

Climate Change Scientist Walks the Walk

Patrick
Gonzalez
prepares the
national
parks for a
hotter
future

FEATURE BY
ELIZABETH
SHOGREN

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THE FIRST UNMISTAKABLE SIGN of climate change Patrick Gonzalez ever saw in the field was in Senegal. It was a dead tree — *Prosopis Africana* or, as the locals call it, *yir* — normally a mid-sized tree with tiny bluish-green leaves and wood so dense that Wolof villagers use it to hold up the walls of their huts, passing the poles down through the generations. But this *yir* was nothing but a gray naked trunk, and Gonzalez knew that climate change had killed it.

Five years earlier, when he first came to Senegal as a Peace Corps forestry volunteer in 1988, village elders told him that many local trees were dying off — including *yir*, mango, cashew and jujube, whose berries are full of vitamin C. Their loss contributed to the people's obvious malnutrition — toddlers with hair of a dull reddish hue instead of shiny black, tragically skinny adults. Women were forced to walk much farther to gather firewood.

Gonzalez helped them revive forgotten traditional methods and re-grow some of their native trees. But he was also determined to figure out what was causing so many trees to die. So he returned to Senegal in the early 1990s and walked to 135 villages to count and measure trees and interview village elders. He wore out six pairs of tennis shoes walking nearly 1,200 miles — and earned his Ph.D. from the University of California, Berkeley as a forest ecologist, and his stripes as a climate change scientist.

His data showed that, since 1945, one out of three tree species in Senegal had disappeared, and one out of every five big trees had died. Over 50 years, tropical woodlands had shifted 15 to 18 miles toward the equator, giving way to grasslands. “Only a substantial change in climate can cause that,” says Gonzalez. The primary tree-killing factors were higher temperatures and lower rainfall, caused by global increases in greenhouse gases. He had unraveled the mystery of the dying trees of Senegal and documented one of the earliest cases of climate change altering the fundamental ecology of a region, causing a biome shift. “So here we have our pollution causing



A dead *yir* tree in Senegal, seen by Patrick Gonzalez in 1993 as an unmistakable indication of climate change.

COURTESY PATRICK GONZALEZ

climate change, causing drought, killing trees and hurting people's livelihoods half a world away,” he says. “And it's the thought of these people and the hardships of their lives that really drove me.”

A quarter-century later, Gonzalez is focusing his considerable passion for deciphering how climate change is altering the natural world on some of America's most cherished landscapes: the national parks. It's melting glaciers, hastening snowmelt, intensifying wildfires, warming streams, and pushing animals and plants out of their usual locations. In coming decades, climate change will magnify these impacts. To what degree depends on whether and how much people rein in greenhouse gas emissions.

As in Senegal, Gonzalez's mission is twofold: He's leading a massive effort to analyze and describe climate change impacts in every park and across the whole system, and with colleagues inside and outside the agency he's pioneering ways to use that science to preserve the landscapes that first inspired Americans to create national parks. Climate data

can help park supervisors make decisions about everything from how to manage wildfires and restore wetlands to how — and whether — to upgrade culverts or move roads.

This new thinking doesn't come easy to a 100-year-old bureaucracy. But the National Park Service acknowledges that, due to climate change, it needs to revolutionize the way it manages the landscapes in its care. The goal, Gonzalez says, is “to go from trying to re-create small pictures of a past to which we cannot return, to national parks that we manage for potential future conditions, so that they remain vibrant through this time of dramatic global change.”

THE MAGNITUDE OF THAT CHALLENGE

inspired National Park Service Chief Jonathan Jarvis, nearly six years ago, to create the job of principal climate change scientist. He hired Gonzalez, whom he calls a “brilliant” scientist with deep experience. A lead author of three reports of the Intergovernmental Panel on Climate Change, Gonzalez shares in the Nobel Peace Prize the group received in 2007. But more importantly, says Jarvis, he's got the heart of a field scientist: “Patrick is a field guy. He gets it, he understands. He has this sort of deep passion about the outdoors and about trees in particular.”

Gonzalez, a trim 51-year-old with short salt-and-pepper hair, regularly walks 10 miles a day. He literally bounces up steep trails in Yosemite, stopping periodically to admire new spring growth on pines or sniff their bark, talking all the while. There's a kind of quiet ferocity to the man, especially when it comes to climate change. An introvert by nature, he acquired the gift of gab from the Wolof villagers, who welcomed him when he showed up unannounced, wanting only his conversation. He owes to them his rare ability to communicate the truth about climate change.

