Arches (left) and Yellowstone (right) national parks, both far from the bright lights of big cities, are prime stargazing sites.
Outdoor Laboratory

A century ago, Congress created the **NATIONAL PARK SYSTEM**—and ended up preserving some of the best research sites in the world.

**BY KRISTIN OHLSON**
Ten miles into Death Valley’s Johnson Canyon, the recreational hikers had thinned out, but Kelly Iknayan was still on the trail, scouting the grizzled landscape for birds.

More than 100 years ago, zoologist Joseph Grinnell, the first director of the Museum of Vertebrate Zoology at the University of California, Berkeley, visited this same spot as part of a massive baseline study of California’s birds and small mammals. Iknayan, a Berkeley Ph.D. candidate, is following in Grinnell’s tracks, surveying birds in Death Valley, Mojave and Joshua Tree national parks as part of a broader 10-year-old effort by UC Berkeley scientists to see how those fauna are faring in the age of climate change.

Few people would deny the value of national parks now, but these national treasures were hard won. Before the National Park Service’s (NPS) official founding in 1916 — 100 years ago in August — there was debate about whether the natural resources in these lands should be managed for economic gain or preserved to provide a necessary respite for the soul, as naturalist John Muir said. At the prod of Muir and other advocates, Congress chose preservation.

But even the national parks, which enjoy the highest level of protection in the world, are not immune to human impact. In fact, much of what we know about climate change’s effects on ecosystems comes from research within park borders.

“Observation of melting glaciers in Glacier National Park and North Cascades National Park has contributed to the global database that tells us glaciers are receding and human climate change is the cause,” notes Patrick Gonzalez, NPS’s national climate change scientist. Research at other parks investigates a wide range of other environmental threats, including air and noise pollution and invasive species.

Many research projects conducted within the parks aim to help conserve these iconic ecosystems — no easy task, given how much they’re changing. “Over the past century, the typical approach to conservation was to try to preserve historical ecological communities, but it’s challenging to do that when conditions have changed so much,” says Steve Beissinger, a UC Berkeley conservation biologist who helped organize a conference last year on science in the national parks. “We might not be able to keep glaciers in Glacier National Park. Instead, we may have to manage for change based on projected future conditions.”

From mountains to seashores, scientists are turning our national parks — called America’s “best idea” — into outdoor laboratories, deploying their own best ideas for understanding the natural world and how we affect it. Here, we highlight 10 key research projects underway at parks around the country.
The Elwha River rushes through the gap where Glines Canyon Dam once stood. Just after this photo was taken in 2014, the final piece of the dam was removed.

Olympic National Park, Washington
Can Removing a Dam Resurrect a River?

One hundred years ago, the Elwha River, which flows through Olympic National Park, was a sort of paradise for salmon, especially chinook. Back then, they reputedly weighed up to 100 pounds. But when an entrepreneur named Thomas Aldwell built a dam for hydroelectric power without the fish ladders that allow salmon to surmount the dam — even though state regulations required them most of the fish were cut off from their spawning grounds upstream. At the same time, sediment that would have flowed downstream and formed sandbars and eddies built up behind the dam, completed in 1913, and another constructed later. The entire riverine ecosystem suffered.

In 1992, at the behest of scientists and conservationists, Congress passed a law to restore the Elwha River. The park service decided to remove both dams over three years to free the river — and the 21 million cubic meters of sediment that had built up behind them. Park officials set off the final explosion in 2014. As they hoped, the river carried away the sediment and deposited most of it in the Strait of Juan de Fuca, the body of water that connects Puget Sound to the Pacific Ocean. Chinooks have been seen in the upper watershed for the first time in 100 years. Research hydrologist Chris Magrill from the U.S. Geological Survey has studied the impact of this huge release of mud: how it changes water flow and turbidity; how the salmon use the sediment to build nests; and how quickly the water clears up.

