Science and Resource Management
Grand Teton National Park
& John D. Rockefeller, Jr. Memorial Parkway

National Park Service
U.S. Department of the Interior

GRAND TETON NATIONAL PARK
& John D. Rockefeller, Jr. Memorial Parkway

Natural and Cultural Resources

VITAL SIGNS 2021

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Grand Teton National Park Foundation and Grand Teton Association.
It shares natural and cultural resource data collected
during the calendar year 2021 and compiled in 2022.

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Back cover: Lidar map of the Snake River created by Madeline Grubb.

Where not otherwise indicated, photos in this report are courtesy of the National Park Service.

Table of Contents

Grand Teton resources include migratory bison herds.

Why We Monitor the Park's Resources

The National Park Service was established in 1916 with the mission of protecting the resources of the parks and providing for the public enjoyment of those same resources in such manner that the resources will remain unimpaired for future generations to enjoy. While Grand Teton National Park was not created until 1929 (and expanded in 1950), the mission remains the same. To protect and manage the wide variety of natural and cultural resources held within the park, resource management staff monitor and study individual resources and ecological processes—vital signs—to better inform decisions made in the park. Systematic monitoring is complicated by the fact that air resources, water resources, and many of the animals' seasonal migrations cross the boundaries of the park where other factors influence their condition. Inside the park, plant and animal species that may change or affect native species have been introduced both accidentally and intentionally. Pressure from humans, both within Grand Teton National Park and outside, may also affect conditions in the park. Data collected on some resources may be too limited to predict significant trends, but hopefully will provide a baseline for future study. Resources summarized in this report are monitored because of their significance to or influence on this ecosystem.

Vital Signs Summaries

Grand Teton's vital signs summaries are grouped into five categories for purposes of this report. They include:

- **Climate and Environment** (air quality, climate, fire, glaciers, rivers, and water quality) are primarily the result of natural processes that operate on distinctly larger scales than the park, but can be affected by human activities both within and outside the park.
- **Natural Resources:** selected plants and animals that
  - are or have been listed under the federal Endangered Species Act (bald eagle, gray wolf, grizzly bear, and peregrine falcon).
  - have experienced declines in the park and surrounding areas or are of special concern (golden eagle, great blue heron, greater sage-grouse, moose, trumpeter swan, and whitebark pine).
  - have relatively small populations in the park and are considered vulnerable (bighorn sheep, Columbia sharp-tailed grouse, harlequin, pronghorn, and red fox).
  - have a significant impact on the ecosystem and park management based on such factors as their large number, size, and movement outside the park, or where they are harvested (bison, elk, and mule deer).
  - are considered important indicators of ecosystem health because they are especially sensitive to environmental pollutants, habitat alteration, and climate change (sagebrush steppe, amphibians, cutthroat trout, and osprey).
- **Cultural Resources** (archeological sites, historic structures, and museum collections) are significant representations of the human evidence in the park and are inventoried, protected, and monitored to ensure that these resources and the information associated with them are passed along to future generations.
- **Challenges** (nonnative plants and animals, park visitation and use, plant and habitat restoration, wildlife collisions, and the human-bear interface) are generally caused or largely influenced by human activity and are monitored to inform park management.

Comparison to Reference Conditions

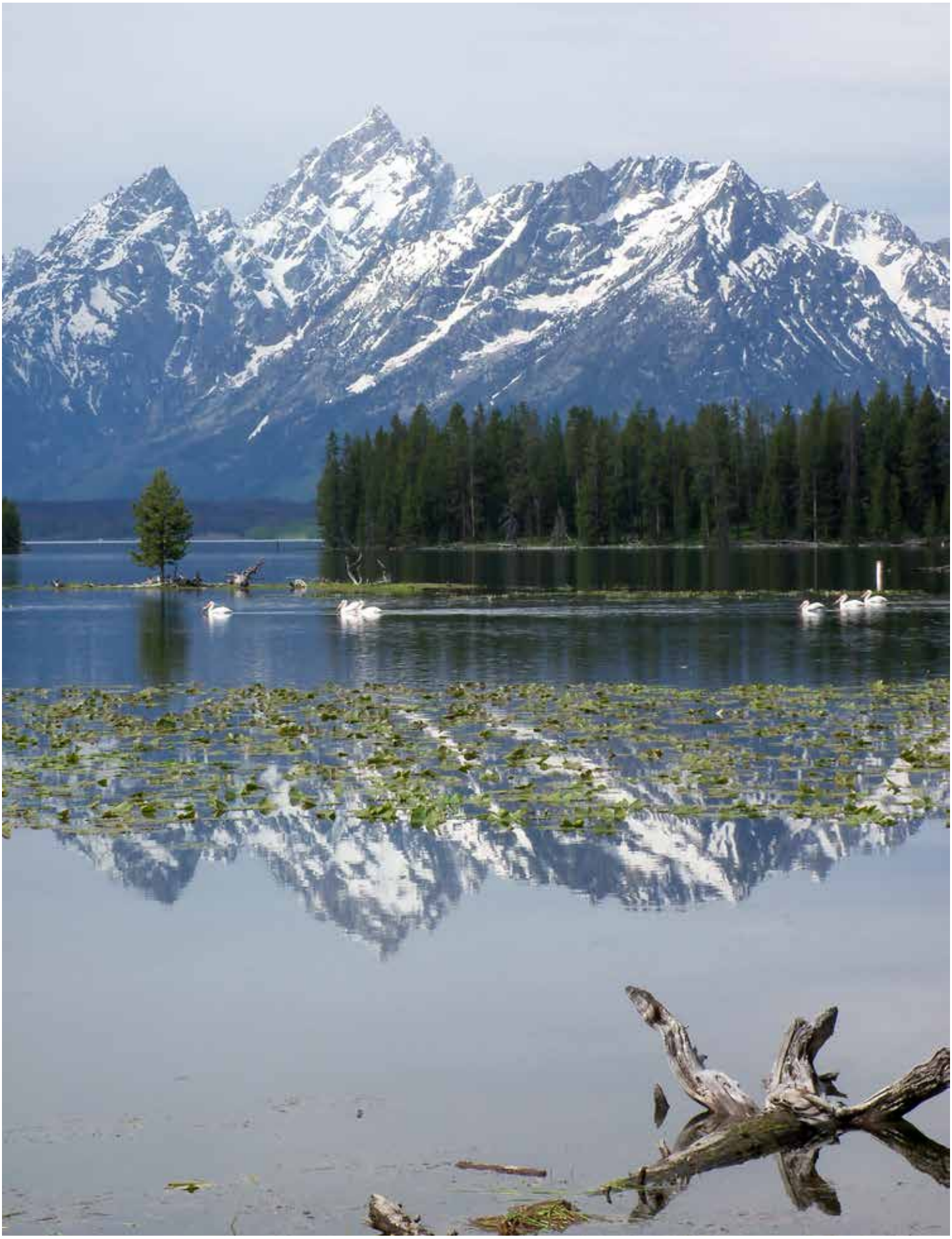
The table on the following page summarizes the current status of selected resources. In most cases, a reference condition is indicated that can be used for comparison purposes. Because conditions may fluctuate widely over time in response to natural factors, the reference condition is not considered the "desired" condition unless it is one that has been specified by government regulation or a plan. In other cases, the reference condition simply provides a measure for understanding the current condition, e.g., a historical range or scientific opinion as to the level needed to maintain biological viability.

Vital Signs Summary

TBD = to be determined

Resource	Indicators	Current Condition 2021 (or latest available)	Reference Condition
Climate and Environment			
Air Quality	Basic air quality parameters at 1 site	Class I Airshed	Clean Air Act
Climate	Average min., max. daily temp. (Moose) Annual precipitation (Moose)	26°F, 56°F 22.73"	22°F, 53°F (1959–2021 average) 21.83" (1959–2021 average)
Fire	Acres burned per year by wildfire	1 acre	1–19,211 (2002–2021 range)
Glaciers	Extent of 10 named glaciers	1.5 km² (2016)	Long-term decline
Water Quality	Basic water quality parameters- 2 river sites	Iron exceeds state standards	State water quality standards
Natural Resources			
Amphibians	% of potential sites suitable for breeding	71%	TBD
Bald Eagle	Breeding pairs	12 pairs	11.6 pairs (2012–2021 average)
Bighorn Sheep	Teton Range herd estimate	≈175 sheep	100–125 sheep (1970–2000 estimate)
Bison	Jackson herd winter count (includes areas outside park)	443 bison	500 bison
Common Loon	Breeding pairs	0 pairs	TBD
Elk	Jackson herd winter count (includes areas outside park) Summer count (portion of park herd)	10,734 elk ≥1031 elk	11,000 elk ≤1600
Gray Wolves	Wolves in Wyoming (outside of Yellowstone) Breeding pairs in WY (outside of Yellowstone)	217 wolves (43 in park) 17 pairs (6 in park)	≥100 wolves ≥10 pairs
Great Blue Heron	Active nests	34 nests	25.9 nests (2012–2021 average)
Greater Sage-grouse	Active lek	5 leks (4 in park)	8 occupied leks (7 in park)
Grizzly Bears	GYE population estimate Distribution of females with cubs	727 18 bear management units	≥500 grizzly bears ≥16 bear management units of 18
Moose	Jackson herd winter count	≥240 (74 in park)	TBD
Osprey	Breeding pairs	7 pairs	11.6 pairs (2012–2021 average)
Peregrine Falcon	Breeding pairs	6 pairs	4.7 pairs (2012–2021 average)
Pronghorn	Jackson Hole/Gros Ventre herd estimate	524 pronghorn	350–900 (modeled range)
Trumpeter Swans	Occupying breeding territories (includes areas outside park) Pairs producing young	6 pairs (4 in park) 2 pairs (5 cygnets hatched)	14 historic territories (10 in park) TBD
Whitebark Pine	Blister rust infection (% of trees in park)	62% of trees	TBD
Cultural Resources			
Archaeological Sites	Percentage of park inventoried	5% of the park	75–100%
Historic Structures	Percentage assessed in good condition	54%	100%
Museum Collections	Percentage that has been cataloged	86%	100%
Challenges			
Aquatic Invasive Species	Presence of nonnative species	13	0 (limit spread & effects on native sp.)
Fish	Species present	12 native 9 nonnative	12 native 0 (limit spread & effects on native sp.)
Human-Bear Conflicts	Injuries, food obtained, or property damaged	6 in park	8.6 (2011–2020 average)
Invasive Plants	Species present Acres treated	30 invasive species 4349 acres	0 (limit spread & effects on native sp.)
Mountain Goats	Estimated number in park	≥50 goats	0 (limit spread & effects on native sp)
Plant Restoration	Restoring native plant communities in former agricultural fields (Kelly hayfields)	1320 acres under restoration treatment	100% of 4500 acres in the former Kelly hayfields area

Reference condition specified by government regulation or management plan.



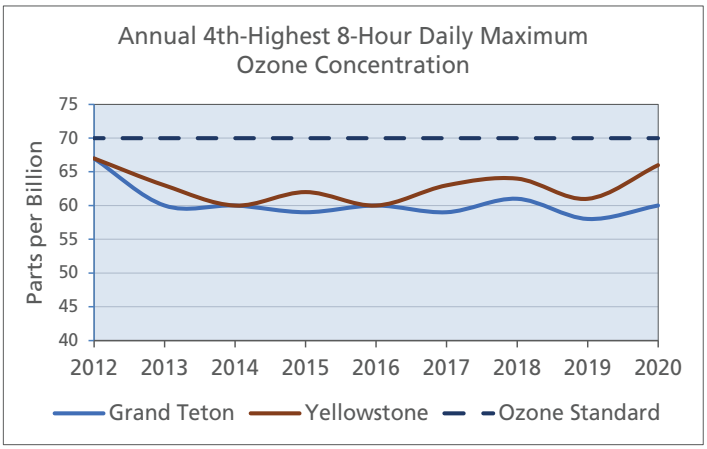
D. Swihart

Air Quality

Grand Teton National Park experiences good air quality; however, both distant and local sources of air pollution affect the park. As a federally designated Class I airshed, Grand Teton is required to meet high standards for air quality. The park conducts monitoring to evaluate the potential for air pollution to affect park resources, such as scenery, ecology, and public health.

Air pollutants of concern include sulfur and nitrogen compounds deposited by precipitation and by settling out of the atmosphere. These compounds can harm surface waters, soils, and vegetation. High-elevation lakes are especially sensitive to acidification from sulfur and nitrogen deposition and excess nitrogen enrichment. Acidification may cause loss of sensitive macroinvertebrates and fish, while nutrient enrichment may alter lake diversity. Alpine plant communities are also vulnerable to nitrogen enrichment, which may favor some species at the expense of others. Research suggests that deposition of nitrogen above 1.4 kilograms per hectare per year affected the diversity of diatoms (single-celled algae) found in high-elevation lakes in the Greater Yellowstone Ecosystem, an area that includes Grand Teton National Park.

The park operates an air quality monitoring station, established in 2011, to track the deposition of these compounds in precipitation. This station is part of the National Atmospheric Deposition Program, which measures precipitation chemistry at over 200 locations across the country. The link for real-time results from this station, including a webcam is https://www.nps.gov/subjects/air/webcams.htm?site=grte. Annual wet deposition of nitrogen measured at the Grand Teton station from 2012 through 2019 varied from 1.1 to 3.3 kilograms per hectare per year. The Grand Teton deposition monitor is located at an elevation of 6,900 feet; higher elevation areas of the park are likely experiencing higher levels of deposition as a result of higher annual precipitation.



Comparison of the maximum ozone levels annually on the fourth-highest day in Grand Teton and Yellowstone National Parks. The fourth-highest day of the year is identified and reported in order to minimize the impact of short-term variations in weather conditions in any given year. (2021 statistics not available.)

Some air pollutants while still in the atmosphere react in the presence of sunlight to form ozone (O_3). Ozone is harmful to humans as well as vegetation and is regulated under the Clean Air Act. Ozone monitoring in Grand Teton began in 2012. The Environmental Protection Agency has established a standard for ozone that is based upon the three-year average of the fourth-highest eight-hour average concentration that occurs during the year. Data collected by the park ozone monitor from 2012 through 2019 indicate that the park meets the ozone standard. Due to the short span of time that the Grand Teton monitor has collected data, it is not possible to determine whether or not there is a trend.

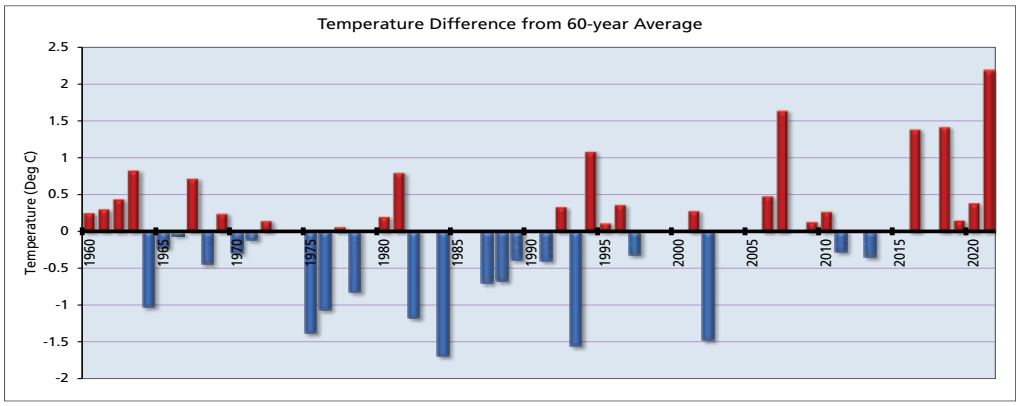
Park staff maintain the air quality station which includes a webcam that shows current visibility.

Visitors come to Grand Teton to enjoy spectacular views of the Teton Range and the Jackson Hole valley. Sometimes the park's scenic vistas are obscured by haze caused by fine particles in the air. Many of the same pollutants that ultimately fall out as nitrogen and sulfur deposition contribute to this haze and visibility impairment. Additionally, organic compounds, soot, and dust reduce visibility. In the region, average natural visual range is reduced from about 180 miles (without the effects of pollution) to about 120 miles because of pollution. The visual range is reduced to about 70 miles on the haziest days and can be even less on days with smoke. While natural fire is recognized for its ecological benefits, smoke from wildfires significantly contributes to particulate matter in the region. Periods of reduced visibility from wildland fire smoke are typical in late summer and were a factor even prior to human occupation.

Climate

Weather records for Moose, Wyoming have been collected since 1960. The average temperature for 2021 at Moose was the highest recorded in 60 years. It was 2.2°C above the sixty-year average.

Water deficit, a measure of drought stress, was near the 90th percentile of dryness. Although annual drought stress was high it did not break records because annual precipitation was slightly (28 mm) above average. Timely precipitation in late July and August substantially reduced fire danger.



Annual average temperature (AAT) difference at Moose, WY in Grand Teton NP compared to the 1960–2021 long-term average, (black horizontal line). Red bars show years of higher AAT, blue bars show years of lower AAT, and years without bars had more than 15 days of missing data. Data from Climateanalyzer.org.

Fire

Recent large wildfires in the western US burned through neighborhoods, prompting many communities to think about fire vulnerabilities and proactive ways to protect structures. One proven response is to reduce fuels by creating distance between trees and structures and cleaning up branches and dry vegetation on the ground. The fire management staff at Grand Teton National Park has been implementing fuel reduction treatments around developed areas for over 25 years. By thinning the vegetation and removing ground debris, they create an environment where an oncoming fire has less fuel so fire behavior moderates allowing firefighters to safely defend valued buildings.

Fire crews complete fuel thinning projects about every 15 years around housing areas, administrative sites, and backcountry cabins. They use chainsaws to remove the lower branches of mature trees and reduce the number of seedlings and saplings making it more difficult for flames to reach the forest canopy. They remove standing dead trees, cut up logs and branches, collect accumulated woody debris, and pile it for burning when snow is on the ground.

In the Flagg Ranch housing area in Grand Teton NP after the 2016 Berry Fire, fire effects were moderate and mainly confined to the understory. Scorch heights on the trees indicate flame lengths were generally less than 3-4 feet.

Fire managers design these treatments based on data collection, analysis, and monitoring. The park's fire effects crew visits all project sites collecting data before and after treatment to analyze changes to fuel loading and potential fire behavior. The crew sets up stand exam plots to calculate forest canopy, ground, and ladder fuels using specialized equations and computer models.

Using forest canopy bulk density (the density of seedings, saplings, and overstory trees) and canopy base height (the average distance from the ground to the lowest tree branches) with predicted flame length, it is possible to calculate whether a fire is likely to stay on the ground or burn into the treetops where it is much harder to control. These computer models also estimate how much wind speed would cause trees to torch and what percent of trees might be killed by fire under specified weather conditions.

The fire effects crew uses line intercept transects to measure the amount of organic material, twigs, branches, and logs on the ground. Together with the understory plants, these fuels determine flame length. A general rule of fire behavior is that firefighters with water and hand tools can be effective when the flames are less than four feet tall. Above that, the environment is too dangerous to operate in and air resources like retardant or water drops are necessary.

To assess the ladder fuels that facilitate the transition from fire on the ground to a crown fire in the tops of trees, they use a visual obscurity plot placing a checkered piece of fabric ten meters distant. The objective of fuels treatments is to reduce the average obscurity to less than 30%.

Over the years, Grand Teton's fire managers used this monitoring data to refine the park's thinning practices. The goal is having the right balance of trees for shade and privacy around buildings while reducing density prone to torching and crown fire. In 2016, the Berry Fire tested fuel treatments around Flagg Ranch. The flames transitioned to a surface fire because of the treatments. Many trees survived and no structures were burned proving the effectiveness of this method.

Glaciers

Grand Teton National Park has 11 known glaciers, previously thought to have formed during a short cold neoglaciation period called the Little Ice Age (1400–1850); however, recent research suggests that Teton Glacier may have been active since the last major glaciation approximately 10,000 years ago. Some of these glaciers are active, while others are considered remnant because they have lost so much volume they have stopped flowing. The Teton glaciers are iconic features of the park landscape, prompting efforts to monitor their fluctuations under current and future climate regimes.

Park staff monitor glacier movement, area and volume changes, as well as glacial influence on stream flow quantity and quality. Glaciers store water that provides critical input for land and aquatic ecosystems during the summer months. This is particularly evident in years of below-average precipitation. Researchers outside the park found summer stream temperatures can be 2–3 ºC cooler in glacier-fed streams than in adjacent glacier-less basins. In 2020, park staff installed gauges in paired glacier-fed streams and glacier-less basins to measure stream temperatures and flow levels over the next few years. Resource staff can use the collected data to calculate the percentage of the flow and the temperature changes that Teton glaciers contribute to late-season stream flows.

Middle Teton Glacier survey sites and ablation stake placement locations that measure the amount of ice melt or snow remaining and glacier velocity.

Changes in glacial extent and volume are significant indicators of changing climate and, as in nearly all glaciated areas of the globe, recent studies show significant and rapid retreat and volume loss of glaciers in the Greater Yellowstone Ecosystem (GYE). High-elevation areas of the Rockies are experiencing changes such as rising temperatures and earlier, more rapid snow melt than the region overall.

In 2013, NPS staff created and tested ice surface elevation survey methods on Middle Teton and Schoolroom Glaciers—both chosen for their relative safety and accessibility. Park staff also installed air temperature sensors to provide data for a GYE-wide sensor network, as well as time-lapse cameras to provide images and monitor summer snowmelt patterns on glaciers too difficult or hazardous to monitor directly.

Annually since 2015, physical science staff and climbing rangers conduct GPS elevation surveys of Middle Teton Glacier. These surveys show changes in the glacier surface and measure volume change over time. Results from 2021 indicate ice thinned everywhere on the glacier, and areas with the greatest amount of thinning (near the glacier terminus) saw up to 6.3 meters of loss for the year.

Park staff return annually to specific spots, like this one near Schoolroom Glacier, to take photographs for the monitoring project.

