Mojave National Preserve
National Park Service
U.S. Department of the Interior
Natural Reserve System
UNIVERSITY OF CALIFORNIA
Sweeney Granite Mountains Desert Research Center

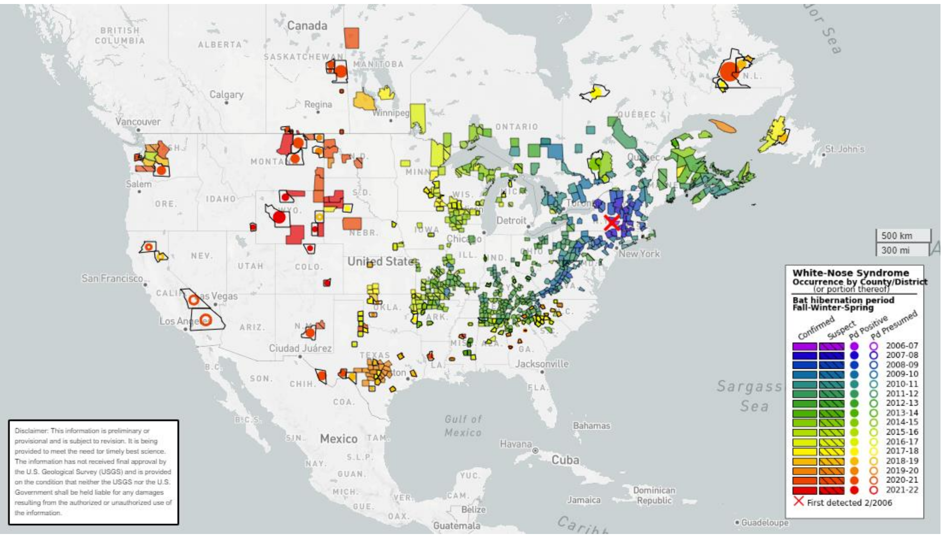
Science Newsletter

Implementing a Bat Monitoring Plan Across National Park Units within the Mojave Desert Network

Allen Calvert[1]

Over the last five years, the National Park Service's (NPS) Mojave Desert Inventory and Monitoring Network (MOJN) has been leading the charge to develop a long-term monitoring plan for bats within the network thanks to additional funding the NPS has provided through a competitive internal funding source for tackling emerging wildlife diseases. Bats face several threats including habitat loss and degradation, large scale wind energy development, and the disease known as White-Nose Syndrome (WNS). White-Nose Syndrome is caused by a previously undescribed fungus now known as *Pseudogymnoascus destructans* (Pd).

Figure 1. A bat with fungus growing on its nose. NPS photo/von Linden.



Disclaimer: This information is preliminary or provisional and is subject to revision. It is being provided to meet the need for timely best science. The information has not received final approval by the U.S. Geological Survey (USGS) and is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

Figure 2. A map showing the spread of Pd and WNS across North America from 2006-2022. www.whitenosesyndrome.org

Pd grows on the nose and wings of some species of bats while they hibernate which causes them to arouse from hibernation more frequently than normal (Fig. 1). This frequent waking depletes their fat reserves and can cause bats to starve to death before spring arrives (*1*). The fungus also grows into their skin tissue, especially on their wings, and can cause significant damage (*2*). It was first discovered in upstate New York in 2006 and has been spreading across the continent ever since, primarily from bat to bat as they leave hibernation sites and seek out their summer homes, mixing with bats from other hibernation sites (Fig. 2). It was later discovered to occur in caves across Europe with little to no impact on bat populations there (*3*). It is believed that a person unknowingly spread the fungus to North America, likely from a spore stuck to soil or other substrate on the individual's shoes or clothing (*4*). The presence of the fungus does not always mean the disease occurs in an area, but surveillance monitoring has often shown that the

In this Issue:

---

[1] National Park Service, Boulder City, Nevada.

presence of the fungus is first detected without signs of the disease, with detection of the disease usually only a year or two behind the detection of the fungus.

The disease first showed up in the western United States in Washington state in 2016. This was a large jump from Midwestern states that had been the furthest west the disease or the fungus had been previously detected. This slightly preceded our initial pilot year of bat monitoring within the Mojave Desert. The plan has been implemented in six NPS units including: Death Valley National Park (DEVA), Mojave National Preserve (MOJA), Joshua Tree National Park (JOTR), Lake Mead National Recreation Area (LAKE), Great Basin National Park (GRBA), and Grand Canyon-Parashant National Monument (PARA) (Fig. 3). Our monitoring plan includes three survey methods: acoustic surveys, Pd surveillance, and bat blitzes.

Acoustic surveys use bat detectors that record and log acoustic bat echolocation calls as bats fly near the microphone. It should be noted that not all bats are detected equally as some species have louder calls that can be detected from farther away. Others have very quiet calls that can only be detected when they fly within just a few feet from the microphone. We cannot determine how many bats are being detected but we can get an idea of activity level of each species. The detectors are placed out onto the landscape for several consecutive days (4-7 nights) to maximize the chance of detecting most species that occur in the area. After the detectors are retrieved, the bat calls are processed with special software that classifies bat calls to species (*5*). Once the calls have been classified, a bat acoustic expert manually verifies at least one call per species per night of each detector deployment. Our sampling methods are adapted from the North American Bat Monitoring Program (NABat) to fit within our sampling scale. NABat created a grid of 10 km x 10 km cells across the entire continent, then used a statistical method to prioritize each of the cells within each state or province (*6*). They recommend the top 3-5% of these cells within each state be sampled. Once a cell has been selected, they recommend up to four detectors be deployed for a minimum of four nights within a cell.

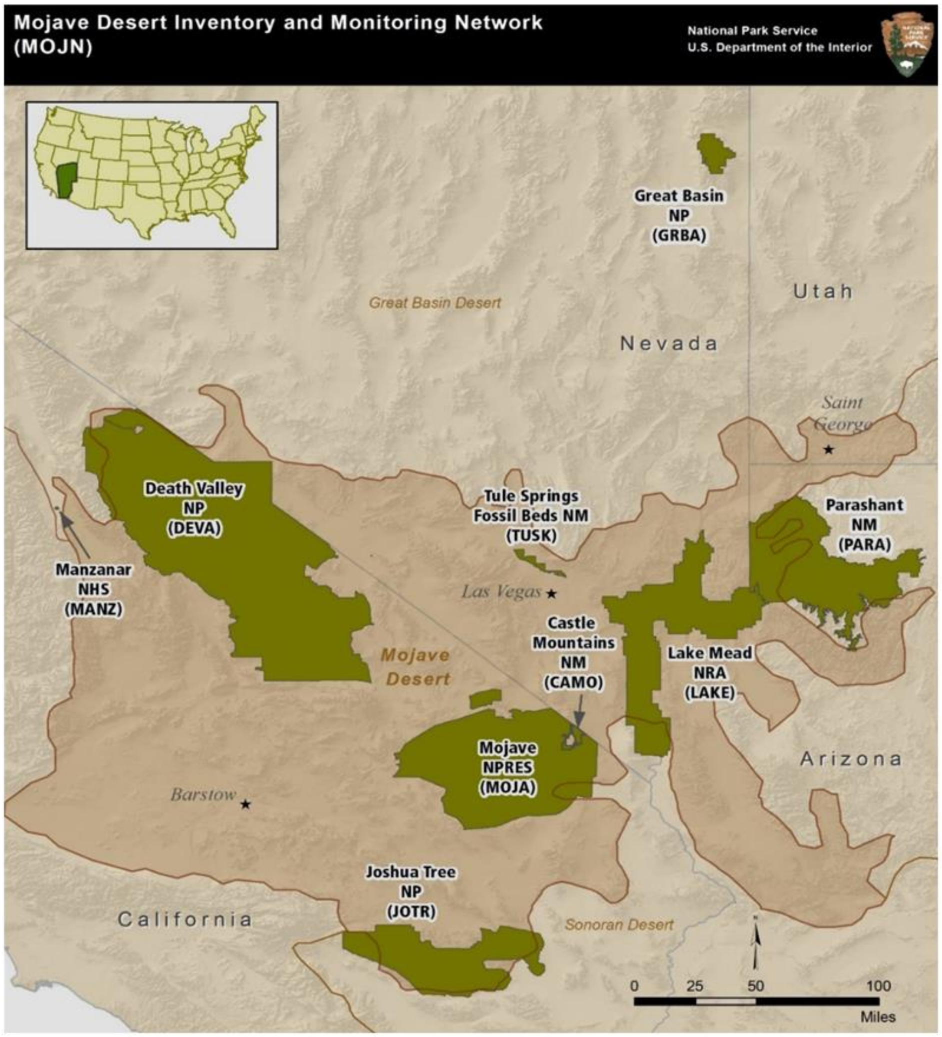


Figure 3. A map showing the Mojave Desert Network park units. The darker tan outline is the approximate boundaries of the Mojave Desert.

