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TOXIC LEGACY

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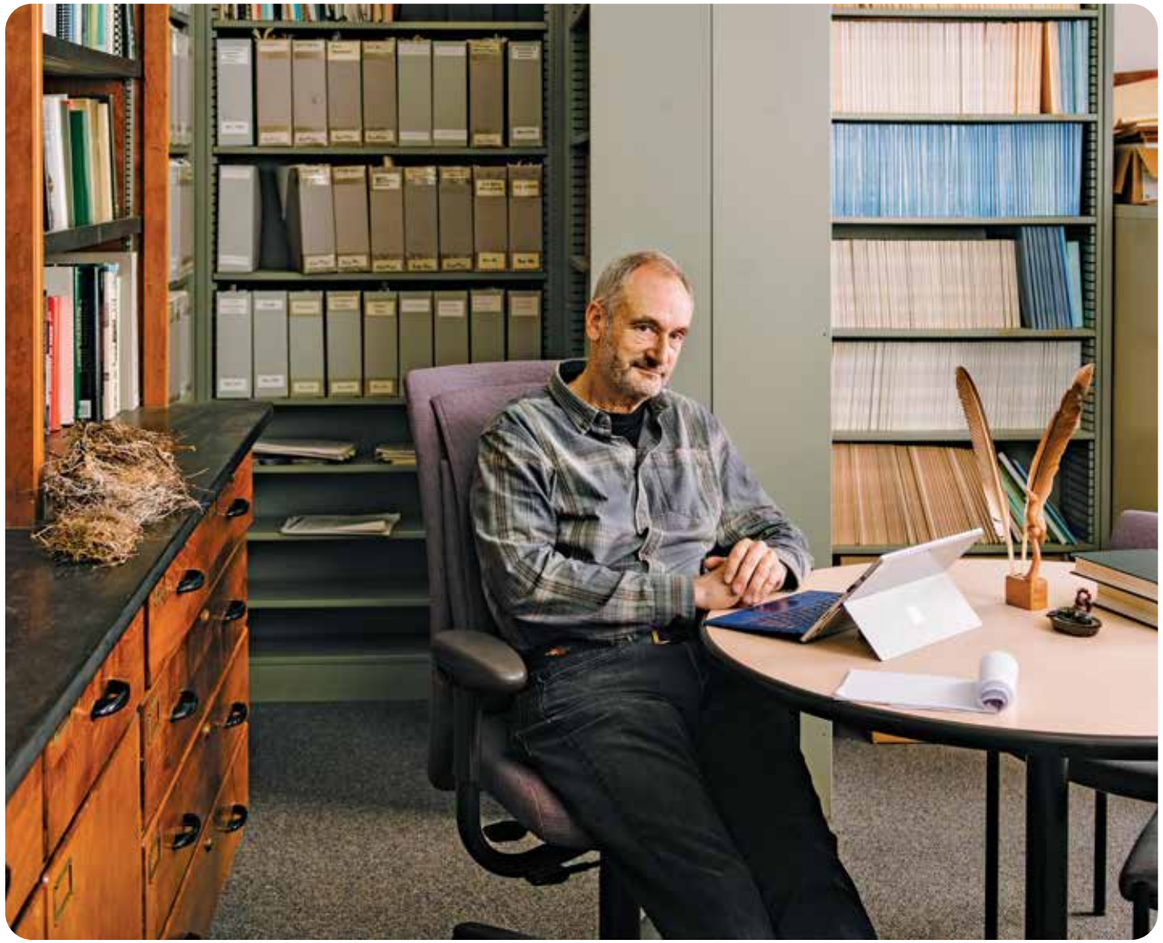
METADATA

IN GRINNELL'S FOOTSTEPS

PHOTO: COURTESY OF THE MUSEUM OF VERTEBRATE ZOOLOGY ARCHIVES, UNIVERSITY OF CALIFORNIA BERKELEY



A century ago, naturalist Joseph Grinnell trekked across California, making detailed notes of all he saw. Now modern researchers are retracing his steps to understand how the state's surging human population has transformed its birdlife.

Joseph Grinnell (left) and Steve Beissinger (right) in their offices at the University of California, Berkeley in 1930 and 2019, respectively.