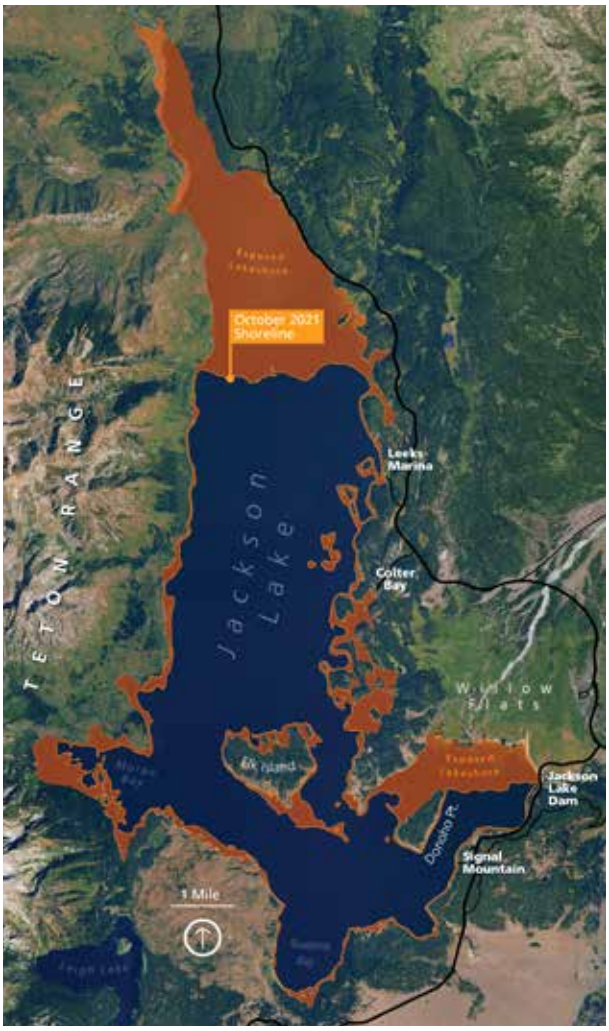
In 2021, physical science staff worked with skilled ski mountaineers to complete the second annual spring survey of Middle Teton Glacier to measure snow accumulation on the glacier prior to the summer melt season. Snow depths were similar to 2020 with accumulation deeper than the 8.5 m (27.9 ft) snow probe could reach. This impressive snow accumulation likely results from avalanches and wind redistribution of snow from surrounding peaks onto the glacier surface in addition to the snow falling there directly. During this survey, the researchers drilled through the snowpack and into the glacial ice beneath to place five ablation stakes. The stakes remained through the summer to measure snow and ice melt, as well as glacier movement. At the end of the melt season, none of stakes had any remaining snow. The total melt at each stake ranged from 5.6 to 8.8 meters. In September 2021, researchers located and measured the movement of the ablation stakes placed in 2020. Their measurements indicated a glacier velocity of up to 7.3 m per year. Park scientists will be able to use measurements from individual ablation stakes to project water loss and gain across the entire glacier surface, augmenting the GPS surface elevation measurements, which characterize volume (but not mass) change. These surveys illuminate patterns of seasonal snow accumulation and melt on the glacier surface.

Rivers

The rivers and streams of the Upper Snake River Basin and Grand Teton National Park drain the Teton Range, Absaroka Mountains, and Yellowstone Plateau. Major tributaries such as Pacific Creek, Buffalo Fork, Spread Creek, and the Gros Ventre River feed into the Snake River from the east. Spring snowmelt released from the surrounding high elevation areas drive annual floods throughout the park. Yearly peak flows can occur anytime from mid-May to mid-June, depending on snowpack and spring temperatures.

The fluvial backbone of Grand Teton, the Snake River, is managed as a Wild and Scenic River. The Wild and Scenic Rivers Act was created by Congress on October 2, 1968 to preserve rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. The segment of the Snake River below Jackson Lake Dam is one of the longest continuous, naturally-braided river systems in the contiguous United States. This dynamic system transports significant quantities of gravel and has diverse fluvial features such as side channels, logjams, and floodplains that support critical wildlife habitat. Although the Snake River is managed as a Scenic River, human impacts influence the hydrologic system.

Jackson Lake Dam, originally built in 1906–07 and reconstructed in 1916 to supply water to Idaho for agriculture, raised the height of the natural lake by 38 feet. Dam operations completely dictate the flow of the Snake River until the Pacific Creek confluence 4.5 miles downstream. In 2021 the Bureau of Reclamation, which operates the dam, released a daily peak flow of 5,280 cfs, slightly lower than the estimated unregulated peak flow of 5,977 cfs. The 2021 actual and estimated peak flows did not differ greatly in magnitude, unlike those in 2020 (actual peak flow of 5,520 and estimated unregulated peak of 10,776 cfs). Due to differences in snowpack, spring participation, and the timing and extremity of spring temperatures; the peak flow at Flagg Ranch in 2021 was about half of what was measured in 2020. Scientists observed this low-water trend throughout the Snake River headwaters and major tributaries. Net inflow from the Snake River into Jackson Lake Reservoir for 2021 was 33% less than in 2020, while net discharge from the dam was 41% greater than in 2020. This combination resulted in lower lake levels.



Aerial image of Jackson Lake in 2019 with a brown overlay showing areas of exposed shoreline by the low water level of October 2021.

Recent extensive research assessing climate and water patterns for the Greater Yellowstone Area suggests conditions observed in 2021 may become more commonplace as the area likely will shift from a snow-dominated watershed to a rain-dominated one with flows driven by rain events and not spring snowmelt. Predictions indicate that transition to a rain-dominated watersheds may cause increases in seasonal summer water deficits of up to 79% by the end of the century. Increased summer water deficits will likely lead to frequent significant drawdown from the reservoir in order to sustain downstream agricultural communities. Greater likelihood of large drawdown years, increased rates of evaporation due to warming temperatures, and a greater unpredictability in the timing and severity of spring flooding leave researchers of Grand Teton National Park unsure of what the future may hold for Jackson Lake and other park waters—all of which are essential not only to Grand Teton's outstanding biodiversity, but to its coveted natural, cultural, and scenic beauty as well.

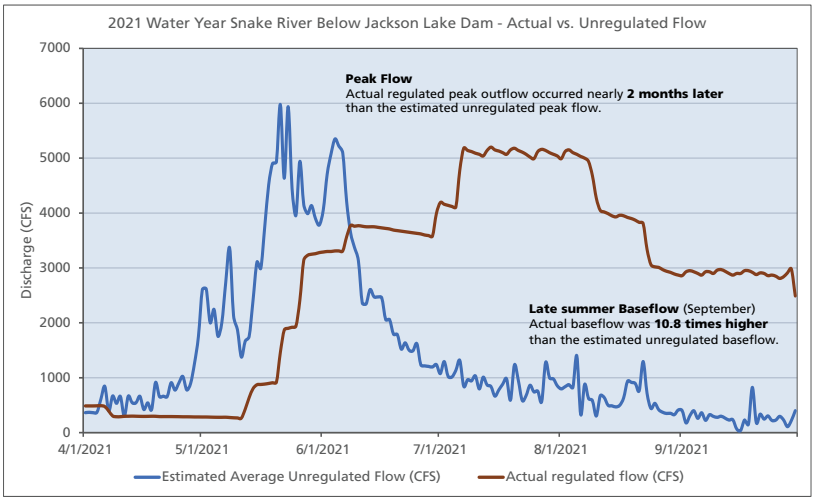


Chart comparing the Snake River's 2021 flow regulated by the dam (brown) compared to the estimated unregulated flow (blue).

Water Quality

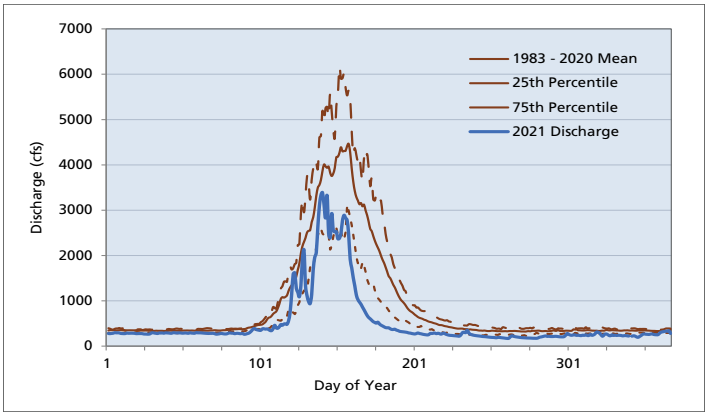
Good water quality is an important component of a healthy habitat.

Less than 10% of Grand Teton National Park is covered by surface water and all waters within the park are classified as Outstanding Natural Resource Waters. The park contains more than 100 alpine lakes, with surface areas ranging from 1 to 60 acres, and many above 9,000 ft in elevation. All surface and groundwater in the park drains to the Snake River. The Snake River is of considerable significance to the biological diversity and functioning of not only Grand Teton and the Greater Yellowstone Ecosystem, but also to the health and vitality of gateway and downstream communities.

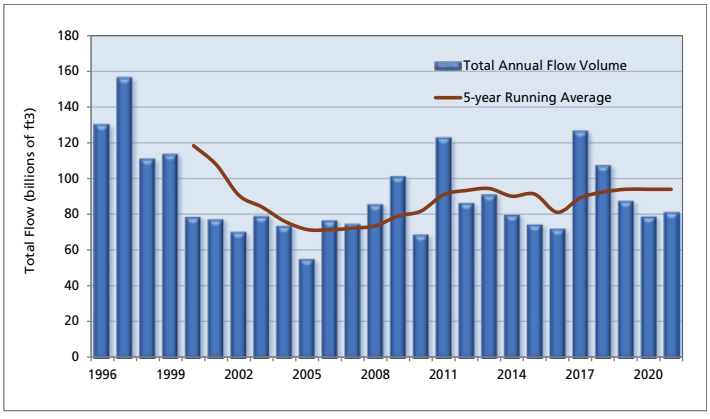
The uppermost reaches of the Snake River in Wyoming are characterized by good water quality with relatively low levels of dissolved nutrients and other anthropogenic compounds (e.g., pesticides). Good water quality and the presence of native fish, including cutthroat trout, are not surprising given that the headwaters of the Snake River include parts of Grand Teton and Yellowstone National Parks. Maintenance of high quality waters and continued support of native freshwater assemblages are among the highest management objectives for Grand Teton National Park. The State of Wyoming also recognizes and values this important resource and has designated the upper Snake River and all surface waters within the park as Outstanding or Class 1 waters—recognized for their exceptional quality and therefore "no further water quality degradation by point source discharges other than from dams will be allowed"(WYDEQ 2001). Along with these designations, the Snake River headwaters also received Wild and Scenic River designation by Congress (Snake River Headwaters Legacy Act, 2009), designed to preserve the Snake River headwaters' outstanding natural, cultural, and recreational values for the enjoyment of present and future generations.

The US Geologic Survey monitors flow levels of the Snake River at two locations—Flagg Ranch and Moose, Wyoming. Discharge in 2021 was below the long-term average for the Flagg site (1983–2021) for most of the year. Peak flows ranked among the three lowest in the 38-year monitoring record of the Flagg site and occurred 6 days earlier than average. Snake River flows at Moose are strongly manipulated by Jackson Lake Dam and reservoir operations, but were near or below average for that site (1995–2021). Despite the drought and below average flows entering Jackson Lake, total volume of annual flow at the Moose monitoring location ranked 13th out of the 26-year record. The date of half discharge (the day marking half the annual flow volume) occurred July 5, 2021, approximately ten days after the average date (June 26) for this location.

NPS resource staff from the Greater Yellowstone Inventory and Monitoring Network also monitor water quality at these same Snake River locations. Results confirm that concentrations of primary nutrients (nitrogen and phosphorus) remain consistently low or near detection limits at both sites. Nitrogen levels show little variation seasonally; however, total phosphorus showed significant variation and was highest during runoff. Trace metals (i.e., arsenic, copper, and selenium) are found in the watershed and are often naturally present in measurable concentrations, but typically below the State of Wyoming's aquatic life criteria. In 2021, copper and selenium were below detection levels at both sites. Total iron concentrations were low but measurable (Flagg 1.6 mg/L and Moose 2.9 mg/L) exceeding Wyoming's Iron Criteria for Aquatic Life 1.0 mg/L). Total arsenic concentrations were measurable at both locations with higher concentrations found at the Flagg site; however, both sites were below the State of Wyoming's Aquatic Life Criterion. Because most of the watershed in the upper Snake River is undeveloped, scientists believe that iron and other trace metals are naturally occurring and that natural fluctuations in metal levels are driven by elevated discharge following snowmelt.



Summary of the average daily discharge in the Snake River near Flagg Ranch, Wyoming by day of year.



Annual Snake River flow totals (in billions of cfs) at Moose, WY. A 5-year average smooths annual variations for a clearer examination of trends.

Whitebark Conservation

As a child of a science teacher and naturalist, I grew up studying the natural world. Working as a field ecologist for the past 28 years, I have had the honor of contributing to the conservation of our precious resources and to the scientific knowledge that promotes good management decisions. I am awed by the gifted scientists who have defined the art of ecology, land management and commitment of caring for the earth. Their commitment and dedication inspires me. Most of my work focuses on whitebark pine conservation in the Greater Yellowstone Ecosystem (GYE).

Whitebark are extraordinary pines that thrive at high elevations and in rugged places where few other plants can survive. They are the elders of the mountains we all love. We find them growing in our favorite wild places. They grace the ridges and steep slopes, defining high elevation forests and alpine slopes. As a keystone species, their outspread canopies are a roof top to the Rocky Mountains. They grow slowly and live long. They endure wind and cold for hundreds of years until sometimes, only a single live branch remains. By capturing and shading snow, they help release precious spring snow melt more slowly while providing food and shelter for other plants and animals. Whitebarks have a far-reaching and profound impact on those living beneath them.

In the last 24 years, we have witnessed the alarming loss of up to 90% of the mature overstory of whitebark in the GYE, including Grand Teton National Park. The story of the whitebark's staggering decline has three main characters. The first is a tiny predator, the mountain pine beetle, an insect native to this forest and as small as a grain of rice. The second character is the nonnative white pine blister rust, a fungus that strangles a tree as it cracks its bark, destroying the tree's circulatory system and killing branches that produce cones. The third character is us, the humans, who both introduced the blister rust and warmed the climate. Whitebarks are increasingly stressed by drought while both blister rust and mountain pine beetles are thriving in the warming climates; together these factors combine and escalate to unprecedented loss.

C. Wann

Whitebark Warriors assess a whitebark pine in winter.

C. Wann

Nancy Bockino rigged to climb into the upper branches of a whitebark pine.

My small and dedicated team of Whitebark Warriors walks thousands of miles in remote, rugged places each season doing conservation work. Supported by an incredible partnership between Grand Teton National Park, the Northern Rockies Conservation Cooperative, and the Grand Teton National Park Foundation, our work includes critical long-term collaboration among land managers and researchers in the GYE and throughout the distribution of whitebark. We work to protect the precious remaining trees that bear the seeds of the future alpine forest by placing insect pheromone patches to deter the mountain pine beetle. We collect bushels of cones for replanting and gather pollen and other plant materials to support the Intermountain Region Genetic Restoration Program in their work to test for and produce blister rust resistant seedlings for replanting. We collect data to monitor, document, and research whitebark's mortality, damage, regeneration, and interactions with other vegetation. We assess the landscape-level condition of whitebark stands and write the GYE-wide management strategies, updating them with new data and research findings. We participate in conferences, and produce videos, photos, and written pieces to educate. Visit https://www.gtnpf.org/whitebark-pine/ to enjoy some of this work.

One of the specialized tasks of the Whitebark Warriors is protecting and then later collecting seed cones. Like any day of whitebark field work, a day of cone work begins days before, understanding the weather patterns and checking sites for cones. For cone work not only do we need the weather to be dry and lightning free, but we also need winds less than 25 mph. All whitebark field work requires an "alpine start", waking at 3–4 am to provide time to hike to the far away whitebark stands, often racing afternoon winds, thunderstorms, and/or snow that will become too soft for traveling on. We pack the night before, using a checklist to avoid forgetting one of the many items that fill our large and heavy packs. We hike many miles in the morning light as quickly as we can.

Whitebark cones must be covered with wire mesh in June and July and left to finish growing until September. We call this first step caging. If we do not cage the cones, the Clark's Nutcracker

will take each and every seed and cache them far and wide, as that is his very important job. We only cage a few cones in each tree as to leave some for these birds. This amount is based on research and the ethic we follow to allow for the continued natural propagation of trees and the feeding of the busy alpine forest engineer, the Clark's nutcracker.

The Clark's nutcracker uses it's sharp bill to extract seeds from whitebark pinecones. They bury large numbers of seeds for winter food. Some of these cached seeds are not recovered and sprout into new trees.

Whitebark cones grow at the very top of the tree. The top of a whitebark tree doesn't have a main trunk, but instead many small branches. Each team member is a certified, well-trained tree climber. I have 17 years of tree climbing experience and other members of the team have 7 years; however, regardless of experience, the task of gathering the cones is always a challenge and requires training, bravery, strength, and composure.

Before the team begins climbing each tree, we perform a standardized inspection: rating the tree's hazards; inspecting our equipment; and reviewing our plan, communication, and safety system. Getting into the tree requires climbing a rope that we install from the ground. This seemingly "magic trick" technique utilizes specialized equipment and allows us to safely and quickly ascend the tree without damaging the branches.

C. Wann

The delicate task of balancing on thin branches to retrieve the mature cones.

Once in the tree, we lovingly call "the green room", it is hard to move about with sticky sap and branches catching your clothing, ropes, and even untying your shoelaces. We use multiple safety lines as we proceed to the top of the tree. In very large trees, two team members work together to get the cages to the top. After the cages are placed or the cones collected, we rappel back to the ground covered in sap and bark dust to begin again in another tree. But not before experiencing a moment of joy and gratefulness for the chance to spend time in the most unusual and beautiful place, high above the ground in the crown of this most magnificent alpine elder.

C. Wann

Mature cones bearing seeds for the future.

My commitment to caring for the Earth and the ancient trees that grace her steepest places, is unwavering. Conserving whitebark pine is crucial to the resilience and health of the ecosystems of the Rocky Mountains, water conservation in the West, and the stability of our wild places. I will have been successful if long from now future generations can meet and fall in love with the whitebark pine, drink the water they protect, and rest in their shelter on a cold windy winter adventure or enjoy the shade from their branches on a hot summer hike.

Nancy Bockino, Whitebark Pine Ecologist
Northern Rockies Conservation Cooperative

C. Wann

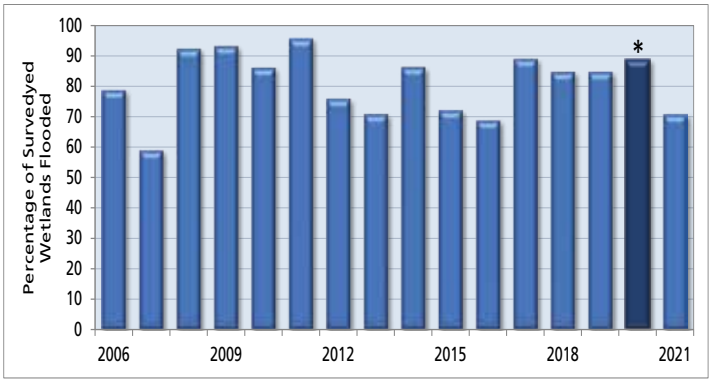
Nancy covers developing cones with protective wire mesh.

Amphibians

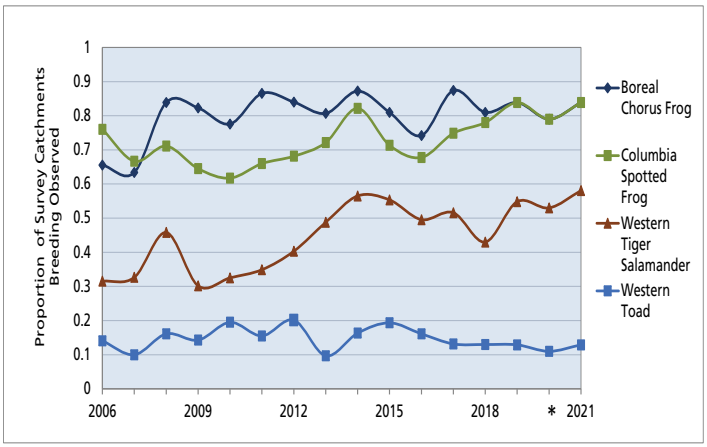
Each year the National Park Service collaborates with the Northern Rockies Conservation Cooperative, US Geological Survey, and university scientists to monitor amphibians in Grand Teton and Yellowstone National Parks. Biologists identified four species of native amphibians: western tiger salamander (*Ambystoma mavortium*), boreal chorus frog (*Pseudacris maculata*), western toad (*Anaxyrus boreas*), and Columbia spotted frog (*Rana luteiventris*) to monitor. The boreal chorus frog and the Columbia spotted frog are the most widely distributed species each year. The western tiger salamander and western toad appear to be less widespread. The northern leopard frog was historically documented in Grand Teton National Park, but only one confirmed sighting occurred since the 1950s. Plains spadefoot toads (*Spea bombifrons*) were recently documented in Yellowstone's Lower Geyser Basin, but their presence in Grand Teton has not been documented.

Annually since 2006, biologists have monitored and documented amphibian breeding activity in 31 catchments in the two parks. Encompassing about 500 acres each, these catchments or watersheds are defined by topography and vary in amounts of seasonal and permanent water. Biologists document breeding activity using visual surveys to detect eggs, larvae (e.g. tadpoles), and metamorphic forms (i.e., transitional forms between aquatic and terrestrial life stages).

In 2021, field crews were able to visit all 31 long-term catchments including all seven Grand Teton catchments after COVID-19 precautions limited field surveys in 2020. In 2021, two of the 31 catchments contained breeding evidence of all four species. Catchments that support breeding of all four native amphibians are relatively rare in the sample locations and are referred to as amphibian "hot spots". Finding two hot spots was consistent with 2017 to 2019 findings and up from 2016 when no catchments contained breeding evidence of all four species. For comparison, biologists found 14 catchments with breeding evidence of three species, 10 with evidence of two species, and four with a single species in 2021. These results illustrate the breeding variability that takes place even in protected areas.



Percentage of surveyed wetlands with standing water suitable for breeding. The asterisk indicates the restricted 2020 field season due to COVID-19 precautions.