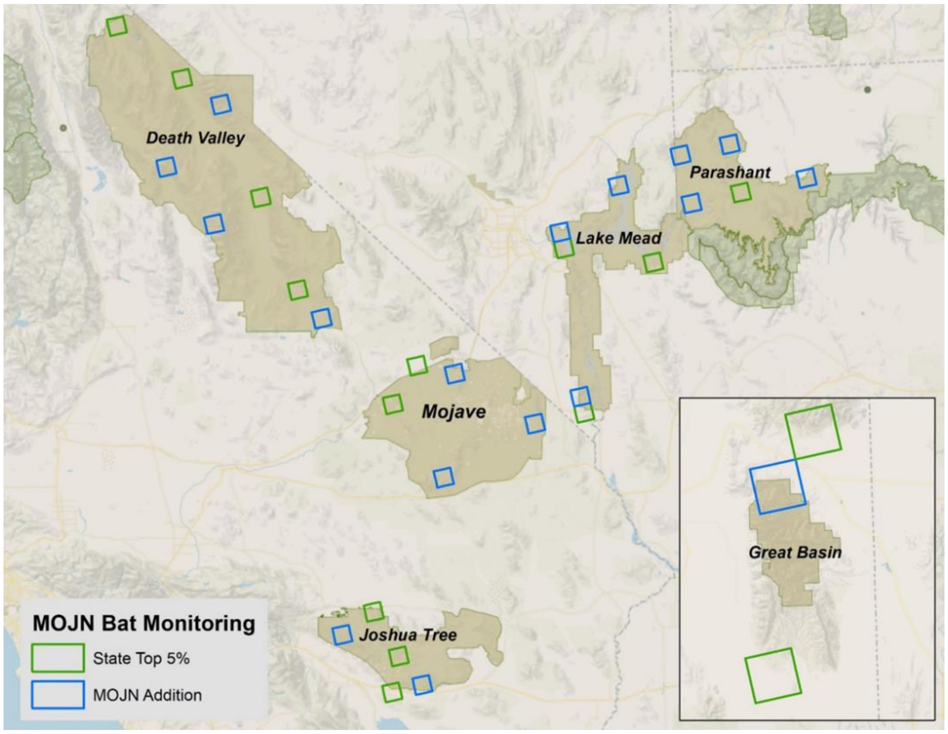


Figure 4. A map showing the NABat grid cells that were selected within or adjacent to MOJN park units.

At MOJN, we reviewed what top 3-5% priority cells fell within the boundaries of our parks. We selected all cells in the top 3% and a few from the top 5% of the sample, which still showed gaps in coverage within most parks. In order to get a more representative sample from across each park and to include an elevational gradient of sites, we nonrandomly selected additional sites using the presence of what is considered good bat habitat (Fig. 4). In the desert, this generally means anywhere there is water! So, we reviewed desert springs and other sites that either had open water that bats could access for drinking or had riparian vegetation which would bring in a higher abundance of insects for bats to forage. Once we selected potential sampling sites, we did a reconnaissance visit and selected the specific detector location. To minimize any impacts to the area, we use a 4-meter extendable pole to mount the detector microphone, which is connected to a cable extending down the pole where it connects to the weather resistant container that houses the detector (Fig. 5). The pole is painted tan or light green and is tied to branches and existing vegetation to blend in with the environment.

Figure 5. An example of a detector deployment from Mojave National Preserve. Note the pole runs along branches of a desert willow tree with the microphone attached to the top and a cable wound around the pole down to the detector that is kept in a weather resistant box hidden beneath camouflage netting at the base of the tree.

Table 1. Species detected during winter surveys at all Network parks from 2018-2021. [1]MOJA had only been sampled in one winter season. [2]The Mexican long-tongued bat detection is considered a possible detection and not confirmed due to the species only uncommonly being found in the area and never confirmed from within the park.

Species	DEVA	GRBA	JOTR	LAKE	MOJA[1]	PARA
Pallid bat	X		X	X		X
Townsend's big-eared bat				X		
Big brown bat						X
Spotted bat	X					
Western mastiff bat			X	X		X
Silver-haired bat			X	X		
Hoary bat			X			
Western yellow bat			X			
California myotis	X		X	X		X
Western small-footed bat					X	
Yuma myotis	X		X	X		
Canyon bat	X		X	X	X	X
Mexican free-tailed bat	X		X	X	X	X
Mexican long-tongued bat[2]			X			
Total Species Detected	6	0	9-10	8	3	6

Our sampling is conducted at 32 cells across six National Park units. Although the NABat protocol is focused on the summer season, we also sample our cells in the winter season due to the mild winters we have in the Mojave Desert. Many of our species are intermittently active year-round. In other areas, WNS has caused hibernating bats to leave their roosts in search of food, even in the dead of winter (*7*). If WNS has arrived in our area before we have confirmed the presence of the fungus, our winter sampling allows for the potential to identify and detect the species that may be affected. In the four years of sampling that we have analyzed so far; we have found at least 12 different species that are active in the winter. Joshua Tree appears to host the most winter active species, which isn't a huge surprise, being the southernmost park in the network (Table 1). You can also see in the table that no bats have been detected during winter surveys at GRBA. Great Basin NP is much farther north and colder than the rest of the MOJN parks. During the summer we have up to 20 species across all parks. However, most individual parks have fewer. As an example, we detected 13 species across the 10 detector locations at MOJA. The sites with open water or more diverse riparian vegetation tend to have a higher number of species (Fig. 6). In the future we hope to assess trends in species composition over time at each park and if a species seems to be in decline, we can inform park management so they may investigate potential causes. In addition, NABat will be able to use our data for large-scale regional analyses (*8*).

In addition to acoustic surveys, as bats are moving from hibernation to summer roosts during the spring (between mid-March and mid-April), we capture them to test for the presence of Pd. We primarily capture bats using finely meshed nylon nets called “mist-nets” that are stretched across open areas of water or across commuting corridors or flyways (Fig. 7). Most sites are only sampled once during the survey season. Bats are swabbed with a moist sterile polyester swab on their faces and wings and sent to a lab that looks for the genetic signature of the fungus (Fig.

8). We also inspect the wings for damage caused by excessive growth of the fungus while hibernating. In 2021, we had samples from eight out of 126 bats from across four parks (including MOJA) that tested “inconclusive” for the presence of Pd. This means that DNA from the fungus was apparently detected; however, it was in such low amounts that there’s a chance it was a false positive. We decided to be cautious with these data by considering these areas as “Pd presumed” which at a minimum allowed us to increase awareness about the spread of Pd and the potential that WNS could be or already is impacting bats in the Mojave Desert. Fortunately, all 172 samples collected in 2022 were negative. Because WNS is just beginning to affect bats in the west, we really don’t know which bat species may be affected or how badly populations could be impacted. As we are in a mild climate and many of our species have been shown to be active in the winter and be able to forage for insects, we hope that impacts will be minimal or only affect a small number of species. At the same time, we don’t know the potential ecological impacts of even one species experiencing large population declines. In other areas, bats have been found to provide ecological services for the agricultural industry, often saving them millions of dollars in costs that otherwise may go to using more pesticides (*9*).

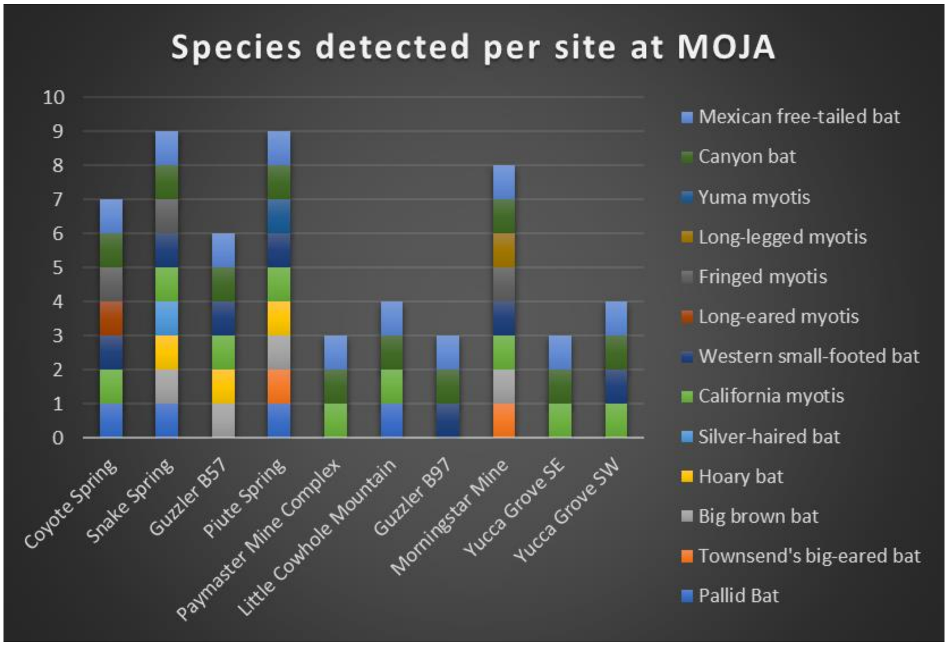


Figure 6. Total species detected per detector location during summer season sampling from 2018-2021 at MOJA. Sites are grouped by cell (i.e. Coyote Spring and Snake Spring are both from the Granite Mountains cell).