He drives himself and his colleagues to combine the latest international climate data with contemporary field observations, as well as the national parks' rich trove of historical research. That has given the National Park Service a major



Patrick Gonzalez, principal climate change scientist of the National Park Service, uses a clinometer to measure tree height in his favorite national park, Yosemite, where he sees first-hand the effects of climate change.

AL GOLUB/
GOLUB PHOTOGRAPHY

Vital signs

Climate change has already brought irreversible changes to the national parks. And more are imminent, without major reductions in pollution from cars, power plants and deforestation. Here's a sampling. E.S.

Melting glaciers

The elevation of Muir Glacier in Alaska's Glacier Bay National Park and Preserve has dropped in places by 2,100 feet since 1948. This is one of many glaciers in southeast Alaska that have shrunk astoundingly in recent decades, dramatically changing what visitors see and contributing to sea-level rise. Scientists estimate that over the latter half of the 20th century, melting ice masses in Alaska and neighboring Canada have increased global sea level even more than the Greenland ice sheet has. Muir Glacier offers a great example of how the rich data from national parks has contributed to the global understanding of climate change. It's among 168,000 glaciers used by the Intergovernmental Panel on Climate Change to determine that human-created climate change is melting glaciers globally.

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Yosemite toad.
PAUL MAIER/CC VIA WIKIPEDIA

Vital signs ... Shifting biomes

Since 1880, lodgepole and other pine trees have moved uphill into what once were subalpine meadows in Yosemite National Park. The thirsty trees have helped dry up a wetland ecosystem important for small mammals like marmots as well as high-elevation frogs and salamanders. Yosemite now is working on a restoration project to restore the meadows' hydrological functioning. "You want them to remain wetlands," says Linda Mazzu, Yosemite's resource manager. "When trees invade, it's like a biome shift." A biome is the community of plants and animals in a particular region, and this was one of 23 biome shifts worldwide documented by the Intergovernmental Panel on Climate Change. Other biome shifts are underway — boreal conifer forests moving into tundra and alpine biomes in the Kenai Mountains-Turnagain Arm Natural Heritage Area and in Noatak National Preserve.

Voracious beetles

Climate change is causing extensive bark beetle outbreaks across the West, because winters have been too mild to kill the insects and trees are stressed by drought. Rocky Mountain National Park has been hit especially hard, with 90 percent of the park's forested areas affected. Hundreds of thousands of lodgepole, ponderosa, Engelmann spruce and other evergreens have died. Park staff remove standing dead trees at campsites and other heavily visited areas so they don't fall on people or property. They also spray insecticide on thousands of tree trunks in non-wilderness areas. But 95 percent of the park is designated wilderness, and the beetles, which are native, have free rein there. The park has planted a small number of trees, but leaves most areas for natural regeneration.

head start over other federal agencies, says Kathy Jacobs, who worked in the Obama White House for four years producing the 2014 National Climate Assessment. The other dozen agencies involved in that report "were more reluctant to use this information or didn't know how to translate science in ways that are useful for decision making," says Jacobs, now a University of Arizona professor and director of its Center for Climate Adaptation Science and Solutions.

Gonzalez serves all the parks, but Yosemite has been his personal favorite since he woke up in a tent in the valley on a snowy morning, 29 years ago. This May, as he headed back there from his home in Berkeley, California, he was full of excitement. He was about to introduce managers from several West Coast and Pacific island parks to his strategy for better managing forests in the face of the increasingly frequent fires that climate change brings.

But before reaching Yosemite, Gonzalez was jolted by a sight reminiscent of his experiences in Africa. He knew that California's four-year-drought had killed trees, but was unprepared for the profusion of rust-colored dead trees on a landscape he loves so deeply. A wave of shock and sadness swept over him. "I was alarmed, actually," he recalls. "It's preventable," he says of the tree losses around the state. "Human climate change has caused a tenth to a quarter of the California drought." The Sierra Nevada's dead trees are part of a West-wide die-off. Climate change caused tree deaths to double between 1955 and 2007, research shows. Scientists haven't yet analyzed the role climate change played in the even larger die-offs of more recent years.