Proportion of surveyed catchments where breeding was observed for each species. Asterisk indicates the 2020 field season restricted by COVID-19 precautions with only 19 of 31 catchments visited.

In 2021, researchers visited 338 individual wetlands spread across 31 catchments and surveyed 230 sites with standing water present. Of the 230 wetland sites surveyed in 2020, approximately 70% were occupied by at least one species of breeding amphibian, compared to 56% out of 281 surveyed sites in 2019 and 62% out of 229 surveyed sites in 2016 (a year with a similar number of dry wetlands).

Annual variations in breeding may be tied to hydrologic fluctuations that are driven by unique meteorological conditions each year. Such annual variations alter the extent and mosaic of wetland breeding sites, which can affect amphibian reproduction. The percentage of visited wetlands that supported surface water suitable for breeding varied between 59% in 2007 and 96% in 2011. In 2021, researchers estimated 71% of the wetlands sites were flooded.

All amphibians in Grand Teton and Yellowstone National Parks require wetlands for breeding, but individual habitat needs differ and may leave some species more vulnerable to changes in wetland condition (e.g., cumulative loss of seasonal water bodies or shrinkage of year-round ponds). The predicted increasing temperatures and changes in snowpack driven runoff for this region could alter wetland habitats and influence amphibian breeding. These expected impacts will disproportionately impact amphibians relying on shallow wetlands.

Long-time amphibian researcher, Deb Patla, holds a large western toad.

Bighorn Sheep

Bighorn sheep (*Ovis canadensis*) were once widely distributed throughout the mountains and foothills of the Rocky Mountain west. They persist today in small, fragmented populations that remain at risk of further decline and extirpation. The Teton Range population is Wyoming's smallest and potentially most isolated core native sheep herd. The population now lives year-round at high elevation along the Teton crest and in steep canyon areas on the east and west slopes of the range. Sheep in this population endure harsh winter weather in windblown areas above 9,500 feet. Historically, Teton Range bighorn sheep occupied low-elevation winter ranges, but these animals either abandoned these ranges or were extirpated as human development and use increased. The remnant Teton Range bighorn sheep population faces the serious threat of local extinction and biologists are working to address the most pressing concerns.

Traditionally, biologists estimate the size of this population from winter helicopter surveys. In 2021, Wyoming Game and Fish Department (WGF) personnel counted a total of 90 bighorn sheep (37 in the south end of the range and 53 in the north) which represents a slight decrease over the numbers counted in 2020. Since 2015, the winter counts varied widely from 46–100 bighorn. Such dramatic variation is unlikely to represent true population increases or decreases, but indicates the difficulties of trying to census the herd by helicopter surveys. Consequently, park biologists are evaluating the effectiveness of two non-traditional count methods based on bighorn use of mineral licks during the summer months: analysis using remote cameras and analysis based on fecal DNA. Beginning in 2018, park biologists placed motion-triggered cameras at mineral licks scattered across the Teton Range to monitor bighorn sheep. To date, biologists have analyzed more than 121,000 photos of bighorn sheep and documented over 2,000 groups visiting the licks. Initially the cameras were used to provide a population estimate based on observations of radio-collared animals, but as the number of radio-collared individuals declined the purpose shifted to documenting mineral lick use, lamb production, and visible health of the animals. In 2019, biologists started collecting bighorn fecal pellets near mineral licks to estimate population size. The DNA obtained from the fecal samples can be used to identify individual bighorn sheep and evaluate genetic attributes such as diversity, inbreeding, and population structure. Of the more than 570 fecal samples collected in 2021, just over 400 were genotyped. The genetic analysis identified 104 adult individuals (53 in the south and 51 in the north). For comparison, biologists on the February 2021 helicopter survey observed 76 adult bighorn.

Annual ground classification surveys started in 1990 provide composition, distribution, and trend information. Biologists from the park and Bridger-Teton and Caribou-Targhee National Forests counted a total of 58 sheep during the late August ground surveys (34 in the south and 24 in the north). Herd ratios were estimated at 52 lambs, 13 yearlings, and 19 rams per 100 ewes. Since ratios derived from summer ground counts are highly variable over time, the counts primarily provide confirmation that the herd is still reproducing and that some of the lambs survive their first year.

For most of the year, bighorn rams live in small groups of two to five males, joining up with the female herd for the mating season.

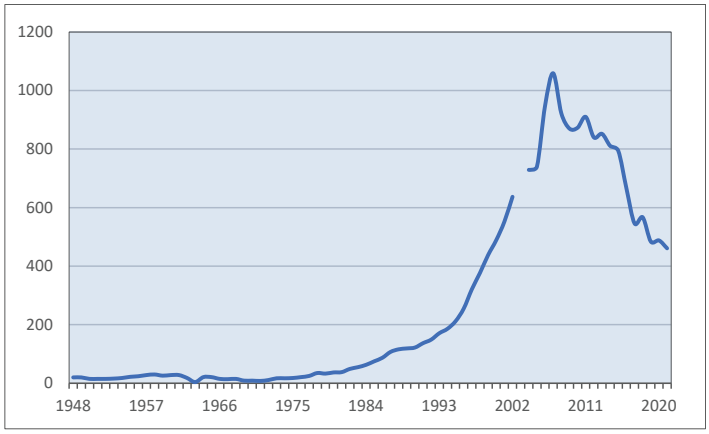
After several consecutive years with aerial survey counts of less than 60 animals, the Teton Range Bighorn Sheep Working Group convened an expert panel in 2019 to help identify and prioritize management, conservation, and research for the population. At the panel's recommendation, the Working Group hired a professional facilitator to guide a series of five collaborative public workshops held in 2020 addressing the issues of backcountry winter recreation and its impacts on bighorn sheep. (Detailed information on the collaboration process is found at https://www.tetonsheep.org/process.) After reviewing community input, the Working Group released a comprehensive report in October 2021, detailing its recommendations stemming from the public workshops. The recommendations consisted of designating areas of bighorn sheep winter range to protect from human disturbance, designating areas to maintain winter recreational access, and a variety of 'non-geographic actions' varying from continued education efforts to improved monitoring of the bighorn sheep population. The Working Group launched a stewardship campaign in December 2021 with the goal of building community engagement and sense of ownership towards the Teton Range bighorn sheep population. Grand Teton National Park will begin an Environmental Analysis in 2022 to evaluate the impacts of different management actions aimed at protecting bighorn sheep winter range within the Park.

Bison

Bison (*Bison bison*), a species native to Jackson Hole, were extirpated from the area by the mid-1800s. In 1948, twenty animals from Yellowstone National Park were introduced to the fenced 1,500-acre Jackson Hole Wildlife Park near Moran. In 1963, after testing positive for brucellosis, all adult bison in the small herd were destroyed while nine vaccinated yearlings and calves remained. Twelve bison from Theodore Roosevelt National Park were added to the population. The herd escaped from the wildlife park in 1969 and was allowed to remain free. Present-day Jackson bison are descendants of those bison and some subsequent migrants from Yellowstone. During the winter of 1980, bison moved onto the National Elk Refuge (NER) and began using supplemental feed intended for elk. This altered the herd's natural population dynamics, as they returned annually to feed on this easily obtainable food source.

Bison summer primarily in Grand Teton National Park. Depending on winter severity and native forage availability, most of the herd moves to the refuge for the winter, where they remain until April or May. In some years, individuals or small groups remain in the park all winter. The joint Bison and Elk Management Plan, approved in 2007 for the park and NER identified a population objective of 500 bison for the herd. The Wyoming Game and Fish Department adopted this objective. With unusually low winter mortality and no significant predation, the herd grew steadily since the 1980s, reaching more than 1,000 by the winter of 2007. More recently bison hunting, allowed on the NER and the Bridger-Teton National Forest, reduced bison numbers to slightly below the objective of 500 animals.

In mid-February 2021, biologists counted 443 bison with almost 68% of the herd (299 individuals) found on native winter range scattered throughout the central portion of the park and 144 bison (37 bulls, 75 cows, and 37 calves) found on the NER. In late February 2021, a large group of bison moved onto the Moosehead Ranch, a private inholding, to access horse feed. To proactively address concerns about potential horse injuries and horse feed damage claims, the Wyoming Game and Fish Department hazed the bison away from the feedlines. Between mid-February and early March, several groups of bison moved south via their traditional corridor that connects the Snake River floodplain south of Spread Creek with the broad sagebrush outwash plain of Antelope Flats. These bison likely made it to the NER as no reports of bison between Kelly and Shadow Mountain were received for the remainder of the winter.



Population size of the Jackson bison herd, 1948-2021. (No data for 2003.)

2021 marked the 4th year that a significant segment of the bison herd did not move to the NER and use the supplemental feed. Bison recruitment (as indexed by the late-winter calf ratio) in 2021 was 49 calves per 100 cows. This represents an increased recruitment rate compared to 2020 (39 calves per 100 cows) and 2019 (38 calves per 100 cows).

Vehicles collided with nine bison resulting in at least six confirmed bison deaths in 2021. In two of the incidents, vehicles hit multiple bison, three bison in one accident and five in the other. Three bison left the accident scenes but may have been injured and died later away from the road. The Shoshone Bannock tribe harvested five bull bison on the NER in April 2021, and hunters harvested another 88 bison outside of the park, including 56 bulls, 21 cows, and 11 calves.

Bull bison compete with other males for the right to mate. This competition can come to blows with aggressive shoving and head-butting.

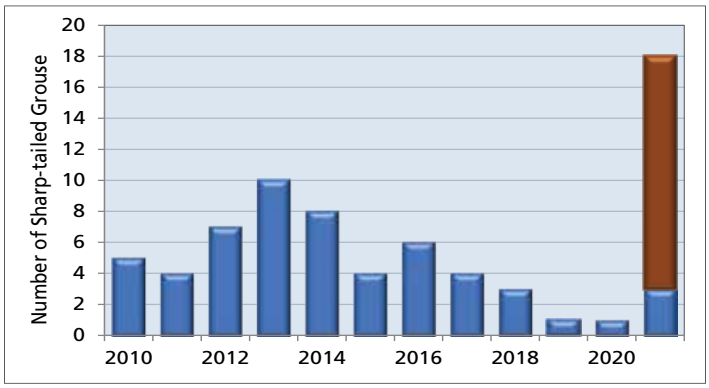
Columbian Sharp-tailed Grouse

Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) are endemic to sagebrush, shrub-steppe, mountain shrub, and riparian shrub communities. Once found in nine states and British Columbia, Canada, this subspecies now occupies less than 10% of its historic range. Excessive hunting in the 19th century combined with habitat alteration and degradation contributed to population declines and range reduction. Sharp-tailed grouse are considered a species of greatest conservation need in Wyoming. The Columbian is the rarest sharp-tailed subspecies and has experienced the largest decline of all sharp-tailed subspecies.

Similar to greater sage-grouse, sharp-tailed males display in the spring to attract females to breeding grounds called leks. Leks are typically positioned on elevated sites with flat, open areas. Columbian sharp-tailed grouse leks tend to have taller vegetation and more shrub cover than leks of other sharp-tailed grouse subspecies. Little is known about the sharp-tailed grouse population in Jackson Hole. Several incidental observations of small groups of sharp-tailed grouse were recorded in Grand Teton in recent years but no leks were found prior to 2010, and the nearest known lek was in Idaho on the western slope of the Tetons.

In the spring of 2010 biologists observed five sharp-tailed grouse displaying on a lek, Elbow West, near the southeast boundary of the park. This marked the first known sharp-tailed grouse lek in the park. In the spring of 2021, a University of Wyoming graduate student conducting survey transects found an additional lek, Warm Ditch. Grand Teton transect locations were determined by modeling preferred lek habitat for sharp-tailed grouse in other parts of Wyoming. Transect surveys in future years based on this modeling may lead to the discovery of more leks.

In 2021, biologists observed one male displaying breeding behavior at the Elbow West lek, marking the third consecutive year with only a lone male observed. Biologists could not identify the sex of the other three birds observed at Elbow West. The observation of unknown birds is encouraging, indicating that more males may have occupied this lek in 2021. The total number of sharp-tails on Elbow West was higher than the previous two years. While biologists have never confirmed the presence of females at Elbow West, the longevity of lekking activity, as well as observations of a hen with chicks within two miles of the lek during the summer of 2016, indicates successful breeding occurs. Observations of the Warm Ditch lek indicate use by a greater number of sharp-tailed grouse than Elbow West. Fifteen sharp-tailed grouse males were observed on the Warm Ditch lek, exceeding the highest number ever observed on Elbow West. Further observations during the spring of 2022 are needed to determine attendance by males and females.



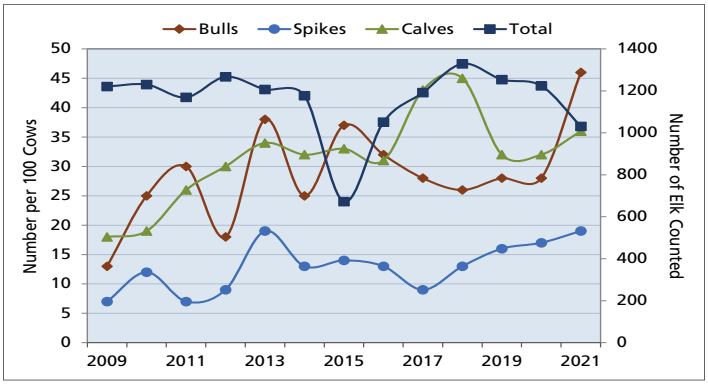
Counts of Columbian sharp-tailed grouse on the Elbow West lek are in blue. Count of Columbian sharp-tailed grouse on the Warm Ditch lek is in brown.

Two Columbian sharp-tailed grouse display on the lek spinning with outstretched wings and tails raised to expose the white feathers underneath.

Elk

Grand Teton National Park and the John D. Rockefeller, Jr. Memorial Parkway support a migratory Rocky Mountain elk (*Cervus canadensis*) population that is part of the larger Jackson elk herd. Elk summer throughout these park lands and occur at relatively high densities in low elevation open sagebrush, willow, and forested habitats. Most of the elk migrate to winter range on the National Elk Refuge near Jackson, but a small number winter in the eastern portion of the park. Other portions of the herd migrate through the park and parkway between the National Elk Refuge and summer ranges in Yellowstone and the Bridger-Teton National Forest. The Jackson elk herd is one of the largest in North America. Its migratory routes cross multiple jurisdictional boundaries as elk travel between seasonal ranges. As Grand Teton's most abundant ungulate, elk have significant effects on park ecology. Their grazing and browsing may affect plant productivity and, as prey and carrion, elk provide sustenance to carnivores and scavengers. They are also popular with park visitors for viewing and photographing.

The mid-winter trend count objective for the Jackson elk herd set by the Wyoming Game and Fish Department is a three-year average of 11,000 elk ± 20%. During the 2021 classification count, biologists counted 10,734 elk yielding a three-year average of 10,449. Estimated at above 19,000 during the early–mid 1990s, the Jackson herd is reduced by annual harvest on the national forest and the refuge, in addition to an elk reduction program in the park (authorized by Congress in 1950 to help manage herd size when necessary). Non-harvest mortality (e.g., from winterkill) averages an unusually low 1–2% of the herd. During the 2021 park reduction program a total of 104 elk were harvested.



Grand Teton mid-summer elk count and classification, 2009–2021.

Female elk leave the herd to give birth to a spotted, scentless calf. The lack of scent helps protect the calf as it lies motionless while the mother feeds nearby. After about two weeks the female and her newly scented calf join the nursery herd where the adults work together to defend against predators.

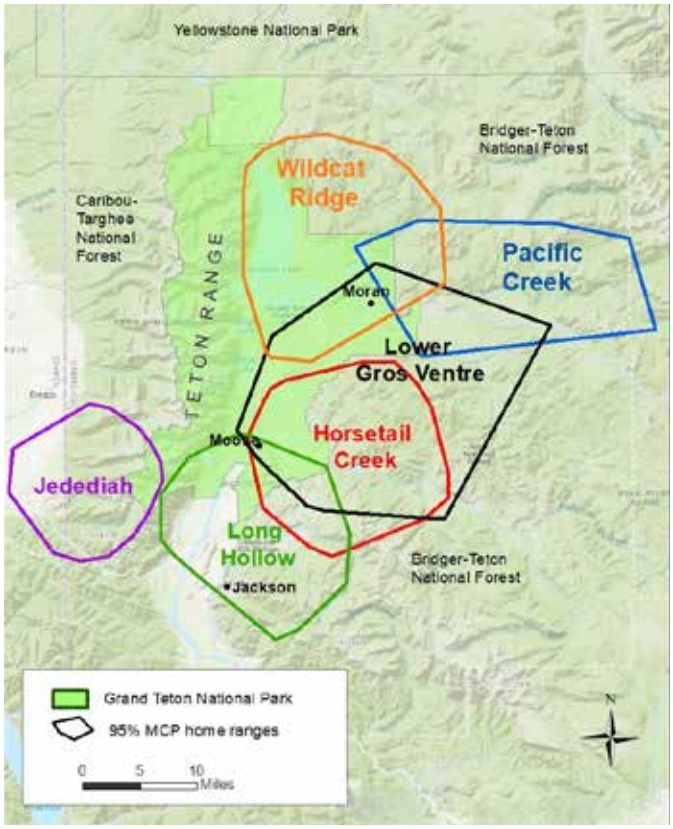
During the summer, park biologists count and classify elk from a helicopter in a portion of the park with high elk density and visibility. The survey is not intended as a census of park elk, but provides a minimum count of elk within the area surveyed. In 2021, park biologists counted and classified 1,031 elk. The total number of elk counted was lower than in 2020, likely because no elk were counted along the Snake River south of Moose. Typically, several hundred elk are counted in this area, but radio collar data indicated the elk were outside of the park on the day of the count. Since 2016, the trend of elk counted in the survey was increasing until this year. Herd ratios were 46 mature bulls, 19 spike bulls, and 36 calves per 100 cows. All herd ratios were higher than in 2020—a difference explained by the fact that 175 fewer cows were counted in 2021 due to a shift in distribution, rather than an actual decrease in numbers of cows. Calf ratios were highest along the east front of the Tetons between White Grass and Rockchuck Peak and lowest in the Willow Flats. Biologists also surveyed elk along northeast and west sides of Jackson Lake and counted 227 additional elk with relatively high calf ratios at 44 calves per 100 cows.

Gray Wolves

After the US Fish and Wildlife Service and National Park Service reintroduced gray wolves (*Canis lupus*) into Yellowstone National Park in 1995–96, wolves dispersed to Grand Teton National Park and surrounding areas. In 1999, a wolf pack denned in Grand Teton and produced a litter of pups—the first in the park in over 70 years. Since then, wolves continue to live and reproduce in the Jackson Hole area, including Grand Teton and the John D. Rockefeller, Jr. Memorial Parkway. The reintroduction of wolves restored a predator-prey relationship absent since humans eradicated wolves from the ecosystem in the early 20th century.

At the end of 2021, a minimum of 43 wolves in 6 packs resided in the Jackson Hole area with home ranges in Grand Teton National Park. Jedediah (2 wolves), Lower Gros Ventre (13), Wildcat Ridge (4), Horsetail Creek (10), Long Hollow (2), and Pacific Creek (12) packs all had home ranges that included the park. Lower Gros Ventre (6 pups) and Wildcat Ridge (3) packs denned in the park. To minimize human disturbance to wolves raising young, park managers implemented closures around den and rendezvous sites.

There were three known wolf mortalities in the park in 2021. A pup from the Wildcat Ridge pack was struck by a vehicle, an adult female from that pack was likely killed by other wolves, and an adult male from the Lower Gros Ventre pack died of natural causes. Two adult males from the Long Hollow pack and three Huckleberry wolves dispersed out of the area. The Huckleberry pack did not maintain a home range and later dissolved with no known wolves at the end of 2021. Ten wolves were captured in 2021 and fitted with seven GPS and three VHF collars.

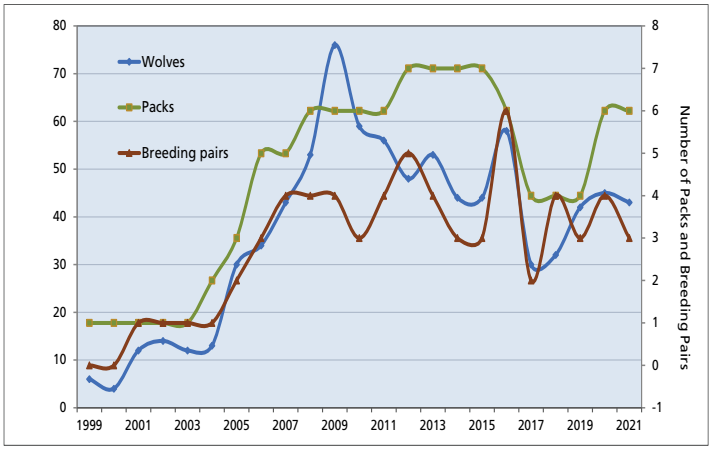


Distribution of Jackson area wolf packs, 2021 MCP (Minimum convex polygons) are home ranges based on collared pack members.

The return of wolves to Grand Teton and the surrounding area presents researchers with an opportunity to study the complex relationships of an ecosystem with an intact suite of carnivores and ungulates. Wolves and other predators affect prey populations and behaviors. In a five-year study, biologists found that in the winter when elk densities were relatively low, wolves preyed primarily on elk (71%) and moose (26%) and fed on deer and bison infrequently (3%). In the summer, when elk densities in the park were high, wolves preyed almost exclusively on elk and their calves, representing more than half of the kills in June and July.

Wolves also prey on other species, including livestock which bring wolves into conflict with humans outside the parks. A long history of controversy surrounds wolf management and the effects of wolves on ungulates and livestock. Wolves in Wyoming were removed from the federal list of threatened and endangered species in September 2012. In 2013, the State of Wyoming implemented a wolf hunt in the trophy management area of northwest Wyoming outside national parks, the parkway, national wildlife refuges, and the Wind River Indian Reservation. In September 2014, a court ruling suspended the hunt and again granted Wyoming wolves federal protection. However, the US Court of Appeals for Washington DC ruled to reverse the 2014 decision and once again officially removed Wyoming wolves from the endangered species list on April 25, 2017.