Figure 7. A mist net is set across a drainage downstream from a spring at Joshua Tree National Park. This type of set up is known as a “triple high” because it stacks three 3-meter tall nets on top of each other on poles with a pulley system that can raise or lower the nets.

Our third sampling approach used in our program is a “bat blitz,” where biologists gather in a specific area or locale to conduct several days of intensive surveys for bats. This allows for multiple sites to be sampled per night, providing a snapshot inventory of bat species in that area. In addition, it provides training opportunities for those that have less experience with different bat monitoring methods. Our first blitz was hosted by Grand Canyon-Parashant National Monument in 2017. We had over 20 people from six NPS units, as well as state agency staff gathered for three nights of surveys. We captured 162 bats of 12 species including the western mastiff bat (*Eumops perotis*), which is the largest bat in North American (Fig. 9). In addition to capture surveys, we also deployed acoustic detectors while the capture surveys were occurring which increased our total species detections to 15. Joshua Tree National Park hosted the blitz in 2018 and we had almost 30 participants with staff from seven NPS units (Fig. 10). We captured 286 bats representing 11 species and detected an additional two species with acoustic surveys. In 2019, Great Basin National Park hosted our most recent blitz. We had almost 40 participants from across nine different park units assist with this blitz. We captured 183 bats of nine species from regular mist net surveys and also assisted a larger scale project that caught over 500 Mexican free-tailed bats at a migration stopover cave as part of a long-distance migration study that had been ongoing for several years. One species of interest that was captured is the hoary bat (*Aeroestes cinereus*) which is the species most heavily impacted by wind energy development in North America (Fig. 11) (*10*). We have been planning to have a blitz at Death Valley, but the pandemic first cancelled our plans and then this year, recent flooding made access to many sites impossible, and we had to postpone again. For more information about our previous blitzes, you can download summary project briefs from our website here: https://www.nps.gov/im/mojn/bats.htm

These collaborations between parks, MOJN, and other partners are helping us build capacity for bat monitoring across the region and we have secured funding until at least 2026. This long-term monitoring plan was established to be able to track bat populations and assess potential changes in species composition over time and we hope to continue this project for many years. In addition, our Pd surveillance efforts are attempting to determine if or when the fungus arrives in our region and then to provide information to park managers to help guide decision making. The ability to use the data at a park scale while also providing our data to NABat increases the robustness of larger scale analyses that will benefit the conservation of bats across the region.

Figure 8. A moist polyester swab is being rolled along a bats face to attempt to collect samples of Pd, the fungus that causes White-Nose Syndrome.

Figure 9. A close-up view of a western mastiff bat that was captured during a bat blitz.

References

1. Lisa Warnecke, James M. Turner, Trent K. Bollinger, Jeffrey M. Lorch, Vikram Misra, Paul M. Cryan, Gudrun Wibbelt, David S. Blehert, Inoculation of bats with European Geomyces destructans supports the novel pathogen hypothesis for the origin of white-nose syndrome. *Proc. Natl. Acad. Sci. U.S.A.* **109**, 6999-7003 (2012).
2. Carol U. Meteyer, Daniel Barber, Judith N. Mandl, Pathology of euthermic bats with white nose syndrome suggests a natural manifestation of immune reconstitution inflammatory syndrome. *Virulence* **3**, 583-588 (2012).
3. Sébastien J. Puechmaille, Gudrun Wibbelt, Vanessa Korn, Hubert Fuller, Frédéric Forget, Kristin Mühldorfer, Andreas Kurth, Wieslaw Bogdanowicz, Christophe Borel, Thijs Bosch, Thomas Cherezy, Mikhail Drebet, Tamás Görföl, Anne-Jifke Haarsma, Frank Herhaus, Guénael Hallart, Matthias Hammer, Christian Jungmann, Yann Le Bris, Lauri Lutsar, Matti Masing, Bart Mulkens, Karsten Passior, Martin Starrach, Andrzej Wojtaszewski, Ulrich Zöphel, Emma C. Teeling, Pan-European distribution of white-nose syndrome fungus (Geomyces destructans) not associated with mass mortality. *PLoS ONE* **6**, e19167 (2011).
4. Stefania Leopardi, Damer Blake, Sébastien J. Puechmaille, White-Nose Syndrome fungus introduced from Europe to North America. *Current Biology* **25**, R217-R219 (2015).
5. Sonobat Bat Call Analysis Software. https://sonobat.com/.
6. Susan C. Loeb, Thomas J. Rodhouse, Laura E. Ellison, Cori L. Lausen, Jonathan D. Reichard, Kathryn M. Irvine, Thomas E. Ingersoll, Jeremy T. H. Coleman, Wayne E. Thogmartin, John R. Sauer, Charles M. Francis, Mylea L. Bayless, Thomas R. Stanley, and Douglas H. Johnson, A plan for the North American Bat Monitoring Program (NABat). *U.S. Department of Agriculture, Forest Service, Southern Sierra Research Station (2015).*
7. Greg. G. Turner, DeeAnn. M. Reeder, Jeremy T. H. Coleman, A five-year assessment of mortality and geographic spread of White-Nose Syndrome in North American bats, with a look at the future. Update of White-Nose Syndrome in bats. *Bat Research News* **52**, 13-27 (2011).
8. Brian E. Reichert, Mylea Bayless, Tina L. Cheng, Jeremy T. H. Coleman, Charles M. Francis, Winifred F. Frick, Benjamin S. Gotthold, Kathryn M. Irvine, Coru Lausen, Han Li, Susan C. Loeb, Jonathan D. Reichard, Thomas J. Rodhouse, Jordi L. Segers. Jeremy

L. Siemers, Wayne E. Thogmartin, Theodore J. Weller, NABat: A top-down, bottom-up solution to collaborative continental-scale monitoring. *Ambio* **50**, 901-913 (2021).

9. Brooke Maslo, Rebecca L. Mau, Kathleen Kerwin, Ryelan McDonough, Erin McHale, Jeffrey T. Foster, Bats provide a critical ecosystem service by consuming a large diversity of agricultural pest insects. *Agriculture, Ecosystems & Environment* **324**, 107722 (2021).
10. W. F. Frick, E. F. Baerwald, J. F. Pollock, R. M. R. Barclay, J. A. Szymanski, T. J. Weller, A. L. Russell, S. C. Loeb, R. A. Medelln, L. P. McGuire, Fatalities at wind turbines may threaten population viability of a migratory bat. *Biological Conservation* **209**, 172-177 (2017).

Figure 10. A group shot of some of the participants from the 2018 blitz at JOTR.

Figure 11. A close-up of a hoary bat captured at the Great Basin Bat Blitz.

Increased Aridity Favors Biocrust Abundance but Decreases Plant-Available Soil Nitrogen in the Mojave Desert

Mariah T. Patton[1], Timothy Ohlert[2], Jennifer Rudgers[1], Scott Collins[1]

Drylands cover ~40% of the Earth's surface and are increasing in extent (*1, 2*). Because of their large geographical scale and pulse-driven tendencies (*3*–*5*), drylands greatly influence biogeochemical cycling, contributing over 50% of the interannual variability in global carbon flux (*6*). Climate models predict that drylands will experience dryer conditions and more variable precipitation (*7*–*9*). Sensitivity to these changes in precipitation is also likely highest in areas with the least mean annual precipitation (*9, 10*), resulting in drylands being considered the most sensitive. As droughts become more frequent and precipitation becomes more variable in drylands, it is essential to understand how these vulnerable, yet influential, ecosystems will respond to future climate scenarios.

Figure 1. An example of cyanobacteria-dominated biocrusts, which are often referred to as "light biocrusts," found in open areas among shrubs on coarsely sandy to gravelly soils within the Granite Mountains Desert Research Center. Notice the darkened patches (shown with red arrows) where cyanobacteria create a matted clump or crust that connects the soil particles together.