As in Senegal, that knowledge motivates Gonzalez to act. Now he and his colleagues are using careful, inventive science to prove that climate change is to blame, communicating that fact to the public and devising management changes that reflect the data. Gonzalez looks for

Patrick Gonzalez, right, and his best Wolof friend, Séex Ley, check the "sowing bags" that contain seeds that have yet to sprout. As a Peace Corps volunteer, Gonzalez innovated new ways to grow native trees in an environment that was becoming less hospitable to them. Far right, some of the trees today, grown by Senegalese farmer Modu Jóob with seeds Gonzalez gave him decades ago. COURTESY PATRICK GONZALEZ



ELIZABETH SHOGREN

"Human climate change has caused a tenth to a quarter of the California drought."

—Patrick Gonzalez, NPS chief climate change scientist, who says he's optimistic that people will do the right thing in the face of climate change

overarching patterns. For instance, his analysis shows that climate change is heating up national parks on average three times faster than the rest of the country. Parks tend to be located at higher elevations and farther north, where temperature increases are greater. The increases vary significantly, park by park. But national parks serve as crucial safe havens: As lynx, wolverines and other high-elevation mammals are pushed into ever-smaller areas, their remaining habitats, often in parks, become increasingly important to their survival.

He's also parsing the latest climate data and synthesizing studies to draw individual portraits of climate change in each park, now and in the future. So far, he's completed reports for 234 of the 412 national parks. They provide specific data tailored for each park about historic temperature increases and precipitation

changes, as well as a range of projections. For coastal parks, they also include historic data and projections for sea-level rise, erosion and storm surge. But the reports also provide much more intimate pictures, capturing the vulnerability of particular animals and plants, as well as impacts to glaciers and other natural wonders. "The Park Service should be applauded for really drilling down and trying to understand how each unit will be affected," says Jonathan Overpeck, professor of geosciences and atmospheric sciences at the University of Arizona.

The sea-level rise and storm surge data come from a major project by University of Colorado climate scientist Maria Caffrey, which examines all coastal and lakeside parks. Gonzalez, who oversees Caffrey, had her recalculate her data using a different measurement technique, to make it more useful for park managers. Despite the inordinate amount of work that caused her, Caffrey says she appreciates his high standards: "Patrick really is the only person at the Park Service I can think of who will dive into the numbers and think about things I haven't taken into account." So far, two parks have resisted Caffrey's projections because they didn't jibe with their own estimates. But Gonzalez stepped in, insisting they use her conclusions because she used more accurate, up-to-date science.

The Park Service sent a summary of Gonzalez's Yosemite report to President Barack Obama's speechwriters before his speech in Yosemite Valley in June. "The biggest challenge we're going to face in protecting this place and places like it is climate change," Obama said that day. "The idea that these places that sear themselves into your memory could be marred or lost to history — that's to be taken seriously."

WHILE THE PARK SERVICE has progressed light-years in terms of conducting climate change science, individual parks have

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Researchers in the Jemez Mountains of New Mexico work to identify how best to protect cultural resources during fuel treatments that are increasingly part of forest management for the National Park Service and other agencies. At left, video and infrared cameras set up on tripods record the progression of fire during a prescribed burn. Following a burn, researchers uncover test artifacts, such as the potsherd above, and check for damage. U.S. FOREST SERVICE

Vital signs ...

Shrinking wildlife habitat

In Mount Rainier, North Cascades and Olympic national parks, scientists predict that climate change will dramatically shrink habitats for high-elevation mammals. As temperatures warm and snowpack decreases, hoary marmot, wolverine, mountain goat, American pika, American marten, snowshoe hare and Canada lynx will probably lose most of their current turf. Small patches of mountain-top habitat in national parks will become increasingly important for the conservation of these species, because other suitable homes for them are likely to be gone.



Saguro National Park in 1935, top, and 2010. NPS

Looming die-offs of desert plants

The exquisite desert plants of Arizona's Saguro National Park are adapted for dry conditions, but climate change may make their Sonoran Desert home too hot even for them. Scientists project major die-offs of saguaro, palo verde, ocotillo and creosote bush. And even if the planet's people manage to modestly reduce their greenhouse gas emissions, scientists project that 90 percent of Joshua Tree National Park could become too dry for Joshua trees by 2100.

A new vision for park stewardship

National parks tackle climate change despite meager help from Congress

Five years ago, just after archaeologist Marcy Rockman joined the National Park Service's new climate change response program, the GOP-controlled Congress slashed its budget by 70 percent. Republicans were determined to squash President Barack Obama's climate agenda, and many federal officials were deeply discouraged. So Park Service Director Jonathan Jarvis convened his top staff and climate team. Rockman says he pounded his fist on a table and bellowed: "Say the 'c' word!" It was a clear battle cry, she adds: "Jarvis was so forceful in saying, 'We are doing this!'"