Aerial view of young wolf pups out in the open.

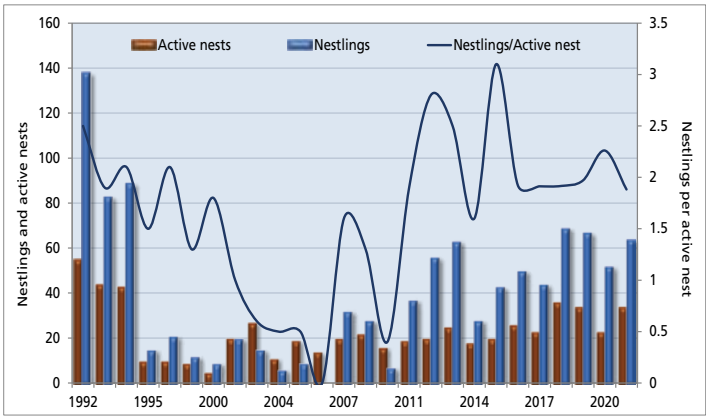


Population of Jackson area wolves, including those in Grand Teton, 1999-2021.

Great Blue Herons

Great blue herons (*Ardea herodias*) are colonial water birds dependent on wetlands for feeding, nesting, and habitat security. Colonial nesters are highly vulnerable to human disturbance. Human activities near heron colonies (heronries) may influence occupancy, disrupt nesting behaviors, change foraging behavior, increase predation, or lead to abandonment. Heronries are also vulnerable to predation. Monitored since 1987 in Grand Teton National Park, heron occupancy and reproductive success vary widely with long-term productivity declining but fairly stable within the last decade. Over the last decade herons abandoned several historic heronries, including two along the Buffalo Fork. In 2018, biologists discovered two new heronries in the Oxbow Bend and Moran Junction areas that are geographically separate from historic heron colonies. These heronries remained active over the past two breeding seasons. In 2021, biologists on an aerial survey located a new heronry at Swan Lake. Additional periodic aerial surveys could aid in finding new heronry locations that may not be visible from boats, roads, or trails.

During the 2021 breeding season, park staff located and monitored six heron colonies, including the newly discovered heronry at Swan Lake. Breeding pairs occupied five of the six colonies. Arizona Lake and Pinto Ranch heronries both had ten active nests, while Oxbow Bend and Swan Lake had six each. Herons produced young at all four locations, Arizona Lake (25 young), Pinto Ranch (16), Oxbow Bend (12), and Swan Lake (11). The Moran Junction heronry was abandoned partway through the season and did not produce any young. The Sawmill Pond heronry was unoccupied, despite one nest still being present.



Great blue heron productivity in Grand Teton NP, 1991-2021. Arizona Lake heronry, discovered just outside the park's boundary, is included in the park's monitoring program since 2009. Monitoring of heronries was not conducted in 1996, 1997, 2002, or 2008.

In 2021, the total number of active nests (34) and nestlings (64) were well above the 10-year average (25.9 and 53.6, respectively), while the number of nestlings per active nest (1.9) was slightly below the 10-year average (2.2). Overall numbers of active nests and nestlings remained generally stable for the last ten years. While heron numbers increased since their historic lows of 1995-2006, current numbers are still well below the historic highs of the early 1990s.

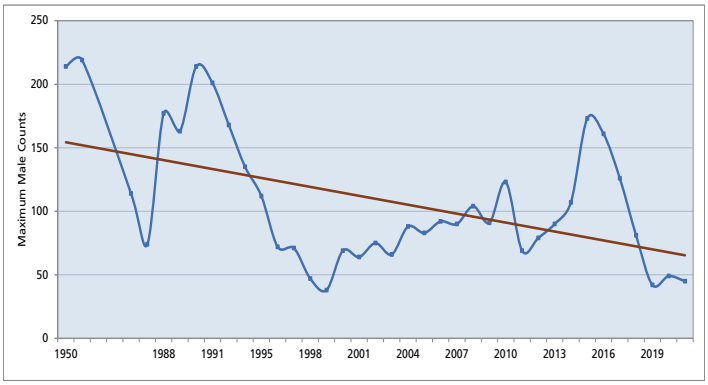
Greater Sage-grouse

Historically, greater sage-grouse (*Centrocercus urophasianus*) occurred in sagebrush habitats across much of Wyoming and the American West. Sage-grouse populations declined up to 80% throughout their range over the past 50 years, most likely due to increased livestock grazing, farming, residential development, invasive plants, and oil and gas development. The Jackson Hole sage-grouse population also declined despite occurring in an area with a high density of public lands and protected habitat.

Sage-grouse congregate on display areas, or leks, during their breeding season each spring. Lek sites are usually open areas such as rocky slopes, burned areas, or gravel pits. Males perform a unique strutting display to attract females for breeding. Biologists began monitoring sage-grouse leks in Grand Teton National Park in the 1940s.

In the spring of 2021, eight leks were monitored weekly [seven in the park and one on adjacent National Elk Refuge (NER) land] and sage-grouse consistently occupied five leks (Airport, Moulton, RKO, Timbered Island, and North Gap-NER). The Airport Pit was last active in 2014, while both the Bark Corral and Spread Creek leks were active in 2020.

Sage-grouse were at historic low numbers in 2021. For the four active leks within Grand Teton, the total count of all sage-grouse was 57 and the maximum male count was 45; well below the 10-year averages of 138 and 95, respectively. Biologists made the highest recent counts in 2015 with 243 total birds and 173 males. For comparison, the 2021 count is less than a quarter of the 2015 total birds count and less than a third of the males. All leks within the park had counts considerably lower than their 10-year averages. Biologists think these historic lows are caused by limited winter habitat. For four of the past five winters, Grand Teton experienced well-above average snowpack that decreased the amount of exposed sagebrush which is critical cover and food for sage-grouse.



Counts of male sage-grouse (with a trend line) on Grand Teton NP leks 1948-2021. No monitoring data for sage-grouse in 1952–1985 and 1993.

Grizzly Bears

Predator eradication programs eliminated grizzly bears (*Ursus arctos*) from most of the western US by the 1950s. Due to its isolation, the Greater Yellowstone Ecosystem (GYE) became one of the last refuges for grizzly bears south of the Canadian border. During this time, garbage became a significant food source for bears throughout the region. In an effort to return bears to a diet of native foods, garbage dumps in the GYE were closed in the 1960s and 1970s. Following the dump closures, human-caused mortality increased significantly and the population declined from an estimated 312 grizzly bears, prior to the dump closures, to 136 bears in 1975. That same year the grizzly bear was federally listed as a threatened species.

Intensive conservation efforts over the next 30+ years allowed grizzly bears to make a remarkable recovery and the U.S. Fish and Wildlife Service delisted grizzly bears in the GYE twice – the first time in 2007 and the second in 2017. However, both times the decision was overturned due to litigation and the grizzly bear currently remains a threatened species in the lower 48 states.

Scientists with the Interagency Grizzly Bear Study Team (IGBST) use the best available science to conduct population monitoring and research. To estimate the GYE grizzly bear population size, the IGBST uses a statistical method to estimate the number of unique females with cubs, which becomes the basis for estimating the total population. In 2021, the IGBST adopted a revised approach to this method by redefining what constitutes a unique female. Prior to 2021, scientists distinguished unique females with cubs of similar composition if they were sighted at least 30 km apart. The 30-km threshold was a conservative statistical model that could detect changes in the population which was low at the time; however, as GYE grizzly bear population increased, this method increasingly underestimated the true population size. To address this bias, the IGBST made a change to how they defined unique females with cubs based on field research and statistical testing. Starting in 2021, unique females with cubs of a similar composition will be distinguished from each other if they are sighted at least 16 km apart. By using the refined 16-km threshold, the population estimate more accurately reflects the true population size in the ecosystem.

A female grizzly bear in Grand Teton NP is known by her research number, 399, because she frequents roadsides with her cubs foraging for natural foods. In 2021, the 25-year-old mother continued to draw attention with her four yearling cubs, who almost matched their mother in size by the end of the year.

For 2021, the GYE grizzly bear population was estimated at 1063 (95% confidence interval = 948–1178). When comparing this population estimate to previous years, it is important to note that the true grizzly bear population size did not dramatically increase since 2020. The change in estimates is due to the refinements in how unique females with cubs are counted. The IGBST will continue to use the best available science to accurately monitor the GYE grizzly bear population and plan to transition to an "integrated population model", which uses data from multiple sources in the near future.

There are more grizzly bears today, occupying a larger area (25,038 mi^2), than there were in the late 1960s prior to the closure of the garbage dumps (312 bears occupying 7,813 mi^2). Grizzly bears now occupy areas where they were absent for decades including all of Grand Teton National Park and the John D. Rockefeller, Jr. Memorial Parkway. The high visibility of grizzly bears foraging on native foods in roadside meadows makes Grand Teton a popular bear viewing destination. Management of grizzly bears and their habitat continues to be a high priority in the park and parkway.

Harlequin Ducks

The harlequin duck *(Histrionicus histrionicus)* is a relatively small species that breeds in northern boreal regions of eastern Canada, the Pacific Northwest of the US and Canada, Alaska, and the Rocky Mountains. The population status for North American harlequin ducks is variable; however, in the Rocky Mountain region they are considered a sensitive species and Wyoming lists them as a species of greatest conservation need. Harlequin duck core breeding range exists in Alaska, Washington, Oregon, Idaho, Montana, and Wyoming. The population in Wyoming represents the extreme southern and eastern extent of the western North American breeding population. The harlequin duck is one of the rarest breeding birds in Wyoming and its current breeding range appears to be limited to Yellowstone and Grand Teton National Parks, and the Bridger-Teton and Shoshone National Forests. Little information is available on survivorship, migration movements, winter habitat use areas, and general breeding ecology. Better understanding of these subjects are needed in order to conserve harlequin ducks in Wyoming.

Efforts to capture and tag harlequin ducks with satellite transmitters and geolocators were undertaken from 2014-2019; however, no similar efforts have taken place during the past two seasons. Biologists expect to tag more ducks in the future to study the population's migration patterns.

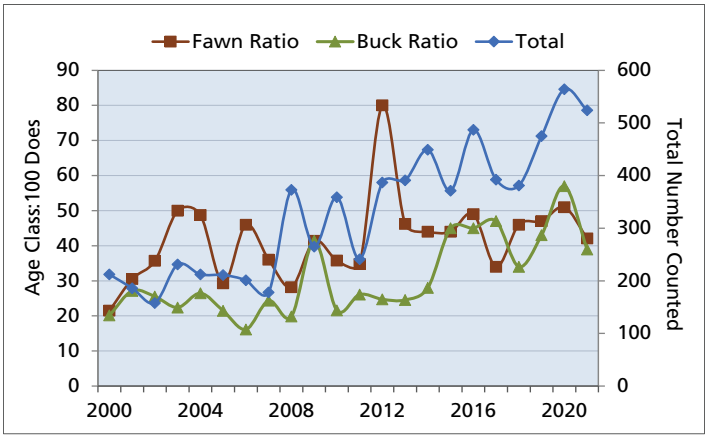
A biologist hikes in a stream hoping to spot females with broods.

In the spring of 2021, biologists surveyed the lower stretches of Berry and Moose Creeks for breeding pairs, but none were located. In mid-August, biologists conducted more extensive surveys along sections of Owl, Berry, and Moose Creeks walking over 6.5 miles in the streams. They located two hens with broods: one of four chicks and the other of two. Two solitary hens were also observed in this survey. This represents the most productive breeding year documented by park biologists since 2018, when three broods and 11 chicks were observed.

Pronghorn

The pronghorn (*Antilocapra americana*) that summer in Grand Teton National Park are a segment of the Sublette herd that undertakes one of the longest terrestrial mammal migrations in the Western Hemisphere. In the fall, these fleet-footed animals cover up to 30 miles a day on a roughly 100-mile route, one-way, that follows the Gros Ventre River to its headwaters and down to winter range in the upper Green River drainage. Pronghorn bones found at the Trappers' Point archeological site support that animals have been using this narrow pathway for at least 6,000 years. Concern for this migratory segment of the pronghorn herd exists because development (residential and energy) occurs along the southern portion of the route and in their winter range.

Park biologists track the number of pronghorn summering in the Jackson Hole and the Gros Ventre River drainage by conducting aerial line transect surveys. This survey technique corrects for groups missed and provides an estimate of pronghorn abundance with a level of precision.



Pronghorn count and age/sex ratios during late summer classification counts, 2000-2021 (data from Wyoming Game and Fish Department).

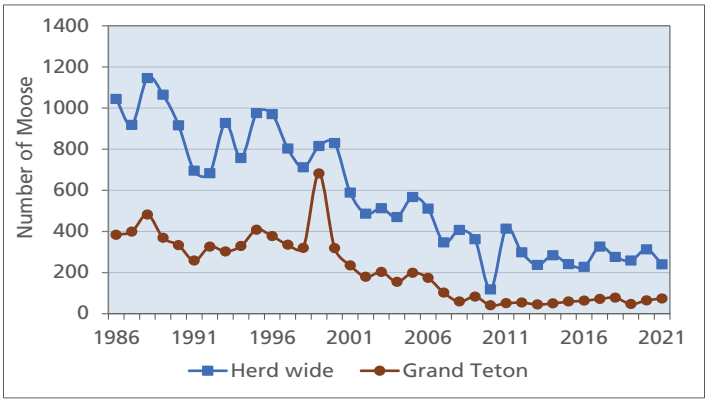
Pronghorns legs may be thin but they are not weak. The muscles are at the top of the legs and provide the ability for great speed.

Grand Teton, National Elk Refuge, and Wyoming Game and Fish Department personnel conduct ground surveys in late summer to count and classify pronghorn after fawns are born. A total of 524 pronghorn were counted during the 2021 survey. Ratios were estimated at 42 fawns and 39 bucks per 100 does. The reproduction rate in this herd segment is typically low, but varies widely. Low pronghorn fawn counts are often seen following a severe winter or a cool, wet spring. Both fawn and buck ratios were lower than the previous year. In general, a ratio of 25 bucks per 100 does will maintain good recruitment for the population.

Moose

Moose (*Alces alces*) were rare or absent from Grand Teton National Park prior to 1912, but became numerous by 1950. They are better adapted to survival in deep snow than other ungulates in the Greater Yellowstone Ecosystem. Except during the rut, moose are usually found alone or in small family groups. Grand Teton moose are part of the Jackson herd which includes animals outside the park boundaries. The herd experienced a decline from an estimated high of more than 4,000 in 1990 to less than 1,000 since 2008. This partially migratory herd moves between distinct but overlapping summer and winter ranges. The Wyoming Game and Fish Department conducts an annual aerial trend count of the Jackson moose herd. The count for 2021 totaled 240 moose (roughly 73 fewer than counted in 2020), including 74 in 44 groups within Grand Teton (32 cows, 22 bulls, 19 calves, and 1 unclassified individual). Ratios were 55 calves and 82 bulls per 100 cows.

The moose herd decline likely resulted from a combination of interacting factors. The ecological landscape of today is dramatically different than the turn of the 20th century when moose populations expanded. At that time, large-scale predator reduction programs were ongoing throughout the west and wildfire suppression was widespread. Today, grizzly, cougar, and wolf populations have recovered, and large-scale wildfires affected portions of the herd unit in 1988, 2000, and 2010. Studies suggest that nutritional quality of moose forage in areas burned in 1988 is significantly lower than in unburned areas. Individuals summering in these areas have lower pregnancy and calf survival rates. Conversely, winter habitat availability does not appear to be limiting the growth of the Jackson moose population. Moose have narrow temperature tolerances. Temperatures above 57°F trigger moose to seek cooler locations. Many of the shady mature forests bordering the riparian forage areas preferred by moose remain absent after large catastrophic fires. Additionally, warming temperatures associated with changing climate may be affecting moose, by altering their feeding and other activities, potentially affecting food intake, and providing favorable conditions for parasites.



Jackson moose herd mid-winter counts, 1986-2021 (data from Wyoming Game and Fish Department). These counts are used to estimate overall herd size.

Twin calves are common in moose, based on the mother's nutritional condition and body weight. Calves weigh about 36 pounds at birth and grow rapidly gaining about two pounds per day while nursing.

Biologists continued to photograph hair loss in moose and analyze the extent of hair loss caused by winter tick loads. Winter ticks are a small, ectoparasite that feeds on the blood of moose. In fall, the ticks amass on vegetation and climb onto moose when they pass by. The ticks feed on the moose, as they go through several developmental stages of their life cycle. In mid-winter to early spring, the adult ticks become engorged and irritate the moose. This can cause moose to groom excessively to rid themselves of the parasite, resulting in loss of insulating hair, blood loss, and changes in foraging behavior. In 2021, biologists analyzed hair loss photographs of 64 moose. In the southern portion of the park, mean total hair loss (broken and bare patches) for all individuals was 7.7%; adult males 5.5%, adult females 9.9%, and calves 7.6%. In the northern portion of the park, moose exhibited a 1.2% mean hair loss; adult males 1.2%, adult females 0.6%, and calves 1.7%. Biologists continue to study the relationship between weather indices (e.g. fall/spring temperatures and amount of snow-on-the-ground) and hair loss in moose as these variables may influence tick survival. Studies elsewhere demonstrated that severe winter tick infestations can negatively impact calf survival and tick reproductive success is positively affected by earlier springs and milder winters.

2021 Field Notes

Park staff share some of their more interesting field adventures.

Luke the Cuke. Glacier Gerkins provide a bit of levity on long field days.

Joni Gore: After a particularly hot week in early June, I spoke to my team members about the importance of staying hydrated and eating salty snacks during fieldwork. "Especially on hot summer days, you need water to stay hydrated and salt to prevent hyponatremia, a medical concern when don't have enough sodium in your blood," I told my team. "You know what, I'll bring pickles as my salty snack on our next field trip."

A week later, I sat down for a snack break after a grueling five-mile, 5,000-foot vertical gain hike to our field site on Middle Teton Glacier. I pulled out my bag of pickles and happily munched on the salty cucumbers. To commemorate the moment, I took a photograph of my pickle with the glorious Middle Teton Glacier as a backdrop. However, I felt the photo was missing something... perhaps sunglasses or googly eyes for my newest trail snack. Thus, my fieldwork salty snack photo series, Glacier Gherkins, was born.

An Abominable Pickle sighting in the high country.

Lindsay Dreger: Last year while conducting early season observations of the peregrine falcons at Webb Canyon, Sarah Hegg and I were discussing the peregrine falcon behavior she still wanted to see before leaving the area to start her new job. She had never seen a peregrine perform a stoop before. (To stoop a peregrine soars to a height then sharply dives at high speed.) Sure, enough just a minute or two later the peregrine we were watching started climbing higher and higher in the sky and then performed a super-fast and steep dive at a red-tailed hawk that was too close to the peregrine's territory. This was the stoop she had hoped to see. I turned to Sarah in amazement and asked her if she had seen the stoop, but she had missed it in the few seconds she turned away from watching the cliffs!

Later in the summer, Mead Binghammer and I helped with the annual bighorn sheep survey week. We hiked into Elk Mountain in the northern part of the park. Hiking just below the shoulder of Elk Mountain, we could not see ahead, but both noticed a very gamey smell. Since we were following a sheep trail up the side of the mountain, we didn't think too much about it. Than as we crested the top, we spooked seven large bighorn rams that were only a few feet in front of us. It was a very good start to our bighorn sheep week.

Survey work can be frustrating. We had just slogged across the "lake" (more of an exposed mud flats due to the low water level). Starting from Lizard Creek Campground, we sank in mud up to our thighs while dragging a canoe along. The canoe was needed to cross the still-flowing Snake River and access the streams in the northern end of the range where we would start our harlequin duck survey week. I had a substantial amount of mud on my legs and feet when we got to the Lower Berry Cabin, so I went to the creek to clean up before we continued our hike up Webb Canyon. I walked to the edge of Berry Creek to wash the mud off and right in front of me in the pool near the cabin was a female harlequin! All the slogging across the lake didn't seem so bad anymore.

Last fall, Mead and I were out using radio telemetry to listen for radio-collared wolves near the north end of the park. We were not hearing any signals, so we decided to switch gears and go look for a bald eagle nest to see the condition of the nest since it had not been occupied for a while. We hiked in from Arizona Lake Picnic area. We walked out onto the lakebed and started heading south towards Honeymoon Bay. While walking south we were approached by the park archeologist, JP Schubert. He informed us that we should not continue walking in that direction because there was a moose carcass just out of sight at the end of Honeymoon Bay.

JP discovered the moose carcass accidentally when he noticed someone fishing in the closed lakebed area. He walked over to talk with the individual and then noticed they were both very close to a carcass with a bear feeding on it!

While he is talking to us, wolves began howling in the woods to the east of us. A few seconds later several wolves emerged from the timber and began walking towards the moose carcass. It was the pack we had been trying to find earlier! We set up our spotting scopes (from a very safe distance) and watched the wolves from the Wildcat Ridge pack interact and dine on the moose.

Lindsay and Sarah spend long hours in the field observing, collecting samples, and managing park resources. Field work is often a favorite task for park staff.