BY HANNAH WATERS | PHOTOGRAPHY BY CAYCE CLIFFORD

Steve Beissinger knows exactly what famed naturalist Joseph Grinnell was doing on June 2, 1932: He was hiking a ridge near Lagunitas, California, with his wife, Hilda. This was no lovers' picnic. On their 3.5-hour trek, the duo undertook three separate bird counts, and Grinnell tallied each of the 94 birds from 31 species that they saw or heard.

Beissinger knows all this because he's been reading Grinnell's diaries. Clues gleaned from two pages of neat cursive written 87 years ago led the modern ornithologist with University of California, Berkeley's Museum of Vertebrate Zoology (MVZ) to what he's certain is the same trail Grinnell investigated. On a May morning, he, his postdoctoral student Kelly Iknayan, and I returned to repeat the hike ourselves. "We were surprised by the luxuriance of the annual vegetation as well as that of the forest trees and chaparral," Iknayan reads from a scan of the pertinent entry. We set out from a paved parking lot, and minutes later our trio is similarly delighted by opulent wildflowers and towering redwoods.

I take each step purposefully, trying to conjure the significance of those who walked here nearly a century ago. This wending path along Lagunitas Creek is just one of hundreds of sites throughout California that Grinnell and a small army of field staff surveyed between 1908 and his death in 1939. They camped in the Sonoran, Mojave, and Great Basin deserts; the Central Valley wetlands and South Coast; and the mountains of the Sierra Nevada and Yosemite National Park. Wherever they went, they trapped mammals and shot birds, ultimately establishing a museum collection of more than 100,000 specimens. They also, at Grinnell's insistence, filled hundreds of field notebooks with observations of every animal they saw and detailed descriptions of the surrounding landscape.

Those surveys came at a pivotal time in California history. Between 1870 and 1900, the population of Los Angeles ballooned from 5,000 to 100,000 people. The Los Angeles Aqueduct, which diverted the Owens River and ultimately destroyed Owens Lake, was finished in 1913, and around the same time people drained the formerly vast wetlands and lakes of the Central Valley to make way for agriculture. "The whole country is being settled up," Grinnell wrote in 1917. "It looks as tho [sic] the desert fauna and flora of San Fernando Valley were entirely doomed."

Worried that California's natural history would be lost, Grinnell was propelled to catalog the state's wildlife before it was destroyed. Even then he foresaw his work's lasting value: "The student of the future will have access to the original record of faunal conditions in California and the west," Grinnell wrote in 1910. "This value will not, however, be realized until the lapse of many years, possibly a century, assuming that our material is safely preserved."

The material was preserved, but no one ventured to examine the full collection until 2004, when Beissinger and colleagues realized: "We are the students of the future." They decided to dust off the field notebooks, extract as much information as possible, and resurvey every field site they could identify. Beissinger led the bird resurveys and MVZ biologist Jim Patton spearheaded the mammal effort.

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PHOTO: COURTESY OF THE MUSEUM OF VERTEBRATE ZOOLOGY ARCHIVES, UNIVERSITY OF CALIFORNIA, BERKELEY

Elmer Aldrich in 1938 (top) and Kelly Iknayan in 2015 (bottom) survey California wildlife in the Mojave National Preserve.

Any decent naturalist could broadly surmise what has, and hasn't, changed across California in the past century. At Lagunitas Creek, for instance, they might deduce (correctly) that Grinnell, too, heard the cheery song of the Warbling Vireo, and rightly presume that he wasn't subjected to the background hum of vehicles zooming down Route 1 (it wasn't built yet). But by combining Grinnell's observations with their own, Beissinger and Patton aimed to capture a far more granular understanding of how California's wildlife has responded to a century of monumental human change.

It's taken more than a decade of grueling work that combines history and science—interpreting sloppy handwriting, geolocating from vague site descriptions, dispatching bands of students into remote habitats, building statistical models capable of revealing otherwise undetectable shifts. From this effort, Beissinger's team has so far published more than a dozen high-profile papers on avian-population changes in California ecosystems. Their findings have revealed novel ways by which birds are—and aren't— adapting to rapid climate change, with immediate implications for how conservationists prioritize and manage wildlife habitat. Though Grinnell never predicted global warming, his painstaking labor is generating unprecedented insights into birds' vulnerability and resilience. And it will help all students, present and future, best position birds to survive even those changes that haven't happened yet.