Soil microbial communities called biological soil crusts (or biocrusts; Fig. 1) are essential to dryland ecosystem function and their presence is often used as indicators of dryland health (*11-13*). These surface microbial communities play a major role in dryland carbon storage via photosynthesis or loss of carbon by respiration and decomposition. Furthermore, biocrusts also dictate much of the nitrogen cycle through fixation from the atmosphere and loss via emissions. Models show that biocrusts are responsible for ~46% of terrestrial biological nitrogen fixation and ~ 7% of primary production globally (*14, 15*). Biocrusts also have indirect effects on soil nutrient availability by reducing erosion and weathering, capturing windborne dust particles, as well as increasing precipitation absorption in the top layer of soil (*16, 17*). Furthermore, biocrusts can also modify carbon and nitrogen cycles in ecosystems through mutualisms with plants and fungi. Some evidence shows support for a "fungal loop," where biocrusts directly exchange their nitrogen for carbon with plant root systems via fungal hyphae (*18*–*21*). In addition, biocrusts can inhibit or promote germination of certain plant species depending on biocrust type and seed traits (*22, 23*). Biocrusts also provide some protection to subsurface microbes from environmental perturbations such as warming and drought (*24*).

Known to exist in the earliest terrestrial ecosystems nearly 3 billion years ago (*25, 26*), these cyanobacteria-pioneered microbial communities are well adapted to harsh environments, though not invincible in the face of climate change (*27*). Biocrusts host a wide variety of genes that mitigate harmful effects from prolonged dry periods through desiccation and dormancy (*28*). However, prolonged periods of dormancy and brief windows of activation from shorter pulses of precipitation can deprive complex biocrusts of their stored carbon reserves. This can happen if the carbon losses were incurred during the first 20 minutes of rehydration and depends on whether photosynthesis reactivation can remain balanced by sufficient synthesis of new carbohydrates immediately after the activation window (*29, 30*). A study in the Mojave Desert showed that mossy biocrusts are already experiencing massive mortality rates with increased temperatures and aridity (*31*). As the North American deserts continue to experience shifts in climate due to anthropogenic climate change, it is increasingly important to understand the consequences of these changes on biocrusts and their ecosystem services.

[1] Department of Biology, University of New Mexico, Albuquerque, New Mexico.

[2] Department of Biology, Colorado State University, Fort Collins, Colorado.

Other than physiological tolerance, biocrust sensitivity to drought might depend on the composition of the community (*32*). For example, evidence suggests that moss-dominant and lichen-dominant biocrusts tend to be more sensitive to climate change such as warming and rainfall variability (*33–37*). Furthermore, the identity of the dominant foundational cyanobacteria can drive biocrusts' response to drought. For example, a study in the Chihuahuan Desert showed that biocrust communities dominated by a drought-tolerant cyanobacteria, *Microcoleus vaginatus*, had more resistance to drought compared to those dominated by cyanobacteria in the Choleofaciculaceae family (*38, 39*). Given that one continental survey showed that sampled sites in Mojave National Preserve (MNP) contained a greater ratio of cyanobacteria in the Choleofaciculaceae compared to the drought-tolerant *Microcoleus vaginatus* (*40*), it is possible that the biocrusts within our plots are more sensitive to drought due to the composition of cyanobacteria present.

Figure 2. An example of a drought-inducing shelter that induces a 66% reduction in rain below the canopy. Notice the white tubing laying in front of Tim Ohlert, this drained the water that was captured in the v-shaped panels across the top. In the background you can see three more of the seven total drought-inducing shelters located at the East site within the Granite Mountains Desert Research Center.

Google Landsat / Copernicus Data SIO NOAA U.S. Navy NGA GEBCO Data LDEO-Columbia NSF NOAA 600 m 34°45'55"N 115°39'08"W 1,203 m

Figure 3. Satellite image (provided by Google Earth) showing the location of the East and West sites, approximately 450 m apart, in the open creosote scrub near the southeastern boundary of the Granite Mountains Desert Research Center. Silver Peak (top left) is the second highest peak in the Granite Mountains; Mojave National Preserve surrounds the GMDRC in all directions.

For this study, we collected data to address several questions (see *41*) assessing plant, soil, and microbial response to drought-induced conditions; however, this paper will address the following question: **What are the effects of manipulated drought conditions on biocrust communities and their biogeochemical contributions within the driest North American desert, the Mojave Desert?** We hypothesized that biocrusts would be highly sensitive and would greatly decline in abundance in response to drought. Furthermore, we investigated the biogeochemical consequences of biocrust decline by quantifying plant-available nitrogen (PAN) in the soil under drought manipulation. We hypothesized that available soil nitrogen would be lower in drier conditions potentially due to lower microbial activity. To answer these questions, we established a drought manipulation experiment in 2018 at the University of California's Granite Mountains Desert Research Center (GMDRC), embedded within MNP in San Bernardino County, CA. We constructed drought-inducing structures in 2018 to impose a 66% reduction in precipitation year-round (42). These angled shelters are 150 cm tall at the high end and 60 cm tall at the short end and consist of a galvanized steel rectangular frame (585 m^2) that supports 15 V-shaped acrylic panels (Fig. 2). These panels create a shelter that blocks 66% of the rain, but not photosynthetically active radiation, from the area below it (Fig. 2). The plots under these ramada-style structures are what we consider our "droughted" plots. The experimental sites utilized for this study are part of a larger global collaboration known as Drought-Net, which has the broader goal of addressing impacts of a "1 in 100-year" drought to terrestrial ecosystems throughout the world (*43, 44*). At the GMDRC, we established two sites (East and West) approximately 450 m apart (Fig. 3). Each site contained 7 replicates of randomly assigned drought-induced plots and control plots (N= 28). Within each plot, we collected data within a 1 m^2 quadrat placed in the center of each 2.5 x 2.5 m plot that was marked for future repeat measurements (Fig. 4).

To address changes in biocrusts after four years (2019-2023) of drought treatment, we quantified biocrust chlorophyll *a* and scytonemin pigments from control and drought-induced plots. Chlorophyll *a* is often used as an abundance estimate for photosynthetic cyanobacteria (*45*). Scytonemin is an excreted sunscreen that only nitrogen-fixing cyanobacteria can produce (*46*). Thus, scytonemin pigment concentration is used as a proxy for the abundance of nitrogen fixers in the biocrust sample (*46*). Specifically, we collected 10 biocrust samples at random within each plot's quadrat. The samples were collected with a 2 ml microcentrifuge tube cap (~ 1 cm depth x 1 cm width) and aggregated by plot. Samples were placed in a dark cooler and kept dry and chilled at 4 ℃ until stored at -20 ℃ upon returning to the University of New Mexico. To process, we homogenized each sample and used a mortar and pestle to grind the sample with 90% acetone for 3 minutes and vortexed for 30 seconds (*47*). Processed samples were stored overnight for ~16 hours at 4 ℃ to induce separation of supernatant from soil. Chlorophyll *a* and scytonemin pigments were quantified by light absorbance of the extracted supernatant at wavelengths 384, 490, 663, 665, and 750 nm using a Synergy H1 Hybrid plate reader (Biotek, Winooski, Vermont, USA), followed by calculations as provided by Garcia-Pichel and Castenholz (*46*). In year three of drought treatment (2021), we deployed Plant Root Simulator (PRS®) probes (Western Ag Innovations, Saskatchewan, Canada) in the southeast corner of each semi-permanent quadrat to compare plant nutrient availability in the form of total PAN (a combined value of nitrate and ammonium concentrations). PRS® probes consist of resin strips that are either positively or negatively charged to absorb nutrients in the soil (Fig. 5). Probes were left buried in situ from January 19th to May 10th, 2021 (Fig. 6) because this four-month period seemed to be a good candidate for high nutrient exchange due to historically higher water availability from winter precipitation combined with slightly warmer temperatures, thus providing conditions for potentially greater plant growth.

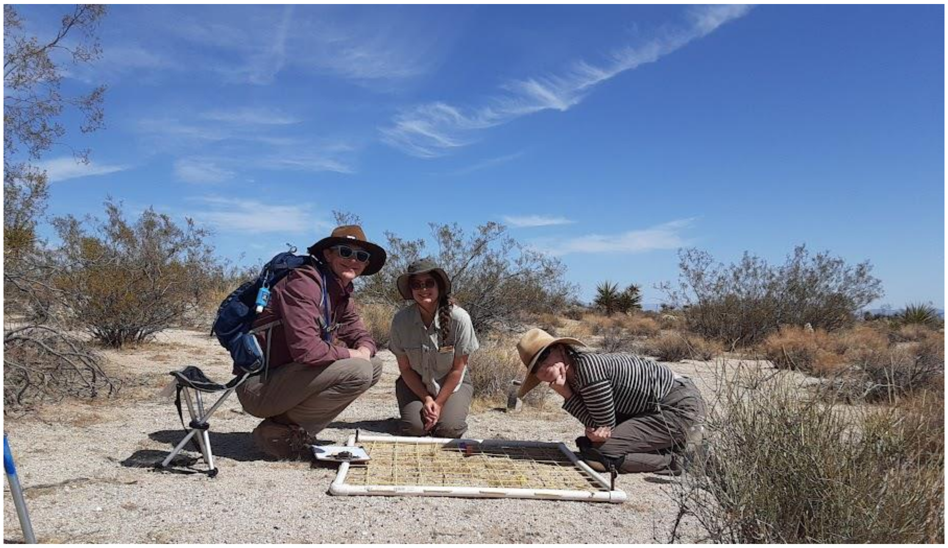


Figure 4. Data collection for this study occurred with a 1 m^2 quadrat marked with rebar for repeat sampling over several years. These quadrats were placed centrally under the rainout shelters, as well as in a control plot without a shelter (shown here). Tim Ohlert, Liz Fain, and Brooke Wainright (left to right) are shown here identifying plant species at the West site.