With only \$2.8 million and a tiny staff, the program began a major research blitz, studying climate change impacts on national parks from Acadia in Maine to American Samoa in the Pacific. Meanwhile, Jarvis convened a panel of independent scientists, who, in 2012 produced a report titled *Revisiting Leopold*. They urged the agency to jettison its decades-old mandate to preserve each park as a "vignette of primitive America." Rather, parks should steward America's treasures through the continuous and unpredictable changes to come. Managers should "act immediately, boldly and decisively" to prepare for volatile conditions, including severe wet seasons and deep droughts, and unite with nearby public lands to address landscape-wide challenges, such as creating corridors for wildlife seeking new habitat. A permanent policy reflecting the panel's thinking is due out later this year.

"That's a huge paradigm shift; it's driven by recognition that climate change is making the former strategy impossible," says University of Arizona professor Jonathan Overpeck. "The shift in climatic extremes will affect just about anything in a park, other than the solid rock. The Park Service is taking climate science and climate change seriously, which is really important if we're going to manage these precious resources into the future."

Many changes are already evident. Yosemite's Lyell Glacier, which covered 1.2 square kilometers when John Muir first studied in 1872, was down to 0.27 square kilometers. At this rate, park geologist Greg Stock warns, it will vanish completely within 10 years. Glacier National Park's much larger glaciers have shrunk tremendously, too. Scientists project other dire consequences for Western parks if humans fail to kick the fossil fuels habit: rampant wildfires, rivers too hot for native trout, mountaintops too warm for snow-dependent mammals like snowshoe hare and Canada lynx.

The parks are working to slash their own emissions. The visitors' center at California's Pinnacles National Park, for

instance, was built with renewable power and runs on electricity from solar panels. Passenger vehicles are no longer welcome in Zion during the summer. And parks are educating the public about climate change.

But they've been slower to adapt management practices. There are good reasons, says Tom Olliff, division chief of landscape conservation and climate change for the Intermountain West Region. Science takes time, as does crafting good policy. And managers are rightfully conservative, says Olliff, because their mission is to leave these magnificent landscapes "unimpaired for the enjoyment of future generations."

Still, some parks are charging ahead. At Golden Gate National Recreation Area, several beach restoration projects are in the works due to erosion caused partly by sea-level rise. At Stinson Beach, the park recently removed its old sewage treatment system on the beach and installed a new one high in the bluffs. For the last three springs, Utah's Timpanogos Cave National Monument has attached pheromone packets to 100 Douglas firs along a steep paved trail to the cave, hoping to help them avoid joining a West-wide bark beetle outbreak exacerbated by climate change.

With the program's budget still stuck at \$2.8 million, Rockman finds it hard to do the job she was hired to do: assessing cultural treasures' vulnerability to climate change. Most available funding goes to protect historic coastal buildings from sea-level rise and storm surge; a 2015 analysis of 40 coastal parks determined that buildings worth \$40 billion are at high risk over the next century. But Rockman worries that the West's archaeological and historic treasures have as-yet-unidentified weaknesses. She wonders if climate change is responsible for crumbling adobe structures at some Southwestern parks. After major deluges uncommon around Tucson, cracks opened up underneath windows at Tumacácori Mission. And following another intense rain, an adobe wall collapsed at New Mexico's Fort Union, the region's largest 19th century fort. "If we don't catch those in time, those resources are just as gone as if they'd been taken away by a storm surge," she says.

Anne Carlson, climate adaptation specialist for The Wilderness Society, says the agency has accomplished much in a short time with little money. That it hasn't done more reflects the scale and nature of the challenge, she adds. "We've never been through climate change before. It is extremely difficult to figure out what to do to adapt to something we have never experienced as a species before." ELIZABETH SHOGREN



Yosemite Fire Chief Kelly Martin inspects a ponderosa pine in Yosemite Valley, burned in a prescribed fire. ELIZABETH SHOGREN

Vital signs ...