Joseph Grinnell developed an early appetite for scientific collection. As a young teen he caught his first specimen, a toad he preserved by stuffing its skin with cotton; by his 17th birthday he had collected his 72nd specimen, a red-shafted Northern Flicker. To expand his bird collection, he sought out adventurers—army inspectors, gold prospectors, field scientists—passing through his hometown of Pasadena and convinced them to let him tag along on their expeditions throughout California and Alaska. At 18 he published a bird list for Pasadena, tallying 158 species. As he expanded his bird studies in his 20s, Grinnell earned praise from leading scientists of the time, including John Muir and Henry Fairfield Osborn.

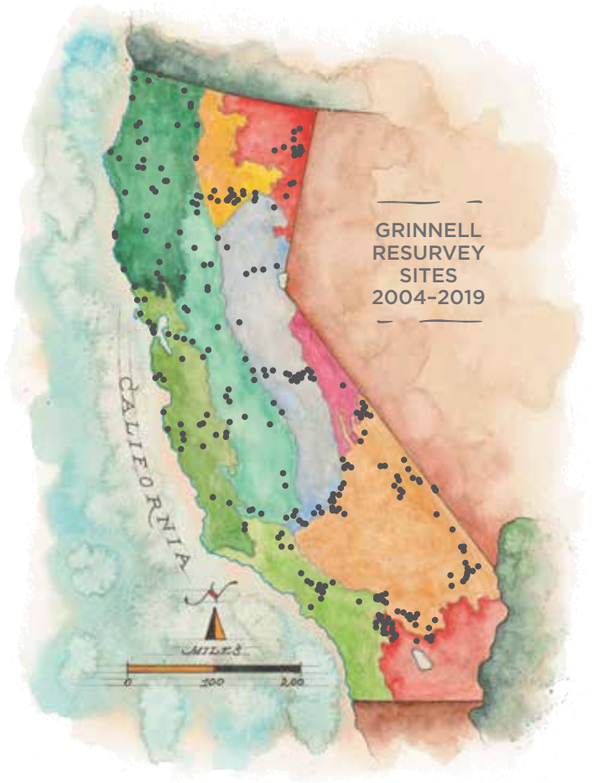
He also caught the attention of sugar cane heiress Annie Alexander, a philanthropist and herself a keen naturalist and field collector. She had decided to create a museum of vertebrate zoology at the University of California, and in 1908 she asked Grinnell to be its first director—never mind that he was 31 and had not yet earned his Ph.D. (He eventually submitted a dissertation at Stanford University in 1913.) He immediately set out to build the richest possible collection of the state's wildlife.

Grinnell targeted regions where he suspected rare animals lived, and he dispatched surveyors over mountains to sample bird diversity at a variety of elevations and temperatures. Over three decades he, his students, and field staff camped at 700 field sites across California. They caught and killed mammals and birds at each, and then processed specimens to preserve them—typical activities for field trips of that era.

But Grinnell went further than other naturalists of his day. Driven, precise, and methodical, he wrote

everything down. "He took field notes on vacation," Beissinger says. And he likewise instructed his team to keep detailed field diaries, following a protocol now known as the Grinnell Method. The result: 74,000 pages of handwritten notes and 10,000 images. "As he was building his collection of specimens, he was also building his field-note collection, which is a dimension none of his contemporaries were thinking about," Beissinger says. Along with jotting down descriptions of vegetation, topography, and landmarks, his team took regular and repeated "pencil censuses" of birds seen and heard on trails around camp.

Those notes were bound inside hundreds of books and sat untouched for nearly a century in a glass case lining the museum's Grinnell Conference Room (Wi-Fi password: grinne11!). The idea of cracking them open and retracing Grinnell's footsteps struck Beissinger and colleagues when they were brainstorming ways to celebrate MVZ's centennial in 2008. "The challenge was figuring out how to work with a lot of these old data," he says. "It took some detective work."