Before analyzing chlorophyll *a* and scytonemin data, we compared several linear mixed-effects models, each included some variation of drought treatment, sample site, and collection date as fixed variables and plot as a random effect to account for repeated measures. Using the lowest AICc score (Akaike Information Criterion for small sample sizes), we found that the best model that explained chlorophyll *a* data was a linear mixed-effects model that included treatment, site, and collection date as interactive fixed effects and plot as a random effect. The best model that explained scytonemin data was a linear mixed-effects model that included treatment as a fixed effect and plot as a random effect. We log-transformed the chlorophyll *a* data to achieve normality of the model's residuals in order to meet assumptions before applying an ANOVA. However, because we were not able to meet ANOVA assumptions after transforming scytonemin data, we used Kruskal-Wallis non-parametric tests to analyze the effect of treatment on scytonemin abundance per plot. If results were significant, we completed post-hoc, Dunn tests with Bonferroni adjustments to further analyze differences between groups. Because PRS® probe data represent one sampling period, we used a linear model to analyze PAN which included treatment and site as interacting fixed effects.

Figure 5. PRS® probe after ~4 months of deployment, with a plant root embedded in the ion exchange material. Probes were shipped to Western Ag Innovations where positive and negative ions (soil nutrients) were stripped from each resin membrane using a strong acid or base bath. Extracts were then analyzed for concentrations of 11 different soil nutrients: Mg, P, K, NH4, NO3, Cd, Ca, Al, Mn, Pb, and Fe.

Chlorophyll *a* concentration (Fig. 7) decreased under imposed drought treatments only in the last year of our sampling (P= 0.94; Treatment x Date: P= 0.007). In 2023, sheltered plots contained around half of photoautotrophic abundance compared to ambient plots (-53%). Both sheltered and ambient plots contained the least amount of chlorophyll *a* concentration in 2023 (P< 0.0001).

In contrast, imposed drought treatment plots contained higher scytonemin concentrations compared to ambient plots (P= 0.001). This trend was mostly driven by differences between sheltered and ambient plots at the West site where scytonemin increased by 6%, compared to <1% at the East site (Treatment|Site: P< 0.05; Fig. 8) and interacted with collection date (Treatment x Date: P= 0.03). Scytonemin concentrations did not vary by site (P=0.99) or date alone (P=0.13).

PAN (Fig. 9) decreased (P< 0.001) by similar amounts under drought at both sites: 42% at the West and 39% at the East sites. Surprisingly, the West and East sites had similar levels of PAN for drought-induced and control plots, though biocrust scytonemin concentrations varied. While scytonemin is a useful proxy for understanding nitrogen-fixing cyanobacteria abundance, this pigment is not produced in other prokaryotes and thus does not provide insight on the abundance of potentially nitrogen-fixing heterotrophs (including Archaea) which could potentially be more active in control plots and thus offset a possible decrease in cyanobacterial activity there.

Figure 6. PRS® probes, shown in orange and purple, were deployed within each quadrat.

While we originally predicted lower biocrust abundance in drought-induced plots compared to control plots, our results reveal varying trends for chlorophyll *a* and scytonemin pigments. Specifically, we see generally higher amounts of scytonemin concentrations in drought-induced plots, but lower chlorophyll *a* only in 2023. These results could be due to a release of competition with plants for light (*48*), especially because biocrusts were increasing production of the sunscreen pigment, scytonemin (*49*). One study conducted in a desert of New Mexico showed that manual removal of plants can initially benefit biocrust biomass, however, it was suggested that this response could vary depending on plant type and biocrust-plant interactions (*50*). For example, in a different study conducted in a shrub-steppe ecosystem of the Columbia Basin, the invasive grass *Bromus tectorum* (cheat grass) had a negative impact on biocrust cover while no relationship was found with the native grass cover (*51*). Vascular vegetation data so far show a net decline in plot-level biomass at our two sites with drought treatment (*52*). Even so, all plots had a general increase in the invasive grass *Schismus barbatus* (common Mediterranean grass) (*41, 52*).

We also predicted lower PAN in drought-induced soils compared to control soils, potentially due to lower biocrust activity. While biocrust activity, as mentioned, increased under drought-induced plots compared to control, PAN in soils, on the other hand, declined in drought-induced plots compared to control plots. While biocrust samples were collected from the surface soil layer, PRS® probes measure soil nutrients down to a depth of ~10 cm. Perhaps, morning dew could provide nitrogen-fixing cyanobacteria with enough water stores for maintenance, but not enough for more expensive biological processes such as nitrogen fixation. Thus, available nitrogen could still deplete from the soil while biocrust activity remains higher in drought-induced plots.

As we continue monitoring vascular plant and soil responses in this experiment, we will observe whether control and drought-induced plots diverge even more or even shift direction of response with increased intensity of drought. One limitation to manipulated drought experiments in deserts, is that with little ambient moisture over the study period (Fig. 10), or without deliberate water additions, there may be only minimal differences in soil moisture between control and treatment plots. In other words, with little ambient precipitation, the drought treatment that we are imposing may not be as extreme as necessary to elicit a response compared to control sites. Due to logistical constraints at these sites, we were unable to provide artificial water additions to our plots. However, our results so far show that biocrusts might have some resistance to drought with interesting relationships to interactions with plants. Perhaps, a droughted Mojave landscape will favor higher biocrust cover as vegetative plant communities can no longer cope.

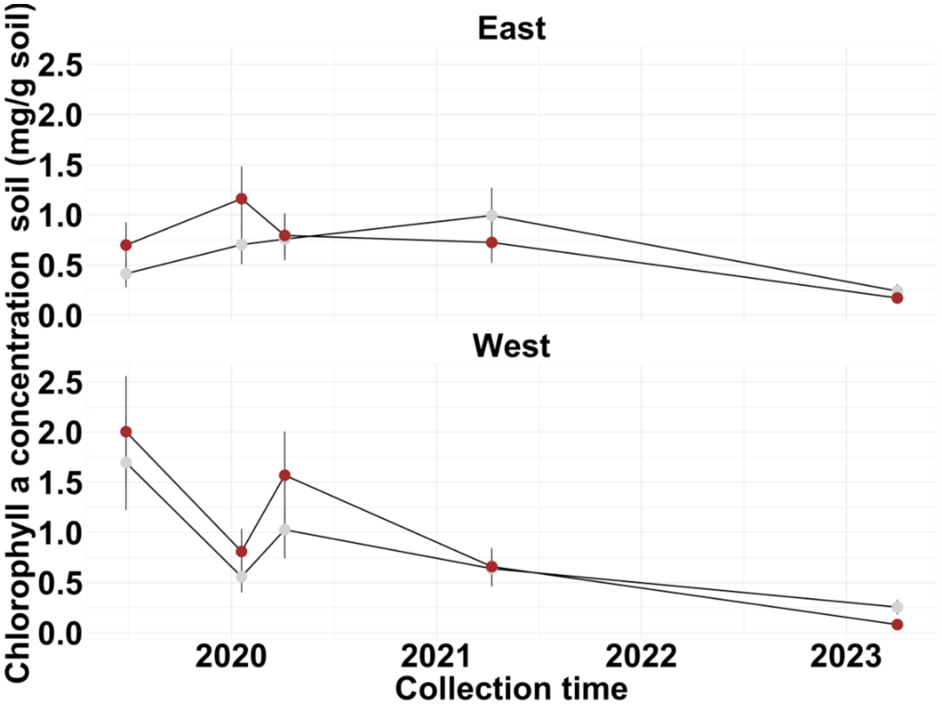


Figure 7. Chlorophyll *a* results between sites, treatments, and collection date. Grey= control, brown= drought.

