Cyanonbacterial biocrusts growing on clay soils on San Clemente Island.

SPECIES SPOTLIGHT: *by Brianne Palmer*[1] *Photos courtesy of the author*

It's Alive! The Hidden Microbial Communities Encrusting Grasslands

California grasslands are harbors of biodiversity — filled with blossoming wildflowers, charismatic animals, and imperceptible microorganisms. Walk through a grassland and you might see a vast landscape of knee-high grasses swaying in the wind. Look a little closer and you might see pops of color, fragrant forbs scattered across the soil. Look a little closer still and you might see something strange — a splash of green slime, a thin black blanket on the ground, multi-colored lichens carpeting the gaps between the plants, diverse communities of biocrusts covertly changing the surrounding soil properties and altering communities. These elusive and cryptic biocrust communities are found on every continent and cover about 12% of the earth's terrestrial surfaces (Elbert et al. 2012). Biocrust communities are diverse and variable across the landscape, composed of bacteria, lichens, fungi, and moss, with each community providing a unique set of ecosystem functions. As grassland enthusiasts, we should pay more attention these ecosystem engineers.

[1]Brianne Palmer is a second year PhD student in the joint ecology program with San Diego State and University of California, Davis. The majority of her work is in the grasslands on San Clemente Island, studying the recovery and functional shifts of biocrusts after fire.

In grasslands, biocrusts grow in the interspaces between plants where there is enough exposed soil surface to establish. They are connected to the above- (plants, animals, UV radiation, etc.) and below-ground ecosystems (soil microbes, micro-invertebrates, soil aggregation, etc.). Unlike mycorrhizae, biocrusts form symbioses within the crust itself, rather than with surrounding plants, benefitting the plant community indirectly by shifting nutrient cycles, increasing water content, and improving soil stabilization. Their connection to the soil and the flora, has spurred much research on the interactions of biocrusts with above-ground organisms, primarily vascular plants, and below-ground processes like nutrient cycling and biogeochemical processes.

Biocrusts are vitally important in the soil carbon cycle and fix more carbon than they respire, thus increasing carbon sequestration (Castillo-Monoroy et al. 2011, Li et al. 2012). Additionally, due to their global presence, researchers determined biocrust communities account for 3–4% of global nitrogen fixation rates, acting as a natural fertilizer for the surrounding plants (Belnap 2002). Although it is known that biocrusts increase available nitrogen in ecosystems, in grasslands, we are uncertain how biocrust nitrogen fluxes differentially

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affect native and nonnative plant species. These shifts in nutrient availability influence the surrounding plant communities, and consequently, ecosystem processes on a landscape scale (Langhans et al. 2009, Garcia et al. 2015, Ghiloufi et al. 2016). In some cases, biocrusts enhance plant growth (Garcia et al. 2015) and promote plant uptake of essential micronutrients (Harper and Belnap 2001). However, biocrusts may also inhibit plant growth by creating a barrier on the soil surface, thus creating heterogeneity across the landscape (Song et al. 2017). These interactions are not fully understood, though some hypothesize that biocrusts may deter plant invasion and maintain community stability (Deines et al. 2007). For example, in the California sage scrub, biocrusts that had been experimentally trampled increased the abundance of exotic annual plants, indicating disturbance of biocrusts may detract from native plant communities because the seedlings that are able to germinate and establish benefit from increased available nutrients (Langhans et al. 2009, Hernandez and Sandquist 2011). The relationship between biocrusts and vascular plants are complex and we don't fully understand how biocrusts are shaping our grassland plant communities.

Given the global importance of these microbial communities, there has been a push for more research and concern regarding the status of biocrusts in conservation and restoration practices as both a community to be restored and a tool for restoration (Bowker 2007, Bowker et al. 2011). Establishing a strong biological soil crust may improve the biogeochemical cycling and relieve stress from the native plant species. In areas where biocrusts have been restored, there is improved soil moisture, reduced erosion, improved soil fertility (Li et al. 2010, Zhao et al. 2016, Gomez et al. 2012). The natural recovery time for biocrusts is slow and inconsistent, ranging from two to hundreds of years depending on the disturbance and the habitat (Belnap and Lange 2003). For example, after a fire in South Africa, it took 8 months for biocrust soil communities to reach a pre-disturbance community composition (Dojani et al. 2011), but in the Great Basin, it took up to fifteen years to achieve the same result (Root et al. 2017). There is currently no published information on biocrust recovery time in California grasslands. However, there have been successful attempts to rehabilitate biocrust communities in the lab and the field. A small field sample was grown in a nursery to re-establish 6000-m^2 of dryland soil in the southwestern U.S. at 1–5% of the historic concentration (Ayuso et al. 2017). Additionally, the restoration of biocrusts improved soil fertility and the micro-environment of the top soil in Chinese semi-arid ecosystems (Wu et al. 2013). The restoration of biocrusts in California grasslands may markedly improve the ecosystem function and enhance grassland productivity.