The benefits of what he’s learning on the Elwha ripple beyond the park. Magrill was called in to consult on the fatal mudslide in Oso, Wash., in 2014 to make sure a second landslide didn’t bury the 1,000 rescuers who rushed to the site. “Many of the scientific tools we used on the Elwha about massive releases of sediment were applied to Oso,” Magrill says.

In this 2014 photo, a newly freed Elwha River carries sediment into the Strait of Juan de Fuca.
A century ago, visitors to the West's forests trod a mosaic of sun and shadow, navigating stands of large trees and open spaces. Today, a walk in the woods is a dimmer experience. Many forests are crowded with trees, and branches obscure the sky. This new denser forest structure is an artifact of 82 years of snuffing out fires across the region. Before the age of fire suppression, wildfires regularly moved through forests — every few years in some, every few decades in others — keeping new growth in check. The result was often a clumpy forest structure with thick stands of large trees separated by open spaces, which forest scientists later learned tends to slow down the speed and intensity of future fires. Today's forest managers are trying to return forests to some semblance of their historic open structure by removing trees that have sprouted up in the absence of fire, through mechanical thinning or controlled burns. Those open spaces serve as natural firebreaks, helping to prevent high-intensity fires.

Environmental and Forest Sciences is studying how fire has changed forest structure in Yosemite National Park. Kane uses a remote sensing tool called LiDAR, which beams laser pulses over the landscape from a plane. The reflection from these pulses — off treetops, foliage and branches, all the way to the ground — reveals both the vertical and horizontal array of vegetation below.

With this information, Kane can assess forest patterns before and after fires, and see where fires have not burned large areas than previously possible. His research shows that all fires are not the same: Severe, superhot fires will kill many trees, but low- and moderate-severity fires can return the forest to a healthy state.

“Researchers have conducted experiments in the past, but this is the first time that we can quantify the effects of fire on forest structure using LiDAR data,” Kane says. “We have data over tens of thousands more acres than previously, and we can really look at the patterns and build up statistics.” Kane says the work is helping forest managers improve fire management strategies.
Everglades National Park, Florida
Restoring the ‘River of Grass’

Florida’s Everglades — the “river of grass” — once covered nearly 4,200 square miles. Humans began to constrict and alter this incredibly rich ecosystem in the early 1900s, when parts were drained for agriculture and urban development. In recent decades, people have come to recognize the many benefits of this vast sheet of wetlands, 100 miles long and 40 miles wide, which provides water to 7 million people. Congress has mandated the restoration of the Everglades, but it’s unclear how to bring back enough of the system’s natural flow to return the ecosystem to health. U.S. Geological Survey hydrologist Jud Harvey and colleagues are studying the impact of restored flow in a 2-square-mile section of the Everglades where a levee has been breached. In 2014 and 2015, Harvey and his team boosted flows from November to January each year. The hope is that these pulses of water will pick up organic sediment particles from sloughs and deposit them on ridges, restoring the patterns that supported diverse flora and fauna in the past.

“It’s been exciting to open the floodgates,” Harvey says. “We can’t restore the Everglades to pre-Columbian times, but we’ll be able to make some decisions about how much flow we need for a big increase in benefits.” Harvey’s work has implications for stream and wetland restoration around the world.
California national parks
How Has Climate Change Altered the Distribution of Native Animals?

In 1908, biologist Joseph Grinnell began conducting a survey of birds and small mammals in the West and tracked their distribution and ecological niches. At the time, he said the value of this work — conducted for the Museum of Vertebrate Zoology at UC Berkeley, where he was director — would not be appreciated for a century, assuming the materials were preserved for students of the future.

Today, Berkeley conservation biologist Steven Beissinger well appreciates the value of those surveys. "We are those students of the future!" he says. He and his colleagues use Grinnell's data to understand how climate change has affected the distribution of these species.