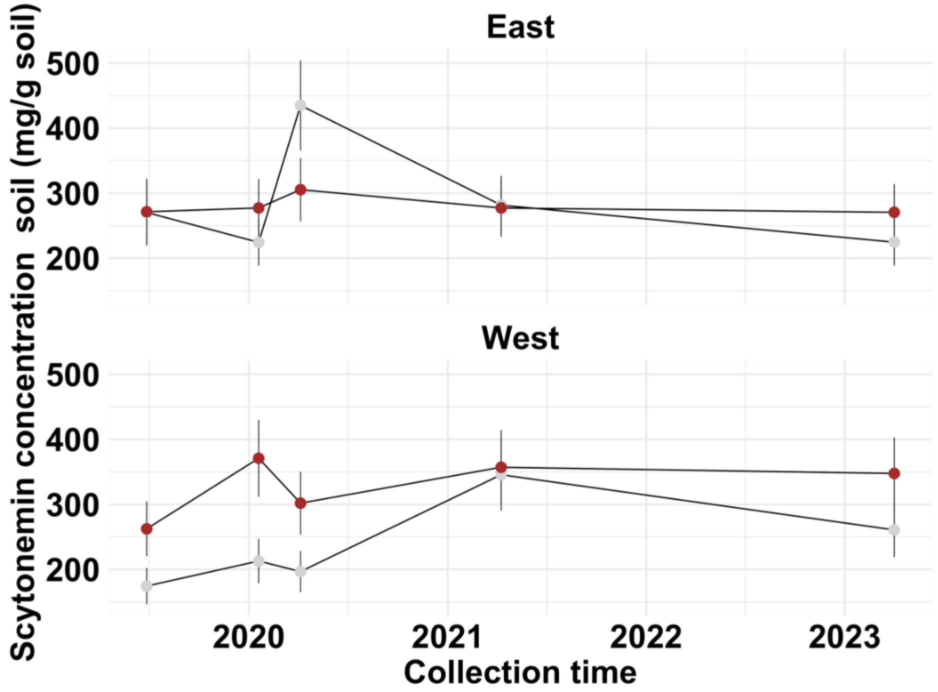


Figure 8. Scytonemin results between sites, treatments, and collection date. Grey= control, brown= drought.

References

1. J. Huang, Y. Li, C. Fu, F. Chen, Q. Fu, A. Dai, M. Shinoda, Z. Ma, W. Guo, Z. Li, L. Zhang, Y. Liu, H. Yu, Y. He, Y. Xie, X. Guan, M. Ji, L. Lin, S. Wang, H. Yan, G. Wang, Dryland climate change: Recent progress and challenges. *Reviews of Geophysics* **55**, 719–778 (2017).
2. J. F. Reynolds, D. M. S. Smith, E. F. Lambin, B. L. Turner, M. Mortimore, S. P. J. Batterbury, T. E. Downing, H. Dowlatabadi, R. J. Fernandez, J. E. Herrick, E. Huber-Sannwald, H. Jiang, R. Leemans, T. Lynam, F. T. Maestre, M. Ayarza, B. Walker, Global Desertification: Building a Science for Dryland Development. *Science* **316**, 847–851 (2007).
3. I. Noy-Meir, Structure and function of desert ecosystems. *Israel Journal of Botany* **28**, 1–19 (1979).
4. M. E. Loik, D. D. Breshears, W. K. Lauenroth, J. Belnap, A multi-scale perspective of water pulses in dryland ecosystems: climatology and ecohydrology of the western USA. *Oecologia* **141**, 269–281 (2004).
5. M. L. Barnes, M. M. Farella, R. L. Scott, D. J. P. Moore, G. E. Ponce-Campos, J. A. Biederman, N. MacBean, M. E. Litvak, D. D. Breshears, Improved dryland carbon flux predictions with explicit consideration of water-carbon coupling. *Communications Earth and Environment* **2**, 1–9 (2021)
6. A. Ahlstrom, M. R. Raupach, G. Schurgers, B. Smith, A. Arneth, M. Jung, M. Reichstein, J. G. Canadell, P. Friedlingstein, A. K. Jain, E. Kato, B. Poulter, S. Sitch, B. D. Stocker, N. Viovy, Y. P. Wang, A. Wiltshire, S. Zaehle, N. Zeng, The dominant role of semi-arid ecosystems in the trend and variability of the land CO2 sink. *Science* **348**, 895–899 (2015).
7. M. D. Petrie, S. L. Collins, D. S. Gutzler, D. M. Moore, Regional trends and local variability in monsoon precipitation in the northern Chihuahuan Desert, USA. *Journal of Arid Environments* **103**, 63–70 (2014).
8. J. A. Rudgers, Y. A. Chung, G. E. Maurer, D. I. Moore, E. H. Muldavin, M. E. Litvak, S. L. Collins, Climate sensitivity functions and net primary production: A framework for incorporating climate mean and variability. *Ecology* **99**, 576–582 (2018).
9. G. E. Maurer, A. J. Hallmark, R. F. Brown, O. E. Sala, S. L. Collins, Sensitivity of primary production to precipitation across the United States. *Ecology Letters* **23**, 527–536 (2020).
10. T. E. Huxman, M. D. Smith, P. A. Fay, A. K.

Knapp, M. R. Shaw, M. E. Loik, S. D. Smith, D. T. Tissue, J. C. Zak, J. F. Weltzin, W. T. Pockman, O. E. Sala, B. M. Haddad, J. Harte, G. W. Koch, S. Schwinning, E. E. Small, D. G. Williams, Convergence across biomes to a common rain-use efficiency. *Nature* **429**, 651–654 (2004).

11. J. Belnap, B. Büdel, O. L. Lange, Biological soil crusts: characteristics and distribution. Pp. 3-30 in J. Belnap, O. L. Lange (eds.) *Biological soil crusts: structure, function, and management*, Springer-Verlag Berlin Heidelberg (2001).
12. J. Belnap, B. Weber, B. Büdel, Biological Soil Crusts as an Organizing Principle in Drylands. Pp. 3-13 in B. Weber, B. Büdel, J. Belnap (eds.) *Biological Soil Crusts: An Organizing Principle in Drylands*, Springer Cham (2016).
13. M. L. Phillips, B. E. McNellis, A. Howell, C. M. Lauria, J. Belnap, S. C. Reed, Biocrusts mediate a new mechanism for land degradation under a changing climate. *Nature Climate Change* **12**, 71–76 (2022).
14. W. Elbert, B. Weber, S. Burrows, J. Steinkamp, B. Büdel, M. O. Andreae, U. Pöschl, Contribution of cryptogamic covers to the global cycles of carbon and nitrogen. *Nature Geoscience* **5**, 459–462 (2012).
15. B. Weber, D. Wu, A. Tamm, N. Ruckteschler, E. Rodríguez-Caballero, J. Steinkamp, H. Meusel, W. Elbert, T. Behrendt, M. Sörgel, Y. Cheng, P. J. Crutzen, H. Su, U. Pöschl, Biological soil crusts accelerate the nitrogen cycle through large NO and HONO emissions in drylands. *Proceedings of the National Academy of Sciences* **112**, 15384–15389 (2015).
16. S. Chamizo, E. Rodríguez-Caballero, J. R. Román, Y. Cantón, Effects of biocrust on soil erosion and organic carbon losses under natural rainfall. *CATENA* **148**, 117–125 (2017).
17. N. N. Barger, J. E. Herrick, J. Van Zee, J. Belnap, Impacts of biological soil crust disturbance and composition on C and N loss from water erosion. *Biogeochemistry* **77**, 247–263 (2006).
18. S. L. Collins, R. L. Sinsabaugh, C. Crenshaw, L. Green, A. Porras-Alfaro, M. Stursova, L. H. Zeglin, Pulse dynamics and microbial processes in aridland ecosystems. *Journal of Ecology* **96**, 413–420 (2008).
19. J. A. Rudgers, E. Dettweiler-Robinson, J. Belnap, L. E. Green, R. L. Sinsabaugh, K. E. Young, C. E. Cort, A. Darrouzet-Nardi, Are fungal networks key to dryland primary production? *American Journal of Botany* **105**, 1783–1787 (2018).
20. L. E. Green, A. Porras-Alfaro, R. L. Sinsabaugh, Translocation of nitrogen and carbon integrates biotic crust and grass production in desert grassland. *Journal of Ecology* **96**, 1076–1085 (2008).
21. Z. T. Aanderud, T. B. Smart, N. Wu, A. S. Taylor, Y. Zhang, J. Belnap, Fungal loop transfer of nitrogen depends on biocrust constituents and nitrogen form. *Biogeosciences* **1**, 3831–3840 (2018).
22. Y. Zhang, A. L. Aradottir, M. Serpe, B. Boeken, Interactions of Biological Soil Crusts with Vascular Plants. Pp. 385-406 in B. Weber, B. Büdel, J. Belnap (eds.) *Biological Soil Crusts: An Organizing Principle in Drylands*, Springer Cham (2016).
23. C. A. Havrilla, V. B. Chaudhary, S. Ferrenberg, A. J. Antoninka, J. Belnap, M. A. Bowker, D. J. Eldridge, A. M. Faist, E. Huber-Sannwald, A. D. Leslie, E. Rodriguez-Caballero, Y. Zhang, N. N. Barger, Towards a predictive framework for biocrust mediation of plant performance: A meta-analysis. *Journal of Ecology* **107**, 2789–2807 (2019).
24. E. Moreno-Jiménez, R. Ochoa-Hueso, C. Plaza, S. Aceña-Heras, M. Flagmeier, F. Z. Elouali, V. Ochoa, B. Gozalo, R. Lázaro, F. T. Maestre, Biocrusts buffer against the accumulation of soil metallic nutrients induced by warming and rainfall reduction. *Communications Biology* **3**, 1–8 (2020).
25. N. Noffke, D. Christian, D. Wacey, R. M. Hazen, Microbially induced sedimentary structures recording an ancient ecosystem in the ca. 3.48 billion-year-old Dresser Formation, Pilbara, Western Australia. *Astrobiology* **13**, 1103–1124 (2013).
26. Y. Watanabe, J. E. Martini, H. Ohmoto, Geochemical evidence for terrestrial ecosystems 2.6 billion years ago. *Nature* **408**, 574–578 (2000).
27. S. C. Reed, F. T. Maestre, R. Ochoa-Hueso, C.