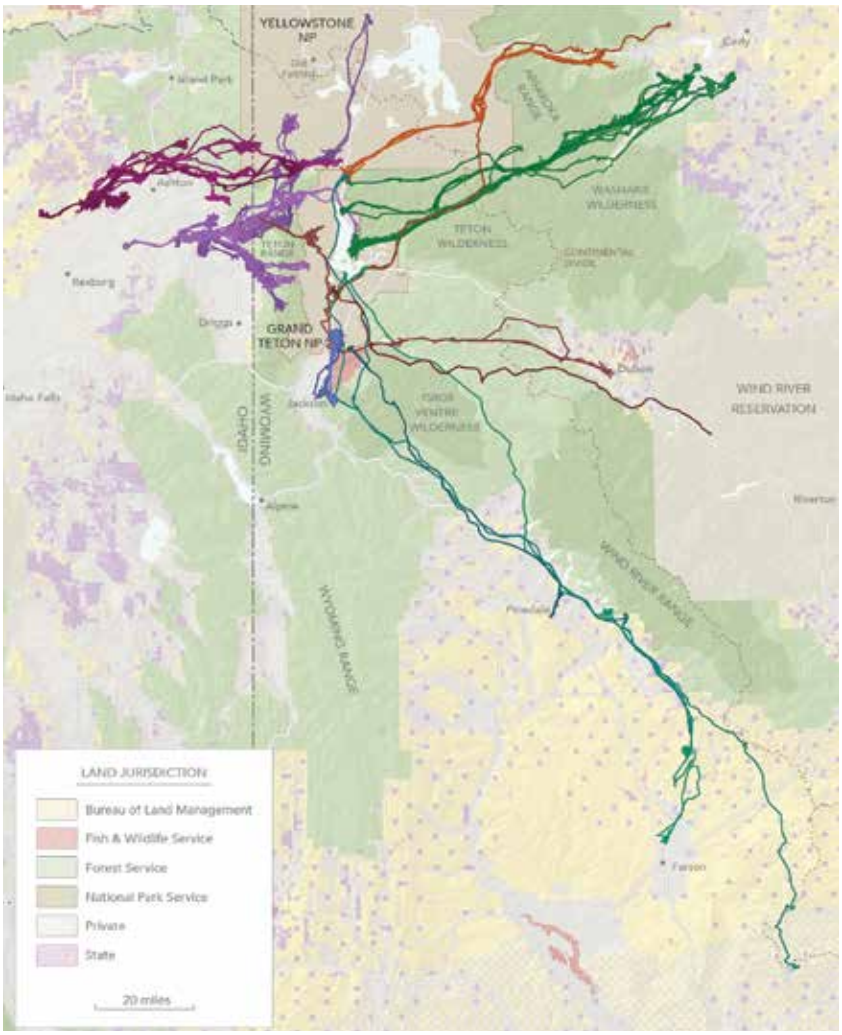
Mule Deer

The yellow eye mask protects and calms the mule deer while a radio collar is deployed.

Mule deer (*Odocoileus hemionus*), one of many park animals that are seasonal residents, undertake annual migrations to distant wintering areas to meet their biological needs. Migrations showcase the behavioral strategies species use to exploit seasonal resources in otherwise inhospitable environments. Despite their intrinsic and ecological value, animal migrations have received little conservation attention until recently. Documenting animal movements is an essential first step to meaningful conservation actions.

Park mule deer research provides information essential to protecting important animal migration corridors in the Greater Yellowstone Ecosystem. Park scientists are documenting the migrations of mule deer moving between summering grounds in Grand Teton National Park and the John D. Rockefeller, Jr. Memorial Parkway and crucial wintering areas throughout the ecosystem. Specific objectives for the mule deer migration research include: identifying important migration routes and seasonal use areas both inside and outside the park; determining the timing of migrations and assessing the variations in mule deer movements; evaluating land use patterns along migration routes to identify potential movement barriers, important deer stopover areas, and conservation needs; and working with partners to conserve migration routes and important seasonal habitats.

Since the project began in 2013, park biologists collared 54 adult female mule deer on summer range in the park and parkway. Our Idaho Fish and Game partners captured and collared 66 mule deer on Idaho winter ranges (including 21 at Sand Creek Wildlife Management Area, 38 along the Teton River, and 7 near the Teton Front outside of Victor and Driggs, ID). Collectively, biologists have recorded 375 complete migration sequences that describe eight population-level corridors (travel paths of differing groups). The travel paths form a far-ranging migration network spanning multiple land jurisdictions in two states. In each corridor, mule deer cross a minimum of three land jurisdictions. Routes traversing the western front of the Wind River Range crossed seven. The migration encompasses a wide variety of habitat types from sand dunes and sagebrush steppe to montane forest and alpine meadows.



Travel paths of 68 mule deer that migrate seasonally from Grand Teton National Park and the Teton Range and the jurisdictional boundaries they cross.

Biologists identified critical stopover areas and potential bottlenecks across the migratory network. They recorded collared mule deer using stopover areas for up to four weeks during the spring, likely waiting for winter snow conditions to wane before continuing their migration. Elevations within the eight corridors ranged from 5,000 feet on wintering grounds to over 10,000 within the mountainous routes. The highest elevation recorded was 11,496 feet along a route crossing the Absaroka Range with several other mule deer crossing elevations between 10,500 to 11,300 feet during their journeys.

Migratory distances ranged from 10 miles in several of the Jackson and Teton River routes to over 150 miles in routes traversing the western front of the Wind River Range. To date, the longest migratory movement recorded by this project (190 miles) was a mule deer traveling between Spalding Bay summering grounds in Grand Teton and wintering grounds northeast of Rock Springs and the Interstate 80 corridor.

Raptors

More than 14 raptor species reside in Grand Teton NP either seasonally or year-round. Bald eagles (*Haliaeetus leucocephalus*), ospreys (*Pandion haliaetus*), peregrine falcons (*Falco peregrinus*), and golden eagles (*Aquila chrysaetos*) are of special interest because of their ecological importance or vulnerable population status in Wyoming or the western US. These top aerial predators are sensitive to human disturbance and are monitored annually.

Bald eagles are large, primarily fish-eating predators that nest in trees, close to water bodies. They also feed on small mammals, waterfowl, and carrion. Within Grand Teton, breeding sites are found along the shores of Jackson Lake and the Snake River. Once listed as endangered under the Endangered Species Act (ESA), bald eagles were delisted in 2007 due to their dramatic population recovery throughout the US. The number of territorial pairs in Grand Teton almost doubled over the past 30 years. In accordance with the Greater Yellowstone Bald Eagle Management Plan (1995), park managers may implement temporary closures around active bald eagle nest sites to minimize disturbances. In 2021, closures were established at nest sites along the Snake River and at the Wilcox Point campsite.

Of the 26 bald eagle territories monitored in 2021, 12 pairs initiated nesting and hatched 9 chicks. At the close of the season, 7 pairs successfully fledged 9 eaglets. The 2021 trends were average for 15 occupied territories (10-year average 14.7) and 12 nesting pairs (11.6), but the 9 fledglings were below the 10-year average (11). The number of fledglings per successful nest in 2021 (1.29) was slightly lower than both the 10-year average (1.33) and 30-year average (1.47). The percentage of successful nests increased this season (58%) over 2020 (48%). Overall data indicates a stable breeding population.

Ospreys are medium-sized hawks that prey almost exclusively on fish. The osprey population in Grand Teton is migratory and research documents that ospreys from the park migrate to the Mexican gulf coast and Cuba for the winter. Park staff started monitoring osprey nests in 1968. While only 6–9 nests were occupied annually 1978–1981, more recently ospreys occupy approximately 13 territories (10-year average 13.4). Generally, ospreys nest near low-elevation lakes and along the Snake, Gros Ventre, and Buffalo Fork Rivers and their tributaries. Osprey are occasionally found in park canyons from mid-to-late summer, but nesting in these areas has never been documented.

In 2021, ospreys occupied 10 of 19 (52.6%) monitored territories. Breeding activity occurred at 7 of these sites and 6 pairs successfully fledged a total of 9 young. These numbers are a marked increase from 2020 when 3 pairs fledged just 6 young; however, they are still below the 10-year averages (6.9 productive pairs raised 11.7 young). Nesting success of breeding pairs (86%) was the highest since 2007, when 100% of active nests produced chicks.

Although the number of territorial pairs has declined since 1990, the trend in active nests success is stable. The decline in occupied territories coincides with an increase in the number of territorial bald eagles. Compared to bald eagles, osprey populations recovered relatively quickly following the banning of DDT in 1972 and now that eagles are regaining their prevalence, osprey populations may be responding by stabilizing at a lower level.

Peregrines do not build nests like other birds. They make a shallow scrape or depression high on a cliff ledge to lay their eggs and raise their young.

Peregrines are cliff-nesting falcons that mainly eat other birds. The lower elevations of the major Teton Range canyons provide peregrines with excellent cliff-nesting and diverse foraging opportunities. Decimated by DDT, peregrine falcons disappeared from the GYE by the 1960s. From 1980–1986, 52 fledgling falcons were released at sites in Grand Teton National Park and the John D. Rockefeller, Jr. Memorial Parkway. Following reintroduction, peregrine falcons first attempted nesting in 1987 at Glade Creek and successfully fledged young the next year. Peregrines, once listed as threatened under the ESA, were delisted in 1999. Recently, peregrines occupied territories in Garnet, Death, Cascade, and Webb Canyons; Blacktail Butte; Glade Creek; Steamboat Mountain; and near the Gros Ventre River in Kelly.

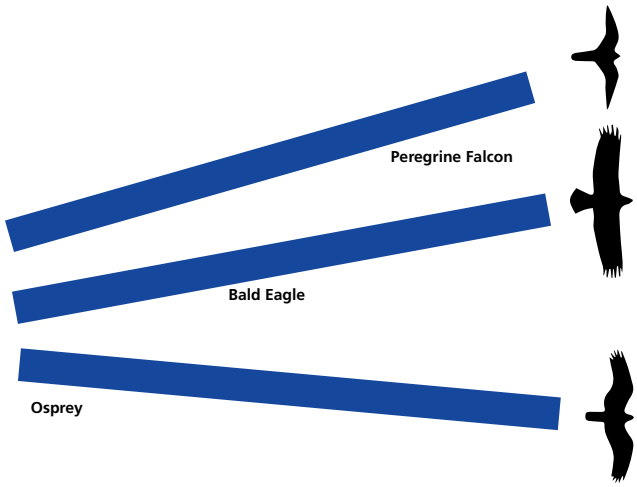
In 2021, peregrines occupied 6 of the 7 territories monitored within the park and parkway. Of those occupied territories, peregrines successfully fledged 3 chicks at Webb (2) and Garnet (1) Canyon eyries. Despite biologists observing mating behavior in falcons at Blacktail Butte and Steamboat territories, the eyries failed to reproduce and were vacated. The Baxter's Pinnacle and Kelly eyries were occupied throughout the nesting season but no fledglings were produced. After adult peregrines displayed courtship behavior near Baxter's Pinnacle in Cascade Canyon, park managers established a temporary closure to protect the eyrie located close to a popular rock climbing route, but reopened it when biologists confirmed that the nesting attempt failed. The Glade Creek territory remained unoccupied in 2021 and the Death Canyon territory was not monitored.

The breeding statistics for 2021 were below most of the 10-year averages: 2 pairs with young (2.4, 10-year average), 3 chicks fledged (4.3), and 33% of the pairs were successful (50%), but 6 pairs attempted nesting (4.7). Historically the percent of successful pairs is highly variable. Overall, the peregrine falcon population in Grand Teton is stable and the trend in occupied territories and successful nests has increased gradually over time.

Golden eagles are large aerial predators well suited to the Teton Range, with its abundance of cliff faces for nest sites and diversity of prey found in the canyons. In the 1980s, biologists

located golden eagle nests in Death, Avalanche, Cascade, and Webb Canyons but did not regularly monitor the Teton Range population. Concerns about golden eagle populations throughout the western US have arisen recently, primarily because of habitat loss and alteration. Like many raptors, golden eagles are sensitive to disturbance around their nest sites.

In 2021, park biologists conducted golden eagle surveys in three of the seven known territories (Granite, Avalanche, and Uhl Hill). Biologists confirmed Avalanche and Granite Canyons were occupied through the breeding season, but did not observe any sign of reproductive success. Park staff observed an adult eagle in the Uhl Hill area early in the season, but the territory was no longer occupied as the season progressed.



The trend for raptor occupancy in the park is increasing for peregrines and bald eagles while slightly decreasing for osprey which may be stabilizing at a lower level.

Red Fox

Habituation of red foxes (*Vulpes vulpes*) to humans in national parks appears to be increasing in recent years. Habituated foxes have been documented at Acadia, Crater Lake, Grand Teton, and Mount Rainier National Parks. Anthropogenic food sources undoubtedly attract foxes and exposure to them can lead to food conditioned behavior. This includes the purposeful feeding of individual foxes by park visitors, ingestion of fish remains left by anglers during winter, and opportunistically acquiring unsecured food in developed areas. Food conditioning and habituation can cause numerous issues, including harm to the wildlife ingesting processed food, traffic hazards for wildlife and humans, health and safety concerns (e.g., aggression and disease transmission) for park visitors and employees, and property damage. Therefore, park resource managers aim to minimize the potential for human-fox conflicts while maintaining this valued ecological and wildlife viewing resource.

In 2021, one food conditioned, habituated male fox had to be euthanized due to continued food rewards and human interaction, emphasizing the need to address habituation issues and make effective management decisions to mitigate negative human-fox contacts. To accomplish this, park biologists continued a monitoring project started in 2016 to gain a better understanding of fox ecology. Data collected from this project aids in assessments of temporal and spatial movements, distribution, foraging patterns, and diets of this resourceful and charismatic species. Increased ecological understanding of foxes coupled with enhanced outreach and education efforts will greatly reduce human-fox conflicts in Grand Teton, as well as provide a template for addressing this wildlife management issue in parks throughout the country. Due to known dens near trails, roads, or human development; three closures were implemented in 2021 to protect the denning foxes and kits. Park staff set up remote cameras to capture data about denning chronology, kit survival, and den attendance by the adult foxes.

A remote camera captures three fox kits carrying the meal of rodents their mother brought them. Kits only nurse about a month before switching to regurgitated food. Eventually the vixen will bring live prey to train them to hunt.

Grand Teton biologists continue to collaborate with research partners from the University of Wyoming, Haub School on fox research. In the winter of 2021, biologists trapped, collared, marked, and collected samples from 12 foxes (including three recaptures) in park developed areas. Measurements and vitals were taken; and blood and hair samples collected (for disease and diet analyses). All foxes were marked with ear tags and fitted with radio collars. To date, a total of 40 individual foxes have been captured and 39 have been collared. University of Wyoming graduate students with the Holbrook Team will analyze the disease, diet, and movement data that is being collected.

Biologists also collect data from fox mortality events (primarily vehicle collisions) to understand disease presence and patterns in Grand Teton. Samples of hair, blood, and muscle were collected from seven deceased foxes in 2021. The 2021 mortalities were the highest since 2018 and included pups, one which featured an all-black coat color that is infrequently seen in the park population.

Sagebrush Steppe

The sagebrush steppe community is one of the most widespread and diverse native plant communities in Grand Teton National Park, as well as across the greater western United States. Where intact, this ecosystem hosts a variety of native plant and animal life, including several species of concern, such as the greater sage-grouse. However, the sagebrush steppe faces numerous threats including invasion by nonnative plants, fire, destruction for human development, and climate change. As of 2020, approximately 50% of the historic range of the sagebrush steppe community across the western US is gone, while much of the remainder is modified or under threat.

In an effort to track changes to this community and monitor its health over time, several NPS Inventory and Monitoring (I&M) Networks use a standardized protocol for long-term monitoring of plots within the sagebrush steppe environment. In 2010, vegetation biologists established 30 sagebrush steppe monitoring plots in Grand Teton and developed protocols in coordination with the Greater Yellowstone I&M. Since 2012, biologists conducted annual monitoring studies of intact sagebrush communities within the park. A 2019 analysis of the data from seven years indicated no change in sagebrush vegetation. In 2021, biologists monitored five permanent plots.

A mother grizzly leads her four cubs across a healthy sagebrush flat.

University of Wyoming and National Park Service scientists also assessed additional sample plots in a collaborative project. Across the 15 total sample units, over 780 distinct quadrats were examined and evaluated for presence/absence, abundance, and cover class of targeted native plant species. This information will be used in analyses to track changes in community composition across the entire Greater Yellowstone Ecosystem and relate them to anthropogenic and natural environmental and changes over time.

Snake River Fine-spotted Cutthroat Trout

Grand Teton National Park is home to 12 species of native fish along with 9 nonnative fish (4 trout species and 5 warm or tropical species). Two distinct looking but genetically undifferentiated cutthroat trout (*Oncorhynchus clarkii*), the Snake River fine-spotted and Yellowstone cutthroat, are native to the park. Historically the Wyoming Game and Fish Department stocked both lakes and streams with game fish including nonnative species: lake, brook, brown, and rainbow trout. With strong support from the park, the last nonnative fish stocking program ended in 2006. The state manages the recreational fishing licenses and catch limits of both native and nonnative fish within the park, with input from the National Park Service. The potential impacts of nonnative trout species on native trout in Grand Teton National Park continues to be a concern.

Grand Teton National Park fisheries staff initiated efforts to develop new tools to census cutthroat trout in the park with the support of the Grand Teton National Park Foundation and the One Fly Foundation. To assess the population status of the Snake River fine-spotted cutthroat trout, they constructed a video weir and installed it at Upper Bar BC Spring in 2019. The spring is one of the primary spawning springs in the park and has been a location for cutthroat recruitment studies for decades. Understanding the number of fish entering spawning springs and streams, helps park managers improve their knowledge of park cutthroat populations.

In order to achieve a non-invasive census of the fish entering the spring, fisheries personnel fabricated an aluminum weir that funnels fish through a chute past a video camera that records footage 24 hours a day. The lights, video camera, and recorder are powered by a solar array. The recorder uses security software to highlight time periods when movement is detected, allowing staff to quickly review footage and count the number of fish passing through the chute. This video weir is the first one constructed in Wyoming. It can make accurate counts of fish without requiring fishery staff to handle them, causing minimal disruptions to fish activities. As the tool is refined and used on other springs and streams, it will provide more accurate park cutthroat surveys.

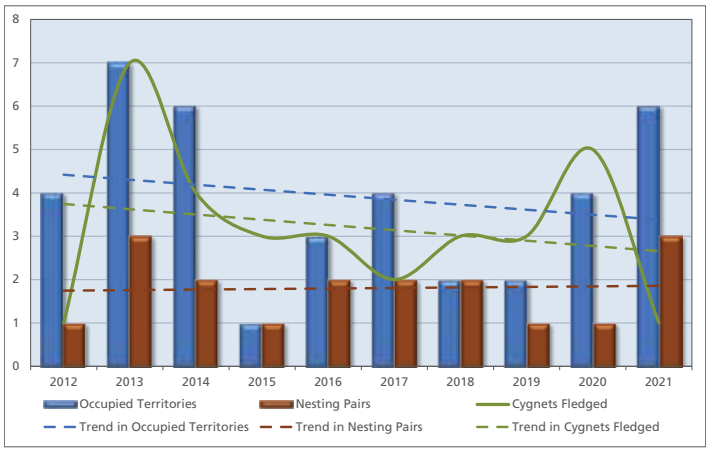
In June 2021, park biologists set up the video weir at Blacktail Spring to avoid redundancy with a University of Wyoming graduate student's work on Upper Bar BC. Despite some technical challenges, biologists recorded a peak of at least 128 cutthroat in the spring during the spawning season. While the count is incomplete, valuable data was collected and further knowledge on using the new tool was gained.

Park staff assemble the video weir across a small stream.

Trumpeter Swans

Nearly extirpated in the contiguous 48 states by the turn of the 20th century, trumpeter swans (*Cygnus buccinator*) made a comeback after intensive captive breeding programs, habitat conservation measures, and protection from hunting. Despite these efforts, swan population growth is low in the tri-state region (the Greater Yellowstone Ecosystem and surrounding areas in MT, ID, and WY). Many factors likely inhibit recovery, including competition with migratory flocks of swans, marginal winter range, variable reproduction rates, limited and low-quality nesting habitat, and high cygnet mortality. Monitored since 1981, Grand Teton provides important nesting habitat for swans.

The number of occupied swan sites, nesting pairs, and young hatched and fledged fluctuated widely since monitoring began. Swan pairs have abandoned some traditional park nesting sites, which could be attributed to predation, increased human activity, or decreased water levels due to drought and hydrologic changes. In the spring of 2021, park biologists adjusted the location of the swan nesting platform that had been installed at Elk Ranch Reservoir the previous spring. The platform was installed in partnership with the Wyoming Wetlands Society and Wyoming Game and Fish to improve trumpeter nesting conditions and success. Swan pairs have occupied the reservoir annually since 1980, but only successfully fledged young during three years in the 1990s. In 1991, park staff made modifications at Elk Ranch Resevoir to improve nesting habitat as part of the Jackson Lake Dam Mitigation Project. These modifications included a dike and several small islands in the southwest corner of the reservoir; however, the dike has since failed.



Trumpeter swan reproductive rates in Grand Teton over the last ten years.

In 2021, biologists monitored 14 historic nesting territories: 10 within the park and parkway plus 4 outside but adjacent to park boundaries. Trumpeter swan monitoring is done primarily from the air. During the breeding season, swans occupied a total of six territories: four within the park (Elk Ranch Reservoir, Colter Bay Slough, Glade Creek, and Swan Lake) and two adjacent to the park (Halfmoon Lake and Pinto Pond). Biologist observed swan pairs initiating nesting activity at three territories (Swan Lake, Elk Ranch Reservoir, and Pinto Pond). The pair at Pinto Pond successfully fledged four cygnets while the pair at Swan Lake fledged one. Biologists initiated a closure on the popular Swan Lake Trail to protect those trumpeters from disturbance during the sensitive cygnet-rearing phase and lifted it once the cygnet fledged.

Swan pairs situate their nests in shallow wetlands on slightly elevated areas surrounded by water. Using existing features like muskrat dens, beaver dams, small islands, floating vegetation, or man-made platforms, they build the nest of twigs, branches, and vegetation. Trumpeter swans have a very strong pair bond and will remain together under most circumstances, occasionally separating after failed breeding attempts. They also have strong fidelity to the nesting site, returning yearly.

