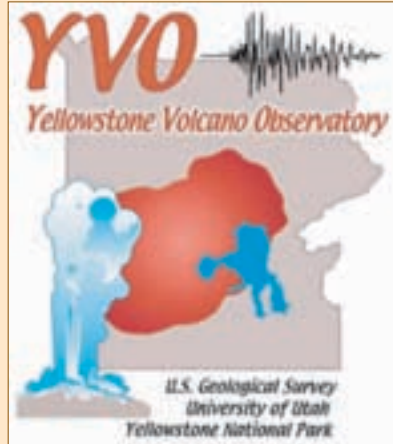
occurred only here. (See Chapter 6.) A similar flurry of research began with the restoration of wolves in 1995 and continues today. This active volcanic ecosystem also fuels a wide variety of geologic studies. Many of these scientific studies have ramifications far beyond Yellowstone National Park.

In 2008, more than 200 permits were on file for research in the park. Current research examples include:

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

THE YELLOWSTONE VOLCANO OBSERVATORY

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



The principal goals of YVO include:

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

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

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

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

Ecosystem Management Challenges

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

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

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

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

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

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

Time also refers to how this ecosystem changes and at what pace. What are the intervals between volcanic eruptions? Between fires? How has forest composition

changed in the past 100 years? How will climate change alter these patterns? These are the types of "time" questions that influence management of Yellowstone.

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

In addition to recognizing that the GYE needs to be managed as a whole, the federal agencies realize they need to work together as much as possible. Prior to 1964, the GYE was managed as individual units drawn along political lines, which resulted in fragmented, inconsistent, and sometimes contradictory management. But in that year, the managers of the two national parks and six national forests in the ecosystem formed the Greater Yellowstone Coordinating Committee to seek solutions to common issues. Four decades later, the GYCC continues to provide guidance and decisions for managing the Greater Yellowstone Ecosystem.

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For More Information

www.nps.gov/yell.

www.greateryellowstone-science.org/index.html

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

Yellowstone Today, distributed at entrance gates and visitor centers.

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

Staff reviewers: Tom Olliff, Chief, Yellowstone Center for Resources; Douglas W. Smith, Wolf Project Leader; P.J. White, Wildlife Biologist; Cheryl Jaworowski, Geologist.

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Yellowstone to Yukon: www.Y2Y.net