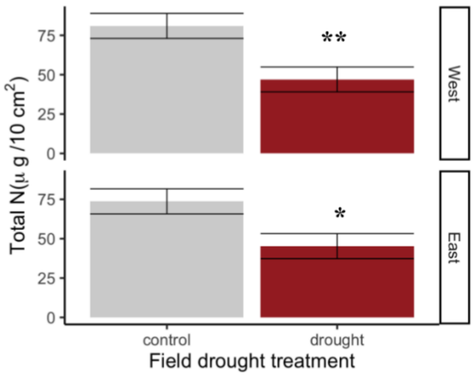


Figure 9. Combined soil ammonium and nitrate (plant-available nitrogen) concentrations collected in situ between 19 January and May 2021. Grey= control, brown= drought. Asterisks indicate significant (* indicates P< 0.05; ** indicates P< 0.01) pairwise comparison difference between control and drought at a particular time period.

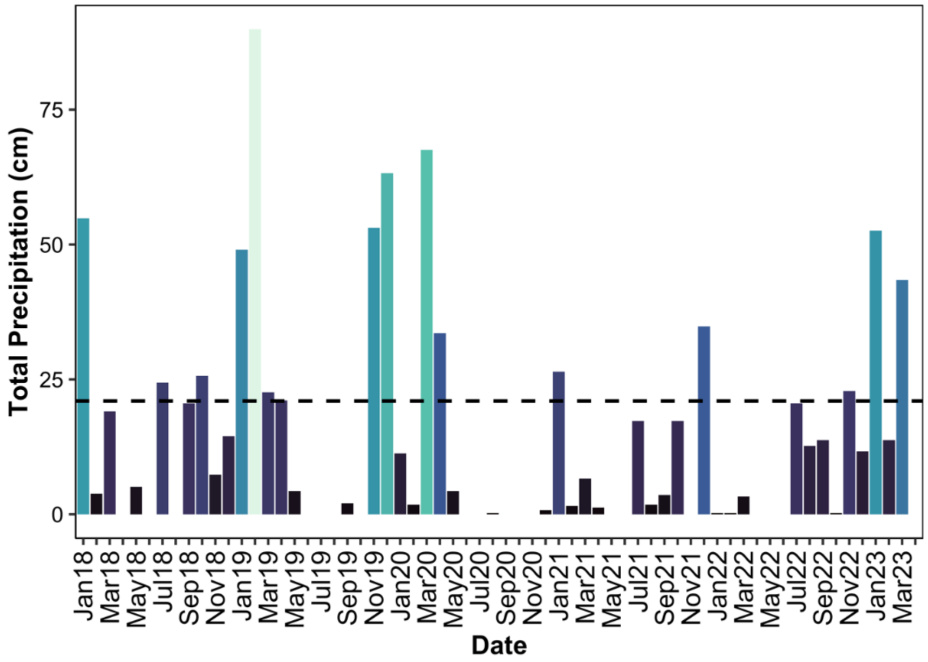


Figure 10. Monthly total precipitation recorded by the meteorological station located at the GMDRC. Time period shown covers the duration of this study. Average precipitation for this location is 20.29 cm (based on 37 years of data); totals for precipitation years represented in this study: 2018-19, 27.9 cm; 2019-20, 23.7 cm; 2020-21, 3.7 cm; 2021-22, 7.8 cm; 2022-23, 19.6 cm (precip. year = July 1 – June 30).

R. Kuske, A. Darrouzet-Nardi, M. Oliver, B. Darby, L. G. Sancho, R. L. Sinsabaugh, J. Belnap, Biocrusts in the Context of Global Change. Pp. 451-476 in B. Weber, B. Büdel, J. Belnap (eds.) *Biological Soil Crusts: An Organizing Principle in Drylands*, Springer Cham (2016).

28. B. Gao, X. Li, D. Zhang, Y. Liang, H. Yang, M. Chen, Y. Zhang, J. Zhang, A. J. Wood, Desiccation tolerance in bryophytes: The dehydration and rehydration transcriptomes in the desiccation-tolerant bryophyte *Bryum argenteum*. *Scientific Reports* **7**, 7571 (2017).
29. K. K. Coe, J. Belnap, J. P. Sparks, Precipitation-driven carbon balance controls survivorship of desert biocrust mosses. *Ecology* **93**, 1626–1636 (2012).
30. K. K. Coe, J. P. Sparks, J. Belnap, Physiological Ecology of Dryland Biocrust Mosses. Pp. 291-308 in D. T. Hanson, S. K. Rice (eds.) *Photosynthesis in Bryophytes and Early Land Plants*, Springer Netherlands (2014).
31. D. H. Barker, L. R. Stark, J. F. Zimpfer, N. D. Mcletchie, S. D. Smith, Evidence of drought-induced stress on biotic crust moss in the Mojave Desert. Plant, *Cell and Environment* **28**, 939–947 (2005).
32. M. A. Bowker, M. C. Rengifo-Faiffer, A. J. Antoninka, H. S. Grover, K. K. Coe, K. Fisher, B. D. Mishler, M. Oliver, L. R. Stark, Community composition influences ecosystem resistance and production more than species richness or intraspecific diversity. *Oikos* **130**, 1399–1410 (2021).
33. S. Ferrenberg, S. C. Reed, J. Belnap, Climate change and physical disturbance cause similar community shifts in biological soil crusts. *Proceedings of the National Academy of Sciences* **112**, 12116–12121 (2015).
34. F. T. Maestre, C. Escolar, M. Ladron De Guevara, J. L. Quero, R. Lazaro, M. Delgado-Baquerizo, V. Ochoa, M. Berdugo, B. Gozalo, A. Gallardo, Changes in biocrust cover drive carbon cycle responses to climate change in drylands. *Global Change Biology* **19**, 3835–3847 (2013).
35. C. Escolar, I. Martinez, M. A. Bowker, F. T. Maestre, Warming reduces the growth and diversity of biological soil crusts in a semi-arid environment: implications for ecosystem structure and functioning. Philosophical *Transactions of the Royal Society B: Biological Sciences* **367**, 3087–3099 (2012).
36. K. E. Young, S. C. Reed, Spectrally monitoring the response of the biocrust moss *Syntrichia caninervis* to altered precipitation regimes. *Scientific Reports* **7**, 1–10 (2017).
37. R. Finger-Higgens, M. C. Duniway, S. Fick, E. L. Geiger, D. L. Hoover, A. A. Pfennigwerth, M. W. Van Scoyoc, J. Belnap, Decline in biological soil crust N-fixing lichens linked to increasing summertime temperatures. *Proceedings of the National Academy of Sciences* **119**, e2120975119 (2022).
38. V. M. C. Fernandes, N. M. Machado de Lima, D. Roush, J. Rudgers, S. L. Collins, F. Garcia-Pichel, Exposure to predicted precipitation patterns decreases population size and alters community structure of cyanobacteria in biological soil crusts from the Chihuahuan Desert. *Environmental Microbiology* **20**, 259–269 (2018).
39. V. Moreira C. Fernandes, A. Giraldo-Silva, D. Roush, F. Garcia-Pichel, Coleofasciculaceae, a Monophyletic Home for the *Microcoleus steenstrupii* Complex and Other Desiccation-tolerant Filamentous Cyanobacteria. *Journal of Phycology* **57**, 1563–1579 (2021).
40. F. Garcia-Pichel, V. Loza, Y. Marusenko, P. Mateo, R. M. Potrafka, Temperature Drives the Continental-Scale Distribution of Key Microbes in Topsoil Communities. *Science* **340**, 1574–1577 (2013).
41. T. Ohlert, A. Hallmark, G. Hamilton, J. Mclaughlin, M. Patton, S. Collins, The Impact of *Schismus* on Biodiversity in Mojave Desert Winter Annual Communities. *Mojave National Preserve Science Newsletter*, 12-15 (2021).
42. D. L. Hoover, K. R. Wilcox, K. E. Young. Experimental droughts with rainout shelters: a methodological review. *Ecosphere* **9**, e02088 (2018).
43. M. D. Smith, K. Wilcox, O. Sala, R. Phillips, Y. Luo, A. Knapp, N. P. Lemoine, Drought-Net: A global network merging observations, experiments, and modeling to forecast terrestrial ecosystem sensitivity to drought. Pp. B11J-06 in *AGU Fall Meeting Abstracts* (2016).
44. N. P. Lemoine, J. Sheffield, J. S. Dukes, A. K. Knapp, M. D. Smith, Terrestrial Precipitation Analysis (TPA): A resource for characterizing long-term precipitation regimes and extremes. *Methods in Ecology and Evolution* **7**, 1396–1401 (2016).
45. E. Couradeau, U. Karaoz, H. C. Lim, U. N. da Rocha, T. Northen, E. Brodie, F. Garcia-Pichel, Bacteria increase arid-land soil surface temperature through the production of sunscreens. *Nature Communications* **7**, 10373 (2016).
46. F. Garcia-Pichel, R. W. Castenholz, Characterization and Biological Implications of Scytonemin, a Cyanobacterial Sheath Pigment. *Journal of Phycology* **27**, 395–409 (1991).
47. A. Giraldo-Silva, C. Nelson, N. N. Barger, F. Garcia-Pichel, Nursing biocrusts: isolation, cultivation, and fitness test of indigenous cyanobacteria. *Restoration Ecology* **27**, 793–803 (2019).
48. K. E. O’Bryan, S. M. Prober, I. D. Lunt, D. J. Eldridge, Frequent fire promotes diversity and cover of biological soil crusts in a derived temperate grassland. *Oecologia* **159**, 827–838 (2009).
49. C.S Cockell, J. Knowland, Ultraviolet radiation screening compounds. *Biological Reviews* 74.3, 311-345 (1999).
50. E. Dettweiler-Robinson, R. L. Sinsabaugh, J. A. Rudgers, Biocrusts benefit from plant removal. *American Journal of Botany* **105**, 1–9 (2018).
51. E. Dettweiler-Robinson, J. D. Bakker, J. B. Grace, Controls of biological soil crust cover and composition shift with succession in sagebrush shrub-steppe. *Journal of Arid Environments* **94**, 96–104 (2013).
52. Personal communication, Timothy Ohlert, DroughtNet postdoctoral candidate. (3 February 2023).