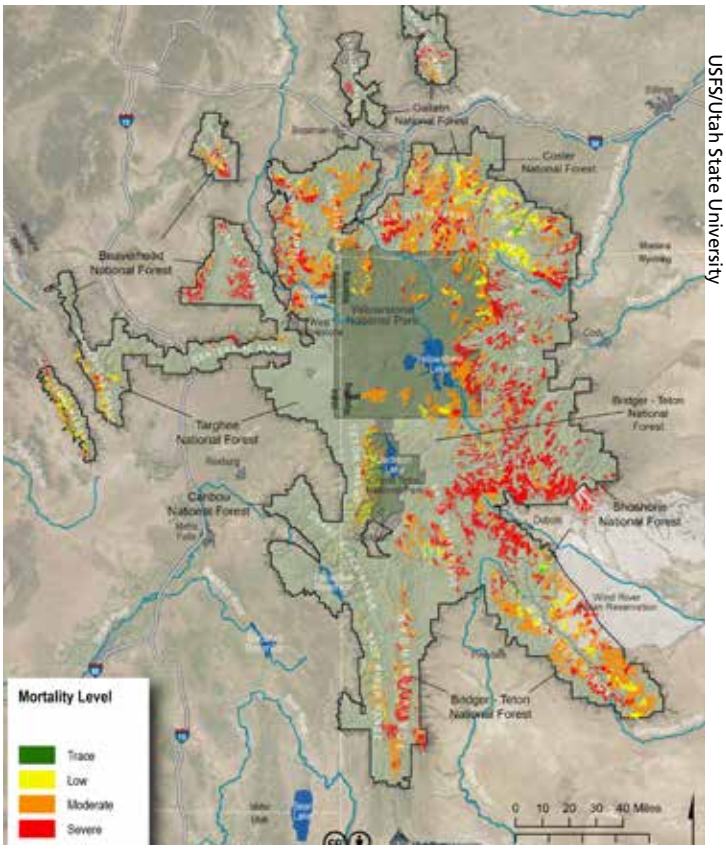
Whitebark Pine

Whitebark pine (*Pinus albicaulis*) is a slow growing, long-lived pine, often the only conifer species capable of establishing and surviving on high-elevation sites with poorly developed soil, high winds, and extreme temperatures. As a keystone species with a significantly greater ecological role compared to its abundance, whitebark influences biodiversity and forest structure. These trees maintain surface and groundwater availability by trapping snow, promoting snowdrift retention and protracting snow melt, and preventing erosion of steep sites. They also produce seeds that are an important food source for wildlife including Clark's nutcrackers, grizzly and black bears, squirrels, and other species.

In the past two decades whitebark pine has experienced unprecedented mortality due to the combined effects of native mountain pine beetle, nonnative white pine blister rust, and changing climate conditions. As a result, in December 2022, the US Fish and Wildlife Service listed whitebark pine as a threatened species under the Endangered Species Act.

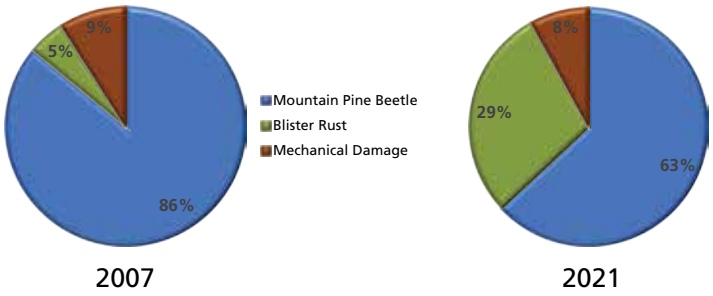
Grand Teton and the John D. Rockefeller Memorial Parkway encompass over 28,500 acres of whitebark pine forests. Of these, 9,726 acres are dominated by whitebark pine and 18,775 acres are stands in which whitebark is co-dominant with other conifer species. The park works collaboratively with other agencies on whitebark pine conservation in the Greater Yellowstone Ecosystem (GYE) and nationally, which increases the opportunities for range-wide protection.

Grand Teton began annual whitebark pine monitoring in 2007 using 26 permanent transects. Scientists monitor five of these transects annually and the remainder in rotation. In 2021, with support from the Northern Rockies Conservation Cooperative and Forest Health and Protection, crews were able to survey nearly all of the transects. The information gathered provided the basis for a 15-year change analysis of whitebark in Grand Teton. Between 2007–2021, total overstory tree mortality increased from 17% to 45%, and transects with any type of mortality rose from 63% to 100%. The 15-year comparison of monitoring sites showed that beetle activity increased (50% to 75%)and cone production decreased (100% to 47%), while blister rust presence (63% to 62%) remains relatively constant.



USFS/Utah State University

Causes of Whitebark Mortality 2007-2021



The causes of the mortality shifted between the main factors (mountain pine beetle and blister rust). Both attack, weaken, and kill trees and in concert their effects are magnified. Pine beetles bore under the bark to lay eggs and when the larvae hatch they feed on the sap layer disrupting the tree's vital circulatory system. Blister rust affects survival of seedlings, the ability of mature trees to grow into large cone bearing trees, and those large trees to produce cones when branches are infected. Beetle activity and blister rust severity (i.e., the amount and location of blister rust on a tree) are greater at elevations below 9,500 feet and on transects with a south aspect. Blister rust severity is greatest on larger diameter trees. Individual whitebark with greater rust severity tend to have a higher incidence of mountain pine beetle attack.

Whitebark regeneration is present on all transects and seedling density varies by the location. Mean seedling density increased from 517 per hectare in 2007 to 893 in 2021. This regeneration does not indicate recruitment into the reproductively capable population, as seedlings must survive approximately 60 years to begin producing cones and can take up to 120 years. Since 2007, 82 saplings have grown into the overstory class (>1.4 meters tall), but none have started producing cones. Conversely, 202 overstory whitebark have died since 2007. So the recruitment to overstory is only replacing 40% of the mortality and still a long time from producing seeds.

All data indicates the critical need for conservation and restoration of whitebark pine in the GYE. This ecosystem contains a significant portion of whitebark found on public land throughout the entire range of the species. The remaining seed trees and whitebark habitat in the GYE are critical to the preservation of the species. Continued monitoring of this foundation species and ecosystem provides crucial data to successful conservation and restoration.

Archeological Sites

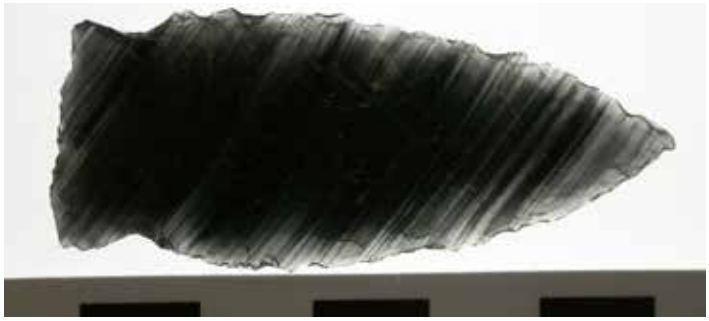
Grand Teton National Park and the John D. Rockefeller, Jr. Memorial Parkway contain an array of archeological resources that reveal the extent of human occupation in the area over time. This diverse archeological record of over 500 sites provides a view into Jackson Hole's past, ranging from 11,000 years of American Indian habitation to historic sites from the last 150 years that are still in use today. Most of the park and parkway's 333,700 acres has not been surveyed, and knowledge about archeological resources comes from inventory of less than 5% of that area.

Prehistoric sites include lithic raw materials such as obsidian, used to make tools, and steatite, used to create stone bowls for cooking. More common lithic sites are those with evidence of stone tool manufacture and use. Other sites contain the remains of stone circles indicating the presence of tipis and are found in association with hearths used to prepare a wide variety of plants gathered from the diverse area.

European American presence in Jackson Hole began in the early 19th century with explorers and trappers frequenting the area. By the latter half of the 1800s, government expeditions documented the sparsely occupied valley. Individuals and families followed, determined to establish themselves in the harsh but beautiful environment of Jackson Hole by "proving up" to obtain federal land through the Homestead Act. Sites relating to the historic occupation of the park begin in the late 19th century and include homesteads, roads, trails, irrigation ditches, and trash dumps.

Information management is critical to archeology because cultural resources are nonrenewable, and past documentation informs current decision making and research. In 2021, the park archeologist worked with Geographic Information System (GIS) staff to develop a mapping system that provides instant data in the field and synchronizes with multiple NPS data sets.

A primary emphasis of archeological work in Grand Teton is to support park planning and compliance with the National Historic Preservation Act (NHPA). A goal of cultural resource compliance is to integrate research with historic preservation laws to identify, document, and interpret the remaining physical evidence of past human use in project areas, and ultimately consider how proposed projects may potentially impact sites important to our nation's past. The goal of NHPA compliance is to consider options to avoid, minimize, or mitigate potential project effects to significant sites that are either listed in, or eligible for listing in, the National Register of Historic Places. In 2021, archeological compliance work included new inventories for Jackson Lake backcountry campsites, Granite Creek Supplemental Ditch improvements, highway culvert improvements, and fuel reduction projects.



An obsidian tool, found in Grand Teton NP, backlit to show the natural striations in the stone.

In 2021, Grand Teton staff worked to increase collaboration with 24 traditionally associated American Indian tribes on park projects. Efforts to build the relationships and better understand tribes' interests included participation in tribal gatherings, leadership-to-leadership virtual meetings, and updates on current and planned projects. Park staff provided educational outreach to Shoshone-Bannock youths and tribal cultural staff with a virtual presentation on NPS cultural resource careers and field events. Other archeology-based education included presentations and field trips for visiting university students and the local Youth Conservation Corps.

One of the tools that aids archeology staff is ground penetrating radar.

Historic Structures

Although the barns of the Mormon Row Historic District are among the most photographed barns in the country, John and Bartha Moulton's pink stucco house is an unexpected surprise for Grand Teton visitors. Built by the family in the late 1930s to replace the log homesteading cabin of John, Bartha, and their four children, the story of how the house became pink is the subject of much speculation. Oral histories from family members indicate that John either painted the stucco pink, Bartha's favorite color, while she was in the hospital as a surprise for her return home, or that he intended a more subdued color but received the bright pink due to a shipping error (difficult to correct in this remote valley). The house also sported bright green doors and windows.

Color aside, the stucco treatment on the exterior of the building is unique in Jackson Hole but keeps with the larger story of the town of Grovont and its development. Now known as Mormon Row, the town had 33 homesteads at its height with most residents being members of the Church of Latter-Day Saints (LDS). The name Mormon Row refers to the centralized settlement pattern that followed the dictates of Joseph Smith, founder of the LDS Church, to include a house of worship, schools, and houses made of brick, stone, and adobe. Although functional in design, attention was given to stylistic finishes on each home. Bartha Moulton decorated her pink stucco house with colorful floral wallpaper, bold linoleum, and cheerful paint colors. Considering that she lived in the house from its construction until her death in 1987, it is very likely that these bright colors helped her through the long Teton winters.

While this home is one building within the six remaining homesteads in the district, its preservation is critical to the history of the Mormon homesteaders, their methods of construction, and the difficulties of living in this unforgiving landscape. NPS personnel noticed significant stucco cracking in the mid-2010s and initiated preservation studies of the building. In 2017, park staff partnered with University of Pennsylvania's Architectural Conservation Program to work with masters candidate Sara Stratte on investigating methods to preserve the stucco. The park also commissioned a Historic Structures Report, a baseline document that identifies features of the building that make it architecturally and historically unique.

John Moulton's distinctive pink stucco house, barn and outbuildings are remainders of the homesteading that predated creation of the park.

Stratte determined that the stucco was in remarkable condition for its age but was cracking due to torsion caused by the partial and uneven concrete foundation. In 2018, park cultural resources staff began monitoring the crack on the exterior stucco. Measurements were taken quarterly until the spring of 2020, when park staff were alarmed to find that the stucco had separated approximately four inches from the building frame. Using emergency funding from Grand Teton National Park Foundation (GTNPF), the park contracted the NPS Historic Preservation Training Center (HPTC) to remove, number, and store the separating stucco in rectangular panels to avoid catastrophic damage to the building over the winter; and place barrier material to keep moisture from seeping into the building in the interim.

In 2021, park staff, GTNPF, HPTC, and historic preservation contractors moved the pink house off of its foundation, poured a new foundation, and moved the house back. This was a monumental effort that required feats of engineering, specialized experience in building moving, and preservation expertise to replicate historic concrete methods for the root cellar. In 2022, HPTC will repair and repaint the stucco; repair and restore the green painted windows and doors; and replace the cedar shingle roof. The house will be preserved. Future plans include developing a virtual tour of the interior and improved site circulation, as well as preservation efforts on additional structures in the district.

Moving the pink house off its foundation to repair the understructure.

Museum Collection & Archives

The delicate task of preparing the Bar BC wagon to move sideways.

Grand Teton's archival and museum collections document the complex history of Grand Teton National Park. The park's Scope of Collection Statement guides park staff on what items are appropriate to place into the museum and archives collections based on existing objects and identified gaps in the collections.

The archives—the two-dimensional paper based unpublished materials—include reports, photographs, and maps documenting subjects ranging from land management, park history, and natural resources generated by park staff. As specified by NPS records management requirements, the park retains permanent records onsite for long-term preservation, management, and access for research by appointment.

The museum collection—the three-dimensional objects— includes natural history specimens, archeological artifacts, historic vehicles, fine art, regional handmade furnishings, and the David T. Vernon Collection of ethnographic materials. All items require preservation and long-term management once accessioned and cataloged permanently into the park's collections.

In 2020, Grand Teton hosted Harper's Ferry Center wooden objects conservator to oversee the temporary removal of a few of the historic vehicles in the park's museum collections to allow for staff from the Historic Preservation and Training Center to replace two purlins, support beams, and shingles on the Transportation Shed. The shed, one of the park's historic buildings is a log building that was constructed in 1949 specifically to exhibit the vehicles that were assembled and then donated to the park by Harold and Josephine Fabian in the late 1940s. The building was constructed around the vehicles, which necessitated Historic Preservation and Training Center staff to construct protective wooden boxes around the wagon and coaches since those three items could not be easily removed from the building. After two years, the conservator returned to the park to assist with moving the vehicles back into place. An interdisciplinary crew of park staff worked together to ensure the careful movement of the historic wagons. In addition, they placed the Deadwood Stagecoach, a smaller light-weight wagon used to transport mail over high mountain terrain, on display in the park for the first time since 2006.

No notable acquisitions to the archives or museum collections occurred in the past year. Staffing and budget restrictions require careful considerations before adding any additional items to the collections due to the long-term care and preservation needs of each item. Park staff recently formed a Collection Advisory Committee to ensure that any new accessions are relevant to the park's history.

The historic wagons had to move sideways and underneath the beam of the Transportation Shed to exit the structure that needed repairs.

Searching for Amphibians

Mary Greenblatt is a NPS field biology technician who works for the Inventory and Monitoring Network and monitors amphibians in Grand Teton NP.

You might wonder what a day of amphibian monitoring looks like? In Grand Teton National Park, we usually monitor our wetlands spending one to several days in each catchment. Except for one catchment in the northern part of the park, we monitor most sites without spending nights in the backcountry. Our catchments consist of multiple wetland areas that are grouped together by proximity. We visit these areas or catchments once a year to survey the wetlands. Our visits consist of two independent surveys spaced fifteen minutes apart. During the survey we walk all around the wetland looking for the presence of this year's young, known as tadpoles or larvae depending on whether we find frogs, toads, or salamanders. We also record the presence of any adult amphibians or reptiles; the air and water temperature; and water depth, length, width, and area using a GPS. We retake the wetland photo from the same exact spot annually. We record all this information on a field form noting habitat information and any changes we observe compared to previous years. Some frequent examples are whether the wetland has changed in size or if there is fresh beaver sign.

This young chorus frog is one of the park's native amphibians.

The third week of June is the time for our annual amphibian survey at Sawmill Ponds near Moose. Wearing chest waders, carrying large day packs, and what looks like butterfly nets; we descended the rocky slope to the water's edge near the overlook. The biggest question on our minds in this notably hot and dry month was had the beavers returned? If the beavers returned and worked on their dams or built new dams this would presumably impound more water creating larger wetlands for us to survey during our annual search for amphibians. We found that indeed the beavers had returned and created larger wetlands for us to survey! While much larger wetlands can sometimes make it harder to detect amphibians, it also creates more habitat for amphibians to breed. Overall, the summer of 2021 revealed that wetlands in Grand Teton and Yellowstone National Parks, that were not beaver influenced, were dryer than in recent years. At Sawmill Ponds, we observed active beaver sign with more water present than in the previous year. In our field notes we suggest that we allow an extra day for amphibian surveys at Sawmill Ponds in 2022. Normally our survey team is small, just me and one additional field partner, but occasionally for the bigger wetlands we use a crew. With additional help, we will be able to survey the same wetlands in two days instead of three and a half days.

Sawmill Ponds are spring influenced and located along the historic floodplain of the Snake River. The area is rich in wildlife including moose, elk, deer, sandhill cranes, great blue heron, and

The amphibian field crew balances on a beaver dam to cross the wetland.

fox, among other species. It is also the only wetland complex we survey where all four native species of amphibians are found in Grand Teton National Park (Columbia spotted frog, western tiger salamander, boreal chorus frog, and western toad). Interestingly, we have only found western toad tadpoles at Sawmill Ponds when the beavers are active and working on their dams.

When beavers have recently worked on their dam, it can have so much fresh mud that we are afraid to cross it during our survey because the mud is still wet and slippery. If their activity has increased the wetland significantly, we occasionally change a few of our repeat photo points because the water was too deep for our chest waders (which means above waist high/chest high). In areas recently flooded by beaver activity, we will find all sorts of plants including dandelions and mushrooms submerged under the much deeper water that we are surveying.

Tiger salamander larvae are identified by their feathery external gills.

Beaver dams hold back water, spreading it across the floodplain and creating more breeding habitat for toads and other amphibians. The abundance of water allows vegetation to grow taller and lusher than a dry wetland. With more water the sedges grow taller and become a challenge because as the wetlands dry out the sedges become dry and sharp or 'angry' as we like to say. Visiting the wetlands in the drying season always reminds me of the well-known identification rhyme, "Sedges have edges…" and how sharp those edges can be.

We returned to Sawmill Ponds in mid-July for water samples. We collect water to determine whether amphibian DNA was present in the surface waters of the ponds. Environmental DNA (eDNA) as it's known, allows for the detection of amphibians and other organisms from DNA present in water samples. When we returned in 2021, the vegetation had grown so tall it was harder to access the wetlands we visited just a few weeks earlier. Elsewhere in the park, many wetlands were dry. Because of the beaver activity, water was still standing across much of the Sawmill Ponds and Snake River floodplain areas. Stimulated by the moisture, reed canary grass, present because this area was historically homesteaded, was almost six feet tall! This is about two or three feet taller than the previous month. Sawmill Ponds is such a rich and productive wetland not just for amphibians but for many species of plants and wildlife. We are glad that we survey in June before the vegetation gets taller than we are!

Park wetlands provide habitat and hiding places for this Columbia spotted frog and other amphibians to conceal themselves from predators like herons.

Mary half hidden by the lush growth of wetland plants.

This frog morph has grown all four legs but has yet to absorb the tail from its tadpole stage.

Seeing this made me think that I had been visiting this wetland over fifteen years, long enough to see it change once again. Now the next question is just how much will change in this catchment before next July? Only time will tell us how long and how active the beavers will be at our catchment or if they will return at another catchment we survey? Seeing these changes and just how much beavers influence our wetlands and create habitat for many other species makes me excited for another field season.

Mary Greenblatt, Amphibian Field Biology Technician
Northern Rockies Conservation Cooperative Partner

Aquatic Invasive Species

Aquatic invasive species (AIS) are aquatic organisms that are not native in a particular watershed. These species vary in size and phylum and are most often, but not solely, introduced to a new watershed via watercraft. Once introduced, many species can thrive without the presence of their natural predators or competitors. This can result in major alterations to native ecosystems, and adversely affect recreation, water utilization, and the local economy. A few examples of species that have recently expanded their range near Grand Teton National Park include curly leaf pondweed (*Potamogeton cripus*), flowering rush (*Butomus umbellatus*), and fish species such as burbot (*Lota lota*). Quagga and zebra mussels (*Dreissena bugensis and D. polymorpha,* respectively) are two of the most impactful invasive species in the US and significantly expanded their range in the last 10–20 years, but have not been found in the park or parkway.

The park has enacted measures to prevent the introduction of AIS, inspecting watercraft and educating boaters on practices to prevent the spread of unwanted species. In 2021, the park had watercraft inspection stations at two locations operating daily during prime visitation periods. Crews inspected 28,811 watercraft passing through the stations. Staff preformed 13 decontaminations to reduce the risk of AIS introduction. The COVID-19 pandemic contributed to the dramatic increase in the number of watercraft entering the park to recreate.

Wyoming Game and Fish also operates inspection stations for boats entering the state. Near Cheyenne in 2021, state personnel found two boats carrying live quagga and zebra mussels marking the first time live mussels were found in Wyoming.

Boaters can help prevent AIS introductions and speed inspections by ensuring they drain, clean, and dry their watercrafts and gear after every use.

An AIS inspector greets watercraft users, ask and records a few simple questions, inspects the craft, and uses a hot-water decontamination tool if warranted.

In 2021, another source of live invasive mussels introductions was identified in the US when decorative aquarium Marimo moss balls were found contaminated with dressenid mussels. The contaminated shipment reached pet stores in five Wyoming towns and two of those had live mussels. In response park staff erected signs at Kelly Warm Springs to inform visitors of the issue and discourage aquarium dumping, a former local practice that resulted in the introduction of many invasive species at the site.

Recreating on park waters is a popular activity for visitors. They arrive from all over the country with small watercraft like stand-up paddle boards, kayaks, rafts, and canoes increasing the chances that they will also bring an aquatic invasive species to park waters.

Chronic Wasting Disease

Chronic wasting disease (CWD) is a naturally occurring prion disease of cervids (species in the deer family). The disease attacks the brain causing animals to become emaciated, display abnormal behavior and poor coordination, and eventually die. Since the 1967 discovery of CWD in a captive mule deer herd in Colorado, the disease has spread geographically and increased in prevalence. CWD is currently found across the majority of Wyoming and continues to expand westward. The spread of CWD in elk generally lags behind deer.

CWD spreads through direct contact between free-ranging animals, through movements of captive animals between fenced facilities (and occasionally via escaped animals from captive facilities), or infrequently as a result of spontaneous protein mis-folding. Animal-to-animal transmission is likely a primary means of disease transmission early in an outbreak. CWD also spreads indirectly via prions shed in feces, urine, and saliva, as well as decomposing carcasses. Scientist have found prions in plant tissues, suggesting that plant material may serve as an environmental reservoir in addition to soils. Prions are highly resistant to decomposition in the environment and may persist and remain infectious for many years.