So far, after conducting studies in Yosemite, Sequoia, King's Canyon and Lassen Volcanic national parks, they've found a perplexing jumble of migrations. While the team observed some consistent upward shifts in range to cooler areas, they also found that some species didn't move, and that others even migrated downslope. "Climate change is lumpy," says Beissinger, who is also studying more arid sites such as Death Valley, Mojave and Joshua Tree. "We still don't see a simple way to predict what some of the effects of it will be."

Once Beissinger and his team better understand which species are moving and why, park managers may be able to help species survive by removing barriers to their dispersal to different elevations or by relocating them to more suitable habitats.
Arches National Park, Utah
Testing the Strength of Fragile Geologic Structures

Few images are as iconic as the soaring sandstone spans in Arches National Park. But should we be walking under them? Are they safe? Not always. In 2008, the 12th largest of the park’s 2,000 arches, Wall Arch, tumbled to the ground during the night.

Geologist Jeffrey Moore has figured out a way to study the viability of the arches with engineering tools designed to test airplane wings and bridges. “Until now, there has been no method available to sense damage or decaying strength in such structures without invasive monitoring,” he says.

Moore measures how the arches vibrate to the background shaking of the Earth caused by natural processes like wind and distant ocean tides to arrive at a vibrational signature for each arch. With this baseline established, scientists can determine whether a recent event — an earthquake or a new fracking operation, for instance — has changed the arch’s vibrational characteristics and, consequently, its mechanical composition. The arches are like geologic harp strings, always moving and responding to events near and far, but scientists are now close to creating a better tool for understanding when one might snap.

Yellowstone National Park, Wyoming
Exploring the Geothermal Piping of a Supervolcano

Park visitors gather around Yellowstone’s Old Faithful geyser expecting a 145-foot gush of boiling water and steam every 90 minutes. It’s a display as seemingly predictable as the park’s live animal shows or nature walks. But scientists have long wondered why geysers spout instead of trickle, like a hot spring.

Studies by UC Berkeley’s Michael Manga of the park’s Lone Star geyser and the El Hefe geyser in Chile suggest a complex plumbing system allows steam to accumulate in a series of traps. The steam heats the water column, which begins to boil from the top, then below, leading to a thunderous explosion.

The University of Utah’s Hsin-Hua Huang has solved another mystery from Yellowstone, the site of one of the world’s largest supervolcanoes. Beneath a known magma reservoir below the park, Huang’s team recently discovered a much larger reservoir of magma 12 to 31 miles underground. Based on the volume of carbon dioxide venting from the earth, scientists suspected this second pit of hot, partly molten rock existed, but it had never been located.

Huang’s work fills in some of the blank space between the shallower chamber and the hotspot plume, which starts at about 40 miles down and extends into the mantle.

He surmises that magma rises from the plume and pools in the lower chamber, a kind of waiting room, before moving to the upper chamber. The discovery of the new reservoir will help geologists understand how these major volcano systems work and, perhaps, provide a way to more accurately assess hazards in the future.
Haleakalā National Park, Hawaii
How Does El Niño Affect Tropical Cloud Forests?

Predicting the impact of climate change on ecological communities is tricky, but predicting the impact of El Niño, the cyclical warming in the Pacific Ocean that affects temperature and rainfall around the globe, is even trickier. El Niño patterns are a strong driver of drought in Hawaii, and Haleakalā National Park offers researchers a great opportunity to study the patterns' impact on ecosystems in the region.

A team led by University of California, Santa Barbara plant ecologist Shelley Crausby is studying high-elevation cloud forests that provide habitat for a number of rare birds, most of which are endangered. The forests have climbed up and down the mountains over millennia. When the forests move upward, they offer more habitat for the birds but squeeze the alpine ecosystem that supports a number of other rare species, including the silversword, a spiky plant that can live up to 90 years, blooming once before it dies. Much as gardeners can distinguish a rose from a daisy just by looking at the flower, scientists can distinguish what kind of plants used to live in a certain landscape by looking at fossilized pollen. By comparing the pollen records at different elevations with paleoclimate records, Crausby has concluded that El Niño-driven droughts determine the upper limits of the forest.