Research Highlights from the Sweeney Granite Mountains Desert Research Center

Tasha La Doux [1]

The mission of the Sweeney Granite Mountains Desert Research Center (Center) is to promote a better understanding of the arid ecosystem found in the Mojave Desert. One of the many ways we fulfill this mission is by facilitating academic research throughout the region. Each year the Center hosts around 130 researchers from a variety of institutions, universities, and government agencies conducting studies in a wide array of disciplines. The Center serves an important "gateway" role to the deserts of the Southwest. For example, many of the research projects facilitated by the Center are conducted on federal lands outside our boundary (e.g., Mojave National Preserve). More importantly, by providing lands that are protected for the purpose of research, we offer a unique opportunity for scientists to establish long-term studies as well as provide protection for sensitive study sites and equipment. Described here are a few examples of research projects that have been facilitated by the Center over the last couple years.

Figure 1. Bendire's Thrasher (*Toxostoma bendirei*) sitting in a Mojave Yucca (*Yucca schidigera*). Photo © Mark A. Chappell.

Region-wide Desert Thrasher Monitoring

Jim Tietz, Ph.D., and Geoff Geupel, Ph.D., are both biologists working for Point Blue Conservation Science, a non-profit organization whose mission is to conserve birds, other wildlife and ecosystems through science, partnerships, and outreach. Point Blue is currently a partner in the Desert Thrasher Working Group (DTWG), which conducts habitat suitability modeling and works to enhance monitoring strategies for thrasher species. The Point Blue field teams have been conducting surveys for Bendire's Thrasher (*Toxostoma bendirei*) (Fig. 1) and Le Conte's Thrasher (*Toxostoma lecontei*) since 2017. Sadly, these are two of the fastest declining desert bird species, which is why these scientists are working to improve our understanding of their current distributions. The effort was fine tuned in recent years to refine existing spatial abundance models and to develop regional habitat suitability models from field habitat assessments. During surveys, they collected data on all avian species present, with special focus on Bendire's Thrasher, LeConte's Thrasher, and the Loggerhead Shrike. Their surveys targeted areas with current or historic sightings of the birds; they also conducted habitat evaluations by recording shrub and tree density, vegetation ground cover, disturbance, ground composition (e.g., boulders, sand, pebbles), physical attributes (e.g., water tank), invasive plants, and adjacent land use. With luck, this research will guide future conservation efforts and hopefully lead to improved conditions for the thrashers.

Arthropod Biodiversity Survey at the Sweeney Granite Mountains Desert Research Center

This project is being managed by Ken Schneider, a volunteer in the Entomology Department at California Academy of Sciences; he is collaborating with Dr. Christopher Grinter, the Collection Manager of Entomology. Dr. Grinter is a specialist in the Lepidoptera, mostly focused on the Pyroloidea, a large superfamily of moths often referred to as Snout Moths. Ken and Chris are undertaking a survey of arthropods found at the Center, with a special focus on obscure and often neglected insect and arachnid families that have thus far remained largely undocumented at the Center. Special attention will be given to Lepidoptera (specifically microlepidoptera), Arachnids, and Hymenoptera; however, collections will be generalized to build up a more complete picture of the arthropod biodiversity present within Center lands. Already Ken has identified many new taxa for our species list. He

---

[1] University of California Riverside, Natural Reserve System, Sweeney Granite Mountains Desert Research Center.

was particularly excited about finding this Mojave mantispid in the genus *Plega* (Fig. 2) during his June 2022 visit. To date, Ken has collected more than 200 insect specimens, nearly 25% of which have never been documented at the Center. For example, Ken found some round spiny stem galls (Fig. 3) on *Senegalia greggii*. Ten days later, three wasps emerged allowing identification as *Tanaostigmodes howardii* (Fig. 4). In addition to collecting museum specimens, most of which will be housed at the California Academy of Sciences, he takes high resolution photographs of nearly everything he catches. Ken has been an incredible resource for Center staff through his efforts to update the species list and maintaining impeccable records of his collections.

Unravelling the influence of endosymbiotic bacteria on the biodiversity of *Mucoromycota* fungi

This international collaborative project involves researchers from three universities in two countries (South Africa and United States). This team of mycologists is studying the evolutionary and ecological significance of a particular group of filamentous fungi, *Mucoromycota*, and the myriad of associated endosymbiotic bacteria. Dr. Kevin Amses (Oregon State University) and Dr. Nicole Reynolds (Cornell University) visited four University of California Natural Reserve System field stations in the fall and spring of this last year (including the Granite Mountains Desert Research Center) to collect data. Their intention is to identify which environmental factors influence the microbial composition living in association with *Mucoromycota*, and more specifically, to compare these factors across environmental gradients on two different continents. To achieve this goal, they collected soil and root samples within two different arid environments (Mediterranean versus Desert shrublands) in California, while their collaborators sampled across similar gradients in South Africa.

Together, this team of scientists aims to identify how the bacterial endosymbionts are driving fungal diversity (and vice versa) and how these symbiotic relationships are influencing the composition, structure, and dispersal of the microbial community in arid environments.

Figure 2. A mantispid in the genus *Plega* caught in a pitfall trap turned out to be a new taxon for the Granite Mountains invertebrate species list. Photo by Ken Schneider.

Figure 3. Stem gall on the branch of *Senegalia greggii*. Photo by Ken Schneider.

Figure 4. Ten days after collecting the gall, the wasp (*Tanaostigmodes howardii*) emerged. Photo by Ken Schneider.

Mojave Broadband Seismic Experiment

Marcy Davis, Ph.D., and Dan Duncan, Ph.D., are both Engineering Scientists at the Institute of Geophysics working with a team of researchers from University of Texas, University of Colorado, and the Swiss Federal Institute of Technology in Zurich. This project started in 2018 with the deployment of 19 seismic sensors placed at roughly two-kilometer intervals across the Eastern California Shear Zone starting in the Granite Mountains heading west toward Ludlow, California. The goal was to test a new type of portable and lightweight seismometer (Fig. 5) developed at University of Texas Institute of Geophysics that has a small-footprint but can still provide details of the structure in the Earth's lithosphere, as well as help to understand how the Earth deforms in young strike-slip fault zones. By recording Earth's natural vibrations continuously over a four-year period, the Mojave Broadband Seismic Experiment aims to show that their mobile instruments allow for easy, but in-depth, studies of fault systems. Fortuitously, the sensors also recorded the M7.1 Ridgecrest earthquake sequence in July 2019. All 19 seismometers were collected in March 2021, such that all data are now in the process of being analyzed.

Figure 5. Dan Duncan and Marci Davis collecting one of 19 seismometers west of the Granite Mountains. Photo by M. Davis.