MAP: MIKE REAGAN

The first step was pinpointing the old field sites—an enormous undertaking, aided by the museum collection Grinnell built. Each specimen has a tag affixed to its ankle that notes where the bird was collected, when, and by whom. Students had previously entered all of that information into a database, so Beissinger mapped the collection site of each specimen, and *voilà*—the resulting clusters indicated a Grinnellian field site. "That's a huge help in getting you into the general vicinity," says Iknayan, now an environmental scientist at the San Francisco Estuary Institute. From there, they'd scour the notebooks for key descriptions of the area. Sometimes Grinnell's team included topographical data from historical U.S. Geological Survey maps, or—jackpot—reference photos. "It was a lot of time with the field notes," Iknayan recalls.

Through those notes the modern surveyors got to know the long-dead researchers. Some indulged in chronicling more superfluous happenings, describing social dynamics and other goings-on at camp; others seemed to simply enjoy writing. "You get this richness and tapestry of these people and their lives," Iknayan says. You also, she adds, gain an appreciation for good penmanship: "You start to like certain surveyors because you're like, 'Oh, it's so legible.'" Grinnell was not a particularly florid writer—"He scorned language that was not exact, scientifically accurate, and colorless," one student said of him—but his cursive flows along each line as neatly as a computer font, and he thoughtfully underlined every species name.

Before starting her graduate work with Beissinger in 2012, Iknayan studied endangered honeycreepers in Maui, where it rains 300 or 400 inches every year. She readily traded in her Wellies for a sun hat to spend several summers surveying the Mojave Desert and the Great Basin. For each of the 106 sites she resurveyed, she'd scan and study every relevant page from the field notebooks, load a tablet with satellite images, and drive her two assistants to remote locales in her Ford Explorer, nicknamed "The Machine" after the hardy Ford Model T driven on Grinnell's expeditions. Once she found the right spot, confirmed by matching what she saw to the old descriptions, they'd make camp, just like Grinnell's minions decades before.

Field tools and bird specimens from the original and modern surveys.

→ Grinnell went further than other naturalists of his day. Driven, precise, and methodical, he wrote everything down.

For years, museum scientists held weekly staff meetings in front of an unrealized treasure trove.

Lassen Peak then and now, with a Ford Model T in 1930 (left) and a Ford Explorer in 2006.

PHOTOS: COURTESY OF THE MUSEUM OF VERTEBRATE ZOOLOGY ARCHIVES, UNIVERSITY OF CALIFORNIA BERKELEY

Grinnell's surveyors were unquestionably more methodical than their peers, but the procedure Iknayan and the rest of the team followed was even more regimented, and repeated exactly the same way at every site across California. "We're trying to take data in a way that's compatible with what they were doing, but also up to our modern standards," she says. Starting at sunrise, she walked 2.5 kilometers along a GPS-plotted transect, pausing every 250 meters to count birds and record ambient sounds. Certain birds, like the Greater Roadrunner or Lazuli Bunting, gave her a thrill no matter how many times she saw them. "They don't lose their charm," she says. "But honestly when you're doing so many point counts, you start to get everything by ear." Having bird-call recordings from the Cornell Master Collection on hand helped her confirm IDs in the field.

After resurveying the Mojave and Great Basin, Iknayan brought her bird data back to Beissinger. Unlike in Grinnell's era, her labor didn't end there. Instead she joined Beissinger and her fellow students in parsing their observations to discover how birds have responded to the landscape transformations, higher temperatures, and altered precipitation patterns that have come about since Grinnell walked the Earth.

Beissinger, with his lean frame, balding head, and direct prose, could pass for a long-lost relative of Grinnell's. And like Grinnell, who eschewed a traditional academic route, he also worked field jobs between degrees, sampling birds throughout the Western Hemisphere. But whereas Grinnell spent weeks on end in the field, Beissinger has rarely visited his counterpart's storied sites during the past decade.

While his students retraced Grinnell's steps outside, Beissinger has been busy indoors organizing the effort and figuring out how to integrate the old records with the new. He's built complex mathematical models capable of analyzing datasets that are comparable in important ways—general survey methods and birds tallied—but whose compilers differed substantially in effort and skill. These same types of models are now used to analyze data gathered by community-science volunteers, whose contributions also vary widely. Beissinger suspects Grinnell would have enjoyed this modern endeavor: "He'd have been hell on wheels with a computer because he was such a workaholic."