In November of 2018, a sample collected in the park from an adult male mule deer tested positive for CWD, marking the first detection of CWD in Grand Teton National Park and Teton County. In response, park biologists completed a CWD Action Plan to address and manage the disease including enhancing surveillance efforts, minimizing disease spread, conducting applied research, and increasing communication and outreach efforts. One action identified to limit disease spread was to hold and test deer carcasses before disposing of them. To that end, the park rented a large walk-in freezer in 2019, to store mule deer carcasses, while test results were pending. A permanent freezer, funded by Grand Teton National Park Foundation, was installed in 2020. To enhance surveillance efforts, the park initiated mandatory CWD testing of all hunter-harvested elk during the elk reduction program (ERP) in 2019. Intensified sampling continued in 2021.

Testing

All samples were tested using enzyme-linked immunosorbent assay (ELISA) at the Wyoming Wildlife Health Laboratory in Laramie, WY. All suspected positives via ELISA testing were subsequently retested via ELISA and further confirmed via immunohistochemistry (IHC).

Road-kills: CWD samples are collected from road-killed cervids throughout the park by NPS staff.

Mandatory sampling of hunter-harvested elk: Samples are obtained from elk harvested in the park during the Elk Reduction Program. Samples were collected from 1) elk heads deposited at a drop location, 2) field sampling by NPS employees, and 3) collection of heads at the meat processer.

Sick/Targeted individuals: Samples are collected from cervids that appeared sick or died of unknown causes.

A park biologist collects tissue samples from a road-killed mule deer for CWD monitoring.

In 2021, 145 samples were submitted to the laboratory for testing: 39 from road-killed cervids, 103 from hunter harvested elk, and 3 from targeted individuals. Of those samples 120 were collected from elk, 19 from mule deer, 3 from white-tailed deer, and 3 from moose. No positive detections occurred. Jackson elk herd managers have been intensively sampling the elk herd for more than a decade. The fact that only one elk has tested positive for the disease suggests that CWD is likely present at a low prevalence. Recent modeling suggests that CWD will probably result in a decline in elk numbers over time, particularly as disease prevalence increases.

Elk Reduction Program

The legislation that created the expanded Grand Teton National Park in 1950 included a provision for controlled reduction of elk in the park, when necessary, for the proper management and protection of the elk herd. A long-term objective of the program is to reduce the need to harvest elk within the park. Management of elk in the park and on the National Elk Refuge (NER) is guided by the Bison and Elk Management Plan (BEMP), completed and implemented by the US Fish and Wildlife Service and the National Park Service in 2007. The plan calls for working collaboratively with the Wyoming Game and Fish Department (WGF) to achieve an objective of 11,000 elk in the Jackson herd, a wintering population of 5,000 elk on the NER, and working toward bull to cow ratios in the park that are reflective of an unhunted population. Also outlined in the plan is a strategy to restore previously cultivated lands in the park to improve habitat condition on elk winter and transitional range. The plan projected that roughly 1,600 elk would summer in the park given plan implementation.

The need for the elk reduction program (ERP) is evaluated and determined jointly by Grand Teton and WGF on an annual basis, based on plan objectives and data collected throughout the previous year during both the mid-summer classification count in the park and the mid-winter trend count that includes elk wintering outside of the park.

Both the annual mature bull ratio and the five-year running average were below the threshold identified in the BEMP, at 28 bulls per 100 cows. At this level biologists recommended no bull harvest for 2021. The 2021 mid-winter trend count was 10,734 elk and the three-year running average 10,449, which the WGF considers at objective. The trend is stable; however, elk wintering on the refuge number well above the 5,000 elk objective. The mid-winter calf ratio, which is strongly tied to the level of population growth, was 20 calves per 100 cows. With the trend for the Jackson elk herd remaining stable, antlerless harvest in 2021 was intended to slow herd growth. The population has remained at objective since about 2013.

A bull elk bugles to announce his dominance over a harem of cow elk.

The 2021 elk reduction program was structured similarly to the 2020 season. No permits were offered in Hunt Area (HA) 79 because biologists observed fewer elk during summer surveys in that area and elk productivity was reduced compared to more southern residents. The number of permits authorized in HA 75 decreased to 400 from 550. The ERP was conducted for 37 days from November 6–December 12. The Antelope Flats portion of HA 75 closed on November 21st.

A total of 104 elk were harvested during the ERP in 2021. The majority (74%) of elk taken were adult cows. About 40% of the harvest occurred during the first two weeks of the season, followed by two weeks of low harvest, then 46% in the last 10 days.

Native Plant Restoration

Native plant revegetation mitigates impacts from disturbed sites, returning ecosystem structure and function while preventing nonnative plant invasions. Native plant communities serve an important ecological function by providing food and shelter to a variety of mammals, birds, and invertebrates, while also providing diverse and stable resources that influence abiotic factors such as air, water, and soil. Successful rehabilitation is accomplished by conservation of native topsoil and revegetation using native plant materials that originate from within park boundaries. Research shows that using native plant materials adapted to the local environment translates into greater restoration success.

In 2021, the revegetation program used native, locally-derived seed mixes to reseed six disturbed sites comprising a total of approximately four acres. Vegetation staff worked to mitigate the ecological impacts of disturbed project sites through communicating best practices to contractors, treating invasive plants, reseeding construction sites, and careful monitoring post construction. Vegetation crews seeded completed sites in the fall before the onset of winter conditions.

To obtain materials needed for revegetation and restoration, NPS staff, contractors, partners, and volunteers collected 63 species of native plant seed resulting nearly 400 lbs. bulk weight. Vegetation staff also reinvigorated the nursery program, starting 1,200 nursery plants and salvaging and storing 150 plants from construction zones. These plant materials will be planted into revegetation and restoration sites next year.

Park staff spend numerous hours on the delicate task of collecting native seed.

Fish Passage

Park biologists monitor the health of park fisheries. Of special concern is the fragmentation of fish habitat, a result of human actions. Alterations to a water course can make it difficult for fish to travel to critical portions of the waterway; however, mitigating obstacles can facilitate fish passage. Irrigation ditches draw from several drainages in the park for agricultural purposes within or adjacent to the park. Water drawn from these streams hosts fish that may end up trapped in the ditches. Once trapped, fish have difficulty finding their way back into streams and often die prematurely. Fisheries biologists monitor fish passage in Spread Creek, the Granite Supplemental Ditch, and Ditch Creek.

The 2010 removal of the diversion dam built on Spread Creek in the 1960s allowed fish to access 65 miles upstream; however, the newly installed irrigation infrastructure still captured some fish as they migrate downstream. The park partners with the Wyoming Game and Fish Department (WGF), Trout Unlimited (TU), the Snake River Fund, and volunteers to help return about 100–300 cutthroat trout back to the stream annually along with other species including the rare bluehead sucker. By 2018, deteriorating rock weirs on the structure caused significant challenges with flow changes and fish entrapment. TU stabilized the stream in 2021 and plans to install a fish screen on the Spread Creek Diversion structure in 2022. The screen will allow water rights holders to draw needed water while keeping fish out of the irrigation ditches.

Another irrigation system, the Granite Supplemental Ditch, draws from the Snake River (10%–15% of the flow at the point of diversion) to irrigate lands in the "West Bank" region of Jackson Hole. This large draw of river water traps fish from all local species and at varying life stages each summer. To understand how this ditch, which crosses paths with two perennial streams in the park, affects the fish that enter the ditch from the river, park fisheries staff teamed with WGF and TU to implant transmitters in 15 adult cutthroat in 2017 and another 30 in 2018 to monitor their fate. Data analysis suggests that the mortality rate for trout is up to 73% after entering the ditch. Some adult cutthroat are able to escape the ditch. High numbers of other fish also get stranded in this ditch and are less capable of escaping the high water velocities at the headgates, likely experiencing much higher mortality rates. In 2019, park staff initiated a project to quantify the number of fish entering the ditch during the summer. Using nets on the downstream end of the headgate culverts, biologists identified, measured, and counted fish entering the ditch. Biologists used the data to estimate the number of fish entering the ditch throughout the irrigation season. The 2019 data suggested significant entrainment occurred at the headgate, though there was some suspected bias due to the lack of night sampling. In 2020, sampling occurred at all hours throughout the season. Data showed that more than 50,000 fish enter the ditch each summer, about a third of which are cutthroat.

Ditch Creek flows out of the Gros Ventre Mountains, through Antelope Flats to meet the Snake River about a mile north of Moose. The creek hosts several species of spawning fish including Snake River fine-spotted cutthroat trout, bluehead (categorized as extremely rare by WGF), Utah and mountain sucker, and other small non-game species. Settlers started manipulating the stream's 9.4-square mile alluvial fan on Antelope Flats in the early 1900s, adding 150 miles of irrigation ditches and channelizing the stream to better facilitate agricultural pursuits. In 1957 and 1960 two bridges with culverts were installed across the stream. These culverts were too long and steep for fish to negotiate when attempting to access spawning habitat upstream of these obstacles.

In 2012 and 2014, park staff installed baffles in the culverts to mitigate the obstacle for fish. The stream avulsed west of Mormon Row Road in 2014, stalling the efforts to restore fish passage. While aggrading and avulsing is the stream's natural tendency, the ditches and repeated channelization of the stream caused a new series of barriers to materialize. In 2017, the park partnered with the Grand Teton National Park Foundation, One Fly, and Patagonia to successfully raise funds and hire an excavation company to reactivate the primary channel and restore Ditch Creek as a fish-passable stream. Starting in spring of 2018, fish from the Snake River could access more than 23 miles of the stream's headwaters for the first time in nearly six decades. From 2016 to 2021, biologists captured and inserted Passive Integrated Transponder (PIT) tags into 182 fish (Snake River fine-spotted cutthroat trout, bluehead suckers, mountain suckers, and Utah suckers) to track how the fish used the newly accessible habitat. Biologists placed antennas and recorded tagged fish swimming past the former barriers. In 2019, additional heavy equipment work was done to reinforce the stream bank at three locations.

Habitat connectivity is vital in maximizing the resiliency of the fishery. Working with water rights holders to increase the efficiency of irrigation ditches and reduce entrainment are strategies that could help keep the fishery healthy.

The baffles installed in the culvert on Ditch Creek allow fish to rest in areas protected from the full force of the current as they journey upstream to spawn, but erosion at the edge of the culvert presents a new barrier.

Human-Bear Interface

Grand Teton National Park and the John D. Rockefeller, Jr. Memorial Parkway provide ideal habitat for free-ranging black and grizzly bears. Grand Teton receives more than five million visitors per year, most of whom visit during the peak summer season. Consistently high levels of human recreation in bear habitat creates a high potential for human-bear interactions.

To decrease conflicts, park staff strictly enforce food storage regulations and emphasize "Be Bear Aware" educational messages. The primary focus is to proactively keep attractants away from bears. Since 2008, the park, with generous support from Grand Teton National Park Foundation, has installed 1,015 bear-resistant food storage lockers in campgrounds and other high-use areas in support of that goal.

Human-bear confrontations are defined as incidents when bears approach, follow, charge, act aggressively toward people, enter front-country developments, or enter occupied backcountry campsites without inflicting human injury. Human-bear conflicts* are incidents when bears damage property, obtain human foods, or injure (or kill) humans.

In 2021, park staff recorded 105 human-black bear confrontations and 31 human-grizzly bear confrontations, primarily bears observed in developed areas or in campsites. Other notable confrontations included a grizzly that charged a cyclist, a grizzly that approached and followed a hiker, and a yearling grizzly that made contact with a stationery vehicle. Additionally in 2021, park staff recorded 13 human-bear conflicts: 9 grizzly and black bears obtained unsecured garbage and human food, 2 grizzly bears obtained garbage from bear-resistant trash cans, a grizzly bear flipped a bear-resistant dumpster accessing garbage, and a grizzly bear broke a residential cabin window in an attempt to obtain food. Park staff investigated these incidents and found that the bear-resistant trash cans were not properly secured to the ground, allowing bears to overturn and compromise the cans. Park staff will survey all bear-resistant trash receptacles in 2022 and remedy any that are not properly anchored to the ground. In addition, park staff recorded seven motor-vehicle collisions involving bears in 2021.

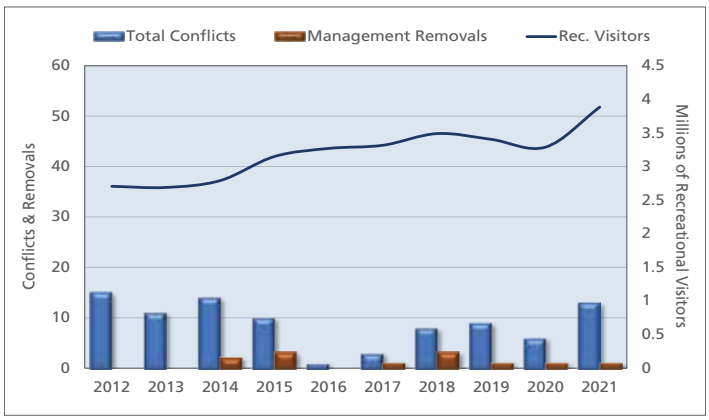
Grand Teton staff work diligently to prevent bears from developing nuisance behaviors. When humans fail to secure their food, bears can develop unwanted behaviors. Trained staff follow an established protocol to haze bears from developed areas and roadways, when necessary. Park staff hazed bears 150 times in 2021, using a spectrum of tools, including noise deterrents, vehicle threat pressure, and firing bean bag rounds.

Wildlife Brigade staff protect visitors and bears by advising people to stay in their cars and park out of traffic when bears are close to the road.

Park managers also implement seasonal closures to protect bear habitat and to address human safety concerns. In addition to regular annual closures (Grassy Lake Road closed to motorized use April 1–May 31 and Willow Flats closed to public entry May 15– July 15 to protect grizzly bear foraging opportunities), 16 temporary closures were implemented (e.g. around carcasses) to provide for visitor safety and/or protect foraging opportunities for bears. Since 2007, the Wildlife Brigade, a corps of paid and volunteer staff, manages traffic and visitors at roadside wildlife jams, promotes ethical wildlife viewing, patrols developed areas to secure bear attractants, and provides bear information and education. In 2021, they recorded 711 wildlife jams including 232 for grizzly bears, 243 for black bears, 3 for bears of unrecorded species, 109 for moose, and 124 for other species such as bison, elk, red fox, and great gray owls.

*Starting in 2017 reports define human-bear conflicts as instances when bears damage property, obtain human foods, or injure (or kill) humans. Human-caused bear mortality will be listed separately (e.g. bear vs. motor-vehicle collisions). Please note of this change when reading 2012-2016 reports.

A black bear investigates a picnic table for food residue.



Bear conflicts and management removals in Grand Teton.

Invasive Plants

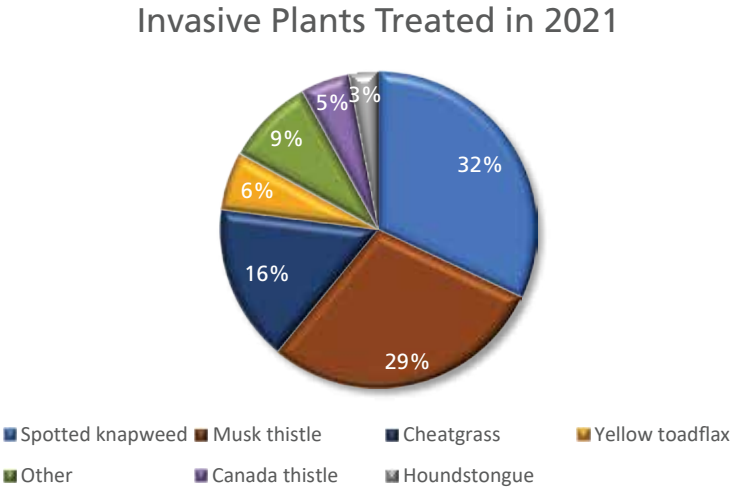
The introduction of nonnative plant species has the potential to alter natural systems by displacing native vegetative communities. When nonnative plants cause economic impacts, environmental harm, or harm to human health, they are determined to be invasive. Invasive plants listed as Federal, State, or county "noxious weeds" are particularly aggressive plants legally deemed to be detrimental to agriculture, waterways, fish and wildlife, and/or public health. Park vegetation staff focus efforts on locating and using the best treatment practices to address listed noxious plant species. Treating invasive plants continues to be a high priority for resource managers at Grand Teton.

In 2021, park biologists prioritized control efforts based on the threats posed to ecological systems and on the likelihood of successful treatments. When population numbers are small and the seed bank is not well established, eradication of invasive plants is achievable. When invasive species have spread across a landscape, containment of infestations becomes the primary goal. Invasive species management is multifaceted and outcomes are often species or site specific.

Three priorities guide management decisions for invasive plants at Grand Teton. The first focuses on disturbance. Invasive plants thrive in disturbed sites and are often better competitors than native plants after a disruption in the vegetative community or soil. For this reason, park managers prioritize invasive plant treatments within and around areas of planned or accidental disturbance.

The second priority emphasizes treatments in areas that provide opportunity for seed dispersal. These vector sites are high traffic areas that lend to the inadvertent transport of invasive plant seeds on vehicles, clothing, and in construction materials. This includes disturbed areas along roads, pathways, trails, levees, and utility corridors. Treatments in these locations have preventative impacts across the entire park and even into the backcountry.

The third priority, vegetative restoration, aims to return natural ecological succession after a disturbance by reestablishing a diverse grouping of native plants while preventing the invasion of nonnative species. The two major sagebrush steppe restoration projects establish native sagebrush shrubland plant communities in former agricultural lands.



In 2021, park vegetation biologists partnered with mapping specialists to create a new geospatial data collection platform. This new platform improved collection of detailed information on plant populations and associated management actions (hours spent, herbicide used, number of individual plants, and extent of site infestation). Using these data, vegetation staff will be able to determine treatment efficacy and refine management actions for each invasive plant population.

Partnerships are integral to successfully managing invasive plants in Grand Teton. The invasive plant program is fortunate to collaborate with local partners like Teton County Weed and Pest District, the Northern Rockies Invasive Plant Management Team, the Jackson Hole Weed Management Association, and the Greater Yellowstone Coordinating Committee. Controlling the spread of nonnative invasive plants benefits the park by supporting the native plant community and enhancing wildlife habitat in Grand Teton.

Weed crews painstaking search park vegetation to target and spray invasive plants while leaving native plants undisturbed.

Kelly Warm Spring

Kelly Warm Spring is a thermal feature that has a long history of aquarium dumping leading to the proliferation of nonnative species in the spring. Nonnatives persisted throughout the warm spring effluent and in 2012 biologists found goldfish (*Carassius auratus*), native to east Asia, and tadpole madtoms (*Notorus gyrinus*), native in much of eastern North America, in Ditch Creek, some within 10 yards of the Snake River.

Park biologists also found an abundance of American bullfrogs (*Lithobates catebeianus*), another species with a wide latitudinal native range, that were introduced for unknown reasons in the 1950s. The bullfrog is implicated in declines of native amphibian populations throughout the world due to both direct and indirect factors. In Grand Teton National Park native amphibians are nearly wholly absent in the bullfrog's occupied range with only a couple western toads, a native species on the decline regionally, being found on the periphery of bullfrog inhabited waters. An NPS study of fall movements and over wintering habitat found American bullfrogs made more upstream movements than downstream movements with their largest movements occurring before the first cold snap of the season. The winter range was more widespread than managers had hoped leaving the species less vulnerable to mechanical removal efforts.

After several years of environmental analysis, park resource managers moved forward with a plan to restore Kelly Warm Spring to a more natural state. NPS staff with vital assistance from Wyoming Game and Fish Department (WGF) personnel used rotenone, a chemical that is lethal to organisms with gills, to treat the nonnative infested spring and its effluent in 2018. The treatment successfully reduced the quantity of invasive species in the spring but failed to remove all fishes present, a necessary first step in restoring a native assemblage to the spring. Rotenone tolerant and intolerant species survived the application. Bullfrog tadpoles experienced high mortality rates but were not completely eliminated from the system. The control action was an important step in improving the condition of Kelly Warm Spring.

Since the 2018 effort, fisheries biologists have continued to develop strategies to efficiently remove invasive species while minimizing collateral impacts. Understanding bullfrog life histories, beyond fall migrations, is a focal point. Other national parks and agencies in the western US have successfully extirpated non-native bullfrogs and Grand Teton staff are working on a removal plan. Fisheries staff are reactivating antiquated irrigation ditches to dewater large portions of the spring's effluent. This allows resource managers to control invasive fish populations without chemicals and will reduce treatment areas for future rotenone applications, a necessary step to fully restore native species in the spring.

A moose cow and calf graze in the spring on aquatic vegetation.

Mountain Goats

Mountain goats (*Oreamnos americanus*) are not native to the Greater Yellowstone Ecosystem. Observations of mountain goats in the Teton Range began in 1977, less than a decade after the Idaho Department of Fish and Game translocated about a dozen individuals from central Idaho to eastern Idaho's Snake River Range where they were not native. Transplanting wildlife to create populations for the benefit of hunters was a common practice at the time. Until 2005, when a breeding population of mountain goats established itself in the Teton Range, observations of goats were sporadic and thought to represent transient individuals. Genetic evidence suggests that the Teton Range mountain goat population originated from the population of mountain goats translocated to the Snake River Range.

Mountain goats in the Snake River Range have tested positive for *Mycoplasma ovipneumoniae* (*M. Ovi*) a pathogen linked to pneumonia in bighorn sheep (*Ovis canadensis*). Pneumonia in bighorn sheep causes die-offs in all age groups followed by significant lamb mortality for varying lengths of time, sometimes decades. Pneumonia in bighorn sheep involves multiple bacterial pathogens that all play a role in the disease, but *M. Ovi*, appears to be necessary for persistent population level impacts. Although limited disease testing of Teton Range mountain goats has not documented the presence of *M. Ovi*, other pathogens were detected raising concerns that resident mountain goats or dispersing Snake River Range individuals could introduce pneumonia causing pathogens to bighorn sheep with devastating consequences. (Biologists documented transmission of pathogens from wild mountain goats to wild bighorn sheep in Nevada.) Competition between mountain goats and bighorn sheep on limited winter range is also a concern.