Snow and snowmobiles

Across the West, snow-packs have plummeted because of human-caused climate change. That trend is likely to continue, disrupting Yellowstone's \$60 million winter tourism industry, among other things, according to a paper published this month in *PLOS One* by Michael Tercek and Anne Rodman, the park's acting branch chief for physical science. By the end of this century, they predict that, during 70 percent of the winter season, there won't be enough snow for snowmobiles and snow coaches to drive into Yellowstone from its West entrance. The agency might eventually have to plow its roads for cars, they say, if it wants to maintain high levels of year-round tourism.



NPS

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moved much more slowly to incorporate that science into management. Agency veterans say the pace is intentional and reflects past experience, when hasty management changes backfired.

For Gonzalez, though, the speed

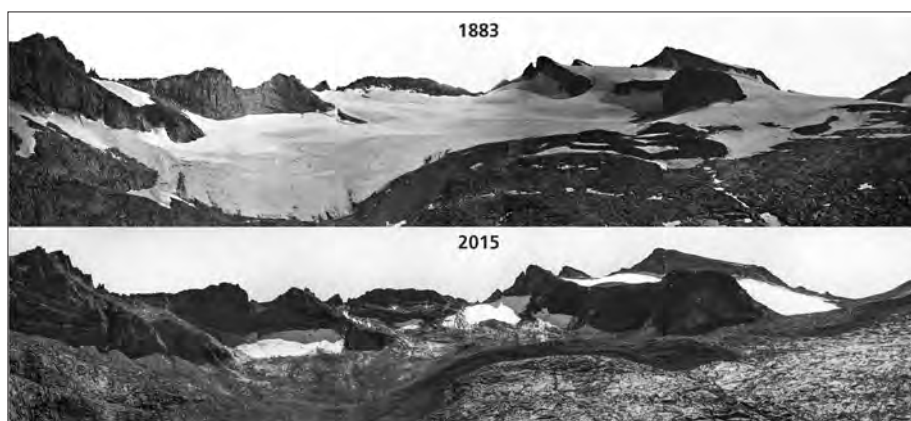
sometimes feels frustratingly slow. He remembers how, in just two years, he was able to devise ways to help remote villages in Senegal regrow the trees people needed for their health and livelihoods. To protect young trees from livestock, he resurrected a traditional practice of surrounding them with hedges intertwined

Historical climate change trends

(based on data collected 1950-2013*). All of these are statistically significant.

Park	State	Change (°C) per century
Denali National Park	Alaska	3.9 ± 1.1 °C
Grand Canyon National Park	Arizona	0.9 ± 0.4 °C
Mount Rainier National Park	Washington	0.9 ± 0.4 °C
Rocky Mountain National Park	Colorado	1.9 ± 0.4 °C
Yellowstone National Park	Wyoming, Montana, Idaho	1.4 ± 0.4 °C
Yosemite National Park	California	1.8 ± 0.4 °C
Zion National Park	Utah	2.0 ± 0.4 °C

DATA: DALY ET AL. 2008. *INTERNATIONAL JOURNAL OF CLIMATOLOGY*; HARRIS ET AL. 2014. *INTERNATIONAL JOURNAL OF CLIMATOLOGY*; ANALYSIS: P. GONZALEZ.
* DENALI DATA COLLECTED 1950-2009



Lyell Glacier, in Yosemite National Park, has retreated about 70 percent since John Muir discovered it in 1871. NATIONAL PARK SERVICE

with thorny branches. One of Gonzalez's proudest moments came when he returned to his Senegalese village this March: A happy farmer showed him 314 trees, jujube and others, planted with seeds that Gonzalez had given him.

But getting the Park Service to adopt such innovative ideas isn't always successful. Several years ago, Gonzalez was part of an effort to incorporate climate science into an update of fire-management policy at Sequoia and Kings Canyon national parks. That project fizzled. Last year, working with Bureau of Land Management and Forest Service officials, Gonzalez used climate change data to create a proposal to use Land and Water Conservation Fund dollars to buy private land adjacent to Redwood National Park and Whiskeytown National Recreation Area and other protected lands in Northern California. The parcels were important safe havens for animals and plants, home to trees that store a lot of carbon or vulnerable due to climate change. But the proposal wasn't selected for funding.

That makes him all the more pleased that managers at Yosemite, Grand Canyon and some other parks are now eager to integrate climate science into their decisions about when to treat landscapes with controlled fires and when to let natural fires burn.

Scientists project that, by 2085, climate change may double or triple the area that burns each year in Yosemite. It's already altering the three main factors that determine how often and with what intensity wildfires burn: climate, ignitions and fuels.