Once Beissinger fine-tuned the models, he began investigating each California region, revealing distinct stories of how birds in specific areas have responded to a century of change. In Los Angeles, where Grinnell predicted development would doom birds, avian numbers and diversity have indeed plummeted. Nearby Central Valley birdlife has also transformed since Grinnell's time. Open-country specialists like Western Meadowlarks sharply declined after the region's wetlands and grasslands were razed, while generalists like Brown-headed Cowbirds moved in.

The results of the desert surveys, meanwhile, challenge the widely held assumption that birds will be able to move to adjust to climate change. Iknayan initially hypothesized that birds would leave areas that have become too hot and dry, like the Sonoran or Mojave, and move into cooler, wetter places nearby, like the Great Basin. She discovered that the Mojave sites have indeed lost nearly half their bird diversity. But she was surprised to find that most of those lost birds didn't relocate. Only two—Gray Vireo and Northern Rough-winged Swallow—shifted north into the adjacent desert. What's more, hot-desert specialists in the Sonoran, like Phainopepla and Verdin, also

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failed to move; only the Common Raven's presence has increased. "That struck me," says Brooke Bateman, senior climate scientist at Audubon, who wasn't involved with the project. "There's a lot of predictions for shifting of species into different biomes, and they might not be able to. It does show that it's not as easy as it seems."

The limiting factor in deserts is water, ecophysicist Eric Riddell, another Beissinger postdoctoral student, found in follow-up studies. It's gotten so dry so fast—rainfall has decreased by 20 percent at some Mojave sites since Grinnell's time—that birds are overheating. American Kestrels, for example, need 17 percent more water than they did a century ago; in other words, they need to catch 15 to 20 more grasshoppers every day to absorb enough water to keep cool. When they can't hydrate, birds die in place or fail to reproduce. To Andrea Jones, Audubon California's director of bird conservation, the findings demand a rethinking of desert conservation: Instead of our current focus on protecting already threatened species, we might better serve all desert birds by protecting springs and streams and removing water-guzzling invasive plants. "It's not just about the rare birds," Jones says. "We also have to keep the common birds common."

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The project has also called into question the notion that mountain birds will continually shift to higher elevations in search of cooler conditions. Morgan Tingley, now an ornithologist at the University of California, Los Angeles, resurveyed Grinnell's 82 Sierra Nevada sites as a graduate student and found that 48 of 53 bird species adjusted their ranges—but not necessarily upslope. Many birds went downslope, following rainfall instead of temperature. Others altered their

Tags affixed to Vermilion Flycatchers and thousands of other specimens were critical for identifying Grinnell's sites.

breeding time rather than location, nesting a week earlier to compensate for warming of 1 degree Celsius. Notably, individuals from the same species responded differently in different places. The findings suggest that safeguarding mountaintops alone will not be sufficient to help birds persist. "We need to be preserving the lower slopes of mountains," Tingley says, areas increasingly populated with new homes. "If birds can't get there because the area has been developed, you're going to lose a lot of biodiversity."

Now that the project has looked at each region separately, Beissinger will pool the data for a statewide analysis. Doing so will encapsulate each species' overall response, capturing its changing presence in multiple habitats over time. It could also help pinpoint reasons for population declines and reveal unique sensitivities to anthropogenic change. "When we put the pieces together," says Beissinger, "I think it will be fascinating."

Whatever they find, it won't be the end of Grinnell's legacy. "Someone undoubtedly will be doing this again in less than a century, maybe in 25 or 30 years, when climate change has really kicked in," Beissinger says. "They'll be able to get even better measures of change than we were."

Those future students will fan out, camping in deserts likely hotter and drier than today's and clambering up the Sierra Nevada's less snowy slopes. As they hike the Lagunitas Creek trail, they'll pause to survey birds at the same intervals, listening to hear if Warbling Vireos still persist, and perhaps documenting an as-yet-unknown avian threat. Back at the museum, they'll use machine-learning algorithms currently being written to extract bird counts from audio they, too, recorded in the field.

As they peer back through time to understand their present, their even-larger dataset—with three sets of observations per site instead of two—will cut through the noise better than Beissinger's, giving new insight. Then they'll shelve their data, just like their predecessors, and know they left behind an invaluable record for the next student of the future. A

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