In the fall of 2019, the National Park Service completed a Management Plan/Environmental Assessment (EA), which recommended removing mountain goats from Grand Teton National Park using lethal and non-lethal means. The plan and the associated EA were finalized after an extensive planning process, begun in 2013. The plan identified the goal of removing the mountain goats as quickly as possible to minimize impacts to native species, ecological communities, and visitors. When the EA was written in 2018, biologists estimated the population at over 100 mountain goats in the Teton Range, mostly within the park.

Removal efforts began in February 2020, when a contract helicopter crew lethally removed 36 mountain goats from Cascade, Paintbrush, and Leigh Canyons in half a day. Following objections raised by the Wyoming Game and Fish Commission and the Wyoming Governor to the Secretary of Interior, this operation was halted. Subsequently park staff developed a ground-based removal program using qualified volunteers starting that fall. Volunteers could retrieve edible meat from the culled animals whenever possible—an action authorized by the John D. Dingle Conservation, Management, and Recreation Act in 2019.

A biologist swabs a mountain goat to determine what diseases might be resident in the herd.

In the fall of 2020, 30 teams consisting of 108 volunteers removed 43 mountain goats from the park over six weeks from mid-September through the end of October. To improve the operational safety of the program in 2021, the volunteer pool was restricted to those who participated in the 2020 program. Seventeen of the 30 original teams (43 volunteers) participated in the 2021 program. Volunteer teams removed 20 mountain goats from the park in 2021 from late September through late October. Since population reduction efforts began in the fall of 2019, 134 mountain goats were removed from the Teton Range through the combined efforts of Grand Teton National Park and Wyoming Game and Fish Department. Park biologists estimate that approximately 20–50 mountain goats remain in the park, with the greatest density in the interior trail-less canyons (Leigh, Moran, and Snowshoe) where the aerial removal did not occur and access by ground-based volunteers was limited.

Measuring Glacial Ice

Warming of the climate system is unequivocal, as is evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (Intergovernmental Panel on Climate Change, 2007).

This quote, shared by my global climate change professor, hung heavily during the last course of the semester. No ifs, ands, or buts about it: global temperatures are rising causing snow and ice to melt. Unfortunately, anthropogenic greenhouse gas emissions and resulting climate warming are not predicted to slow down based on existing models. So how do snow and ice, that make up the glaciers in Grand Teton National Park, respond to the changing climate?

Shortly after graduating, I joined the Physical Science Program in Grand Teton National Park where we seek to answer that question. Grand Teton National Park is home to 11 named glaciers. Glaciers form where snow accumulates, compacts, and recrystallizes into dense ice that moves under its own weight. These glaciers are critical freshwater reserves, especially in late summer when seasonal snow has already melted. Middle Teton Glacier (MTG) is one of these 11 glaciers. MTG is a benchmark glacier (i.e., it is representative of other glaciers in the Teton Range) and is the primary focus of our monitoring efforts here in the park.

Monitoring of MTG by park staff began in 2014. Our monitoring plan includes measuring glacial volume and tracking glacial movements, a process that starts in late spring at the end of the snow accumulation season. At the glacier, we probe the snow and ice, record snow densities and depths, and install ablation (A.K.A. "melt") stakes. These stakes are comprised of several marked PVC pipes connected inside by a string and are steam-drilled into the glacial surface. As the summer progresses and the glacial surface melts, the PVC pipes move downslope and become exposed. We track the movement of the stakes with GPS devices and record the length of PVC pipe exposed each month. In late summer, we coordinate with the Jenny Lake Climbing Rangers to survey the glacier's surface elevation. Using data from the ablation stakes and elevation surveys, we can quantify the glacier's balance (i.e., gain vs. melt) over a given year and compare against previous years.

Monitoring MTG is no easy task. Our late summer fieldwork on the glacier requires detailed preparation: organizing our field crew, testing field equipment, packing our bags with food and supplies for 2–3 days in the backcountry, and checking weather forecasts. Weather permitting, we hike 5,000 vertical feet in five miles while carrying 30–50 lbs. backpacks. At the glacier, we attach GPS devices to three-meter survey rods; carefully walk on the steep, wet glacial ice to pre-determined locations; and record glacial surface elevations to centimeter accuracy. After surveying for several hours, we pack up our equipment and move to camp in the high country. We rise early and return to the glacier the next day to continue the survey. In total, the survey takes two or three field days and an additional week in the office to process data.

The physical science field staff (Justin Culman, Joni Gore, Joey Nadeau, and Elizabeth Case) geared up for long days in the high country.

Joni wears safety gear (helmet, microspikes, and an ice axe) while carefully picking her footing on the downslope of Falling Ice Glacier.

Even with extensive preparation, we inevitably face serious challenges during glacial fieldwork such as equipment failure or rockfall. During an early-spring visit, crews began steam-drilling an ablation stake hole in the glacier, but the drill bit and hose froze in the ice. Recovery efforts for the drill were unsuccessful, delaying fieldwork until we could purchase new equipment. To mitigate rockfall risks, we start early (when temperatures are cool and before ice starts to melt), wear helmets, and designate a spotter while others survey. However, during a late summer survey, glacial melting dislodged a couple microwave-sized boulders that tumbled towards our field crew. Our spotter warned the crew members in time to run out of the way and avoid the falling boulders. With a clearly defined and regularly practiced safety plan, we reduce risk as much as possible while collecting valuable data on the state of the park's glaciers.

Unfortunately, as expected, the data confirms that MTG is overall melting faster than it is gaining. In 2021 alone, our team calculated 2–5 meters of ice loss from the ablation stakes and found overall glacial thinning (up to 6.3 meters of ice loss) from the GPS survey. This ice, which took generations to form, was gone in 3 months with little chance of coming back: If this rate of melting continues, it is possible that MTG will cease to exist in my lifetime. The remnants of the incredible glaciers that shaped the Teton Range will disappear, forever altering the natural, cultural, and scenic characteristics of the Tetons.

After reading these results, my colleagues and I left the office overcome with sadness. We bought ice cream at Dornan's, sat on a bench and ate in silence. How do we scientists, reading these results within the confines of our office cubicle, process the questions that come with the disheartening results of our hard work? How are we to preserve these glaciers for the enjoyment, education, and inspiration of current and future generations?

Joni Gore, Hydrologist

Sagebrush Steppe Restoration

Sagebrush steppe occupies much of the valley floor and represents an incredibly diverse vegetative community. Home to sage-grouse, bison, pronghorn, and many other wildlife species, maintaining and restoring native sagebrush habitat is a high priority for park managers. Approximately 15% of the park's sagebrush steppe has been impacted by human habitation and agriculture over the past two hundred years. Vegetation staff work diligently to restore the affected areas by removing nonnative pasture grass, surveying and treating invasive plants, collecting and spreading native seed, monitoring effectiveness of restoration, and implementing follow-up treatments.

One long-term restoration project is Antelope Flats, sagebrush steppe lands converted for agricultural use at the turn of the 20th century and later integrated into the park. Vegetation staff focus on the removal of the nonnative pasture grass, smooth brome (*Bromus inermis*), and planting native sagebrush steppe species in those relic hayfields. In 2021, biologists treated 91 new acres of Antelope Flats by boom spraying glyphosate herbicide on the smooth brome monoculture from a tractor. The treatment of smooth brome requires two years of repeat herbicide applications followed by reseeding of the area with a variety of native plant species.

In addition to removing nonnative grasses in Antelope Flats, the vegetation crew and contractors continue to manage invasive broadleaf plant populations in restoration units. Invasive plant populations thrive on disturbed lands and by removing smooth brome, park managers create an environment where other invasive species could flourish. Managing the potential reinvasion of nonnative species into these restoration units requires years of focused effort following the smooth brome removal and reseeding of native plants. Park staff and volunteers, in association with the Jackson Hole Wildlife Foundation, removed 11,250 ft of obsolete fencing material that was a barrier to wildlife movement, achieving another step in restoring old pastures to native habitat.

Sagebrush Steppe Restoration 2021	
Pasture grass treatment in Antelope Flats	91 acres
Pasture grass treatment in McBride	18 acres
Invasive plant survey and treatment in restoration units	1621 acres

The vegetation crew treated an additional 18 acres of pasture grass at the McBride unit as part of the Jackson Hole Airport Wildlife Hazard Mitigation Plan. This sagebrush restoration has a specific goal of creating sage-grouse habitat; the site is unique because of the high cover of mature sagebrush among the smooth brome. To protect the sagebrush while treating smooth brome, the vegetation crew tested a grass specific herbicide in place of glyphosate, which is a nonselective herbicide that targets any actively growing plant species. Monitoring efforts showed that glyphosate treatments were more effective than grass specific applications. While park vegetation biologists predicted this outcome, the performance of the glyphosate was more dramatic than anticipated. Therefore, field staff will apply glyphosate for future smooth brome treatments. Carefully targeted backpack sprayer applications of glyphosate will be essential to selectively spray smooth brome while avoiding the foliage of sagebrush plants.

Locally collected native seed will be used when these restoration sites are ready to seed next year. Research of park restoration success indicates that seed mixes with a higher percentage of forbs and shrubs improve restoration outcomes.

Restored sagebrush steppe provides remarkable diversity, both in plants and animal habitats.

Trail Use & Pathway Use

The visitor monitoring program in Grand Teton National Park, led by the park social scientist, collects information about the use of park trails and pathways. Since 2009, there is generally an increasing trend in visitor use for trails leading to the backcountry. Infrared trail counters are installed at key locations throughout the park, and estimate the number of visitors entering the backcountry via the trail system during the summer months (June to September). There are also counters located further into the backcountry. Trail counters count visitors traveling in both directions, and data is aggregated by the hour. Some trail counters are validated by comparing the counter-recorded visitor use and actual counts taken by a research technician; most counters have a low error rate.

In 2021, monitoring visitor use of the trail system gave insights on park visitor experiences. Many indoor locations within Grand Teton National Park remained closed due to the COVID-19 pandemic and trail counters indicate an overall increase in trail use compared to the five-year average. Between June and September of 2021, the Jenny Lake trail counter detected the highest number of people compared to other trail counters, with an estimated 79,781 visitors (a 14% increase in visitor use compared to 2020). The Cascade Canyon trail counter recorded the next highest number with an estimated 74,763 visitors (less than a 1% increase in detections compared to 2020).

In addition to trails, park staff monitor the multiuse pathway system within Grand Teton National Park. Construction on the first section of the paved pathway, between Moose and Jenny Lake, was completed in May 2009. Completion of a second section of pathway, between the park's south boundary on US Highway 89 and Moose, followed in May of 2012. Starting in 2009, researchers installed infrared counters and trail cameras at key locations to understand the timing and volume of use, including potential effects on wildlife. In the summer of 2021, five infrared counters were installed along the pathway at the same locations used since 2012: Jenny Lake, north of Taggart parking, west of Dornan's, north of the airport, and south of Gros Ventre junction (from approximately June to August).

Visitors follow a ranger on a guided hike.

These counters give an approximation of use, and also batch the total number of users in one hour periods. Counters cannot determine the direction a visitor is traveling, or if one user is triggering multiple counters along the pathway (which is likely). Overall, there were a total of 70,213 detections on the five pathway counters between June and August of 2021. This is a 4% decrease in use over 2020. Given the limitations of the counters, a liberal estimate would be that pathway use comprises approximately 3% of the park's total recreation visits during the same time frame.

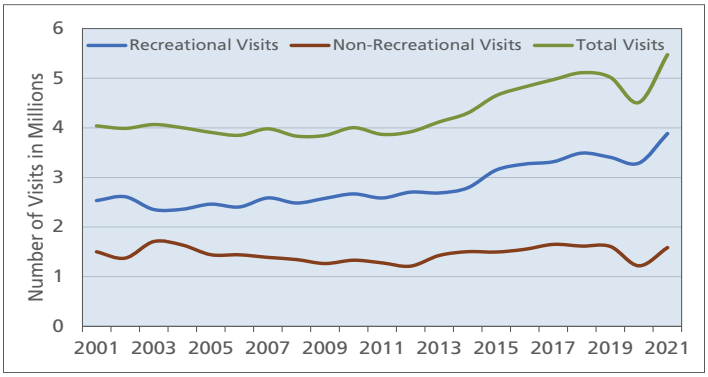
Analysis of trail and pathway data helps park managers to better understand visitor use (including levels of use, timing of use, and distribution of use). This in turn aids in decision making to meet the objectives of providing for visitor enjoyment while protecting park resources.

Visitor Use

Use of Grand Teton National Park and the John D. Rockefeller, Jr. Memorial Parkway by visitors is both a primary reason for their establishment and a factor influencing resource condition. Increases in visitation may affect natural and cultural resources, as well as the quality of visitor experiences. Some factors that may influence visitation to parks include economic conditions, natural disasters, weather, gasoline prices, and even a pandemic.

In 2021, public lands continued to provide visitors opportunities for outdoor experiences and domestic recreation during the ongoing COVID-19 pandemic. Outdoor places provide opportunities to safely recreate and promote both physical and psychological health. National parks played an important role by hosting more than 297 million recreation visits in 2021. This number is a 29% increase from 2020 when visitation was affected by temporary park closures, restrictions, and the changes in park operations that were implemented in response to the pandemic. Recreation visits are defined as visits where the visitor entered lands or water administered by the National Park Service to use the area (alternatively, examples of a non-recreation visit include commuters, employees going to work, access to inholdings, etc.).

Visitors enjoy taking pictures of the park entrance sign and impressive backdrop.



Annual Grand Teton NP visitation 2001–2021.

Grand Teton National Park experienced the highest number of recreation visits to date with 3.9 million recreation visits. The majority of recreation visits occurred between June and October. Although there are no day-use limits, lodging and campgrounds in the park have limited available space and during the pandemic many options were further restricted. On most July and August nights, one or more forms of accommodation are full.

Visitors enjoy a campfire at a backcountry campsite. Park campsites are popular and often full during summer nights.

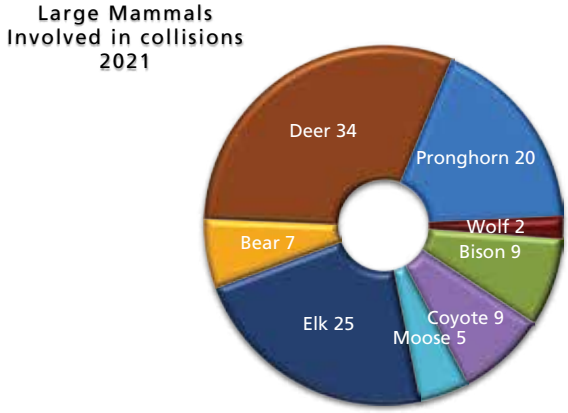
Wildlife-Vehicle Collisions

Wildlife casualties from motor vehicle collisions on Grand Teton National Park and the John D. Rockefeller, Jr. Memorial Parkway roads are common occurrences. Since 1991, park staff record data on wildlife-vehicle collisions to document impacts and help identify appropriate measures to lower the number of collisions and improve the safety of park roads for humans and wildlife.

In 2021, 159 collisions occurred involving 170 animals, a 17% increase in collisions and a 21% increase in animals involved from 2020. Due to the global pandemic, the park was closed from late March through mid-May 2020, which may have contributed to that year's lower number of collisions. The number of collisions in 2021 remained consistent with the numbers from 2019. Of particular note in 2021, more pronghorn were involved in collisions than any previous year (18) and over 75% of the incidents occurred near Elk Ranch Flats. In 2021, 84% of all collisions resulted in a confirmed animal death. In incidents where a carcass could not be located near the road, some animals may have died later from injuries sustained in the collision. The majority of collisions occurred during the snow-free months (133 from May–Oct.) and peaked in August, the highest visitation month for both the park and parkway.

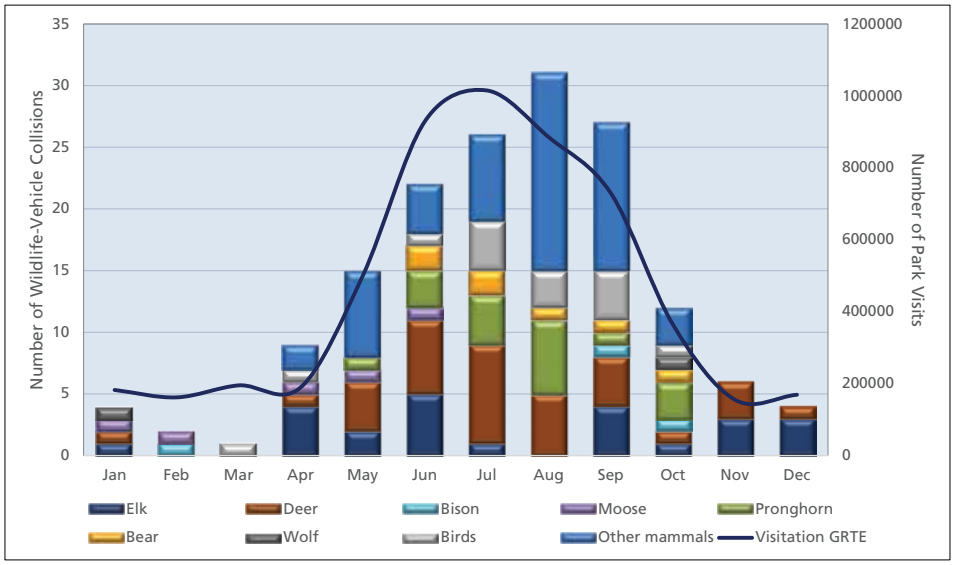
A total of 31 species (23 mammals and 8 birds) were involved in collisions in 2021. Large mammals accounted for 115 of the 170 animals involved. Ungulates comprised 57% of individuals (97) involved, a 31% increase from 2020. Mid- to large-sized carnivores accounted for 11% (18), small mammals 23% (39), and birds 9% (16). Collisions involving birds and small mammals rarely cause property damage, are less conspicuous, and are under reported. There are likely significantly more birds and small mammals struck by vehicles, and it generally remains unknown how these mortalities influence their population demographics.

When possible, park staff also record the time of day that a wildlife-vehicle collision occurred. For the 31% of incidents with a known time of day, more than 80% of those collisions involving mule deer, 71% involving pronghorn, and all involving white-tailed deer occurred during the day. All incidents involving bison, 90% involving elk, and 80% involving moose occurred under diminished light (twilight/night).

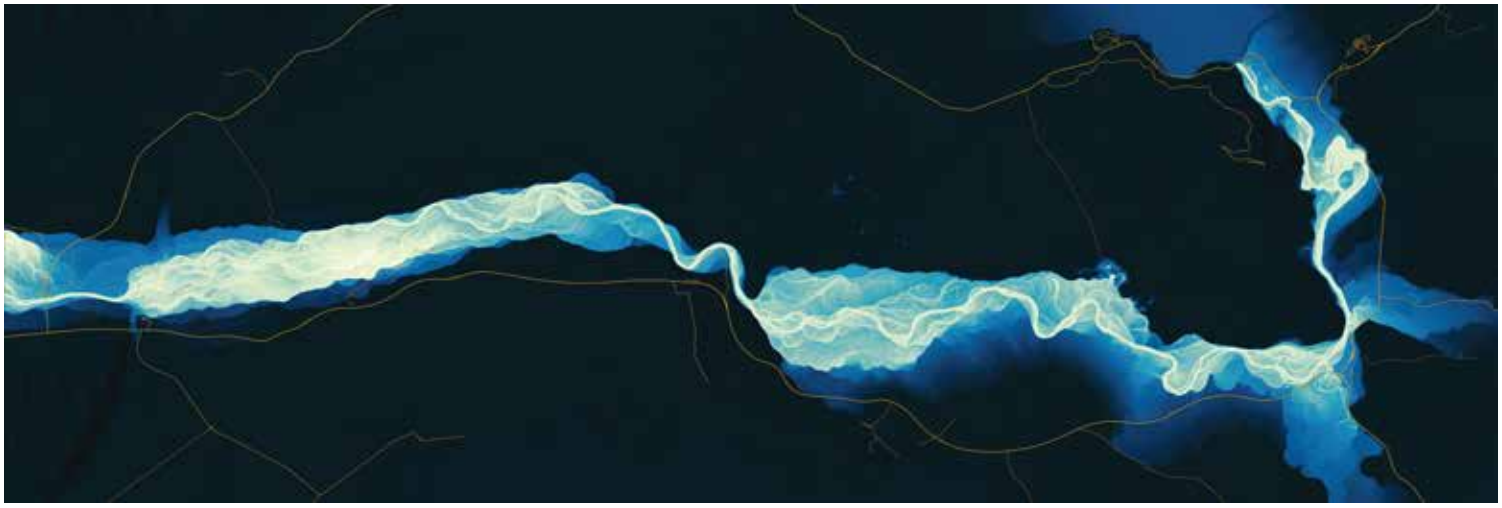


Park staff documented the highest number of wildlife-vehicle collisions (53%) on US Highway 89/191/26 (Hwy. 89), followed by the North Park Road (30%), Teton Park Road (9%), Gros Ventre-Antelope Flats loop and Pacific Creek Road (2%), and other roads (4%). On Hwy. 89 most incidents occurred between Spread Creek to Moran Junction (39%), followed by Moose Junction to Snake River Overlook (27%), and Airport Junction to Moose Junction (11%). The majority (69%) of incidents with bison, moose, and elk occurred on Hwy. 89. For deer, 46% of collisions occurred on Hwy. 89, 36% on North Park Road, 14% on Teton Park Road, and 4% on the Gros Ventre-Kelly Loop Road. For pronghorn collisions, more than half occurred on Hwy. 89 (83%) and 17% on Teton Park Road.

The park implemented several mitigation measures in the last decade to address wildlife-vehicle collisions, including the permanent reduction in nighttime speed limit from 55 to 45 mph on Hwy. 89; continued use of variable message signs at strategic locations to inform drivers of current wildlife activity near roads; the installation of permanent digital speed readers at Moose Alley, Elk Ranch Flats, Snake River Hill, and the Gros Ventre River; and painting wider road surface lines to delineate narrower travel lanes that indirectly encourage motorists to follow designated speed limits.



Animals involved in wildlife-vehicle collisions by month during 2021, Grand Teton NP and the JDR Parkway.



Map of the Snake River, from the outlet of Jackson Lake to Moose, made using Lidar imagery to show elevation changes in the river bottom. This highly accurate mapping tool reveals the history of braided channels. It is featured in part on the back cover. Created by Madeline Grubb, NPS Academy- GIS and Geoscience Member.