"Looking at this older material allows us to get a deeper baseline on some of these ecological phenomena that can play out over thousands of years," Crausby says. "You can only get a glimmer of that by looking solely at the modern landscape."
Superstorm Sandy in 2012 was a disaster for the places where humans live, but not for natural coastal ecosystems. That’s the conclusion of NPS ecologist Mary Foley, whose team is studying the response of natural ecosystems in Fire Island National Seashore in New York and in Assateague Island National Seashore in Maryland and Virginia, Gateway National Recreation Area in New York City and New Jersey, and others.

“Sand was moved around and altered, but the ecosystems were not damaged by this enormous hurricane,” Foley notes. Some of the 30 studies suggest features of coastal ecosystems may even protect the built environment during a natural disaster. In particular, Foley points to the ridges of sand perpendicular to the shoreline at Fire Island. While cities and the Army Corps of Engineers sometimes mine them to shore up eroding beaches, they may want to reconsider: Those sandbars might slow down hurricanes, reducing the damage to communities along the shoreline.

**Shifting Sands**

Left: NPS researchers measure sand depth. Right: Maps show the extent and thickness of sand ridges along the ocean-facing side of Fire Island in 1996 (middle) and in 2014 (right), after Superstorm Sandy tore through the area. Thicker areas are in green; thinnest areas are in red.
Theodore Roosevelt National Park, North Dakota
Tracking Oil and Gas Development's Effect on Air Quality

Hikers and campers heading into the backcountry of Theodore Roosevelt National Park tip their heads back when the sun goes down, expecting a brilliant display of stars set against a dark sky. But what they often see in the distance are gas flares and the lights of drilling rigs, bleaching the sky so that it's hard to make out the stars. In the daytime, especially when the winds are low, they sometimes strain to see natural vistas through a scrim of haze.

Roosevelt, which lies in the heart of the Bakken shale formation, is surrounded by oil and gas development. North Dakota alone is home to about 10,000 active wells that together produce more than 1 million barrels of oil each day, and the number of wells is expected to grow to up to 60,000 over the next 25 years. Extracting oil also releases natural gas from the formations, but since North Dakota doesn't have the infrastructure to pipe it away, about one-quarter of the gas is burned on site, or "flared off." NPS chemist Tony Prenni and colleagues are studying the impact of all that petrochemical activity on visibility in Roosevelt and other parks in the region. Because of Clean Air Act regulations, visibility has steadily improved around the country in recent decades, but it remains a problem in this area.

“The good news is that the emissions are not at the point where they’re a health concern,” Prenni says. “Still, you don’t expect to go into a national park and find poor air quality. And night skies are considered a resource in the park.” Prenni is gathering better measurements and conducting particle analyses that will help park managers assess this threat, not just at Theodore Roosevelt but also at other parks in the West surrounded by oil and gas development.

The park’s nighttime view now includes the glow of an oil field.

In this spacecraft view of the U.S., the luminosity of North Dakota’s Bakken oil field rivals that of even the largest cities.

A pumpjack plumbs the Bakken oil field against a backdrop of gas flares.
White Sands National Monument, New Mexico

How Quickly Can New Species Evolve?

The alabaster dunes at White Sands National Monument are a geologically recent phenomenon, formed only a few thousand years ago and still changing. Many of the creatures in the White Sands ecosystem, including the lesser earless lizard and the Apache pocket mouse, have undergone rapid evolution in response to their unique environment, developing a lighter appearance that allows them to blend into the gypsum sands and escape predators.

Berkeley evolutionary biologist Erica Bree Rosenblum is studying this phenomenon in multiple species, including lizards, invertebrates and mammals, comparing them with their brown relatives in the adjacent desert and tracking changes in everything from genes to mating patterns. So far, she has found that the

Kristin Olsson is a freelance writer based in Portland, Ore.
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