Temperatures in Yosemite are increasing at a rate of 1.8 degrees Celsius (about 3 degrees Fahrenheit) per century, with the highest increases in the spring. That translates into longer fire seasons as the snow melts earlier. Lightning strikes that would have been snuffed out by snow now spark fires more frequently and at higher elevations. With hotter temperatures, fire-resistant red fir forests are moving farther upslope and being replaced by more fire-prone trees, such as ponderosa pine. That all adds up to more frequent, more intense fires.

Other parks face even more daunting challenges. Steeper temperature rises in Yellowstone set the stage for "potentially astounding" increases in the frequency of fires, Gonzalez says; some scientists project that fires could become three to 10 times more common there by 2100.

In Joshua Tree, invasive plants have brought fire to a landscape that did not evolve with it. The double whammy of fire and hotter temperatures could push the gorgeous, goofy trees out of the park named for them.

Gonzalez wants to help park managers adapt to this new reality. The prescription

would vary: Forests projected to get wetter might need less fire, for example. This variability translates into tremendous amounts of data-crunching for Gonzalez, but he says: “The potential to help this special place and other places survive into the future really motivates me.”

Several factors make him optimistic that Yosemite and other parks will embrace his new approach. The climate data, which were coarse several years ago, are now so detailed that Gonzalez can plot projected temperatures and precipitation for quarter-mile-square parcels of Yosemite. That’s fine-grained enough to guide a fire chief’s decisions about whether to set controlled fires or let natural fires burn. Key people are ready, too.

Fire Chief Kelly Martin can barely contain her enthusiasm when she bumps into Gonzalez at Yosemite’s visitor center in June. “I really appreciate your work; I really want to know what I can do from my perspective.”

Later, she strides across a stretch of ponderosa forest that her crew had burned a few years before. The trees are widely spaced, with blackened trunks and green canopies. “These larger trees won’t be destroyed by fire because there is nothing now to let a fire into the canopy of these trees,” says Martin.

She wants to use low-intensity fires to clean out underbrush and small trees in large swaths of forests, thus preparing

them to withstand hotter, drier conditions and wildfire. Gonzalez’s data will help her target prescribed burns and decide where to let natural fires burn.

Her one worry is politics. It’s hard to get support to set fires when so many people view fire as always harmful.

So when she learned that President Obama was coming to Yosemite, Martin hoped to light a controlled burn in the Mariposa Grove, the park’s largest collection of giant sequoias. Maybe Obama would watch it and use his bully pulpit to burnish fire’s image. “Think how powerful that would be,” she says. That particular burn didn’t happen, but Martin plans to keep working with Gonzalez to prepare Yosemite for the wildfires of the future.

THE EVIDENCE OF CLIMATE CHANGE that Gonzalez has seen from Senegal to Yellowstone inspires him to encourage people to jettison fossil fuel-dependent lifestyles. He hasn’t owned a car since he returned from Senegal and avoids using elevators, even in skyscrapers.

To get to Yosemite in June to give a lecture, Gonzalez took the Bay Area Rapid Transit from his home in Berkeley to an Amtrak train, and then rode a bus to the park. “Every gram of carbon that I save is not going up in the atmosphere and melting that snow and shifting those trees or those mammals up higher,” he says. “It’s helping to avoid these impacts on the

most special places, our national parks.”

Walking the walk gives also him moral authority when he asks people to follow his example. Unlike many climate scientists, he’s extremely optimistic that people will do the right thing to slow climate change.

Gonzalez imagines visitors learning about the parks’ vulnerability to climate change and deciding to make a difference by walking and taking public transit, not just in the park but when they get home, too.

When Gonzalez was wrapping up his time at Yosemite, a family waiting for the same shuttle bus approached him. They had listened to his speech a couple of days earlier, and wished all visitors to national parks could be so lucky.

“I would love it if we could just fill up the rooms every single day with the likes of Dr. Gonzalez, so he and people like him could say we need to change,” said the father, Franz Limonta. His 12-year-old son, Ansel, named after the photographer, chimed in, saying the family could drive less.

Afterwards, they wrote Gonzalez to tell him that his lecture was the highlight of their vacation. They’re moving to San Diego and have already begun searching the internet for carpools, so Crystal Limonta, an ER nurse, can limit the greenhouse gas emissions from her new commute. □



Correspondent Elizabeth Shogren (shown on assignment in Yosemite National Park), writes from Washington, D.C. @ShogrenE

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