So, what can we do to help?

Becoming a crust-odian, a caretaker of crusts, is as simple as being aware of their existence and minimizing damage to them when found. Often, biocrusts are nestled between bunch grasses, or smashed below our shoes, and we aren't aware of the community we are impacting. Due to the high disturbance in our grasslands from human recreation, grazing, and fire, it is likely that the biocrust communities are remnants of what they once were. However, since biocrusts were largely absent from the literature until the late 20th century, we lack the perspective to restore biocrusts to their historical state (Bowker 2007). Given their influence on ecosystem functioning and the growing support of biocrust research around the world, biocrusts should be considered in restoration plans and could potentially be used as a restoration tool to assist the recovery of degraded ecosystems. We can do our part in conserving them by simply acknowledging their existence, watching where we step, and sharing the importance of these organisms with others.

References

Ayuso, S.G., A.G. Silva, C. Nelson, N. Barger, and F. Garcia-Pichel. 2017. "Microbial nursery production of high-quality biological soil crust biomass for restoration of degraded dryland soils." *Applied and Environmental Microbiology* 83:1–16.

Belnap, J. 2002. "Nitrogen fixation in biological soil crusts from southeast Utah, USA." *Biology and Fertility of Soils* 35:128–135.

Belnap, J., and O.L Lange. 2003. "Biological soil crusts: structure, function, and management." Vol 150. Heidelberg: Springer.

Bowker, M.A., R.L. Mau., F.T. Maestre, C. Escolar, and A.P. Castillo-Monroy. 2011. "Functional profiles reveal unique ecological roles of various biological soil crust organisms." *Functional Ecology* 25:787–795.

Bowker, M.A. 2007. "Biological soil crust rehabilitation in theory and practice: An underexploited opportunity." *Restoration Ecology* 15:13–23.

Castillo-Monroy, A.P., F.T. Maestre, A. Rey, S. Soliveres, and P. Garcia-Palacios. 2011. "Biological soil crust microsites are the main contributor to soil respiration in a semiarid ecosystem." *Ecosystems* 14:835–847.

Deines, L., R. Rosentreter, D.J. Eldridge, and M.D. Serpe. 2007. "Germination and seedling establishment of two annual grasses on lichen-dominated biological soil crusts." *Plant and Soil* 295:23–35.

Dojani, S., B. Budel, K. Deutschewitz, and B. Weber. 2011. "Rapid succession of biological soil crusts after experimental disturbance in the Succulent Karoo, South Africa." *Applied Soil Ecology* 48:263–269.

Inset: Seedling growing out of a moss-cyanobacterial biocrust on San Clemente Island.


From left: Moss biocrust growing in the interspaces of the grasses on clay soil on San Clemente Island. | Lichen biocrusts growing on clay soil in a large gap between the grasses on San Clemente Island.

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Elbert W., B. Weber, S. Burrows, J. Steinkamp, B. Budel, M.O. Andreae, and U. Poschl. 2012. "Contribution of cyptogamic covers to the global cycles of carbon and nitrogen. *Nature Geoscience* 5:459–462.

Garcia, V., J. Aranibar, and N. Pietrasiak. 2015. "Multiscale effects on biological soil crusts cover and spatial distribution in the Monte Desert." *Acta Oecologica* 69:34–45.

Ghiloufi, W., B. Budel, and M. Chaieb. 2016. "Effects of biological soil crusts on a Mediterranean perennial grass (*Stipa tenacissima* L.)" *Plant Biosystems* 151:1–10.

Gomez, D.A., J.N. Aranibar, S. Tabeni, P.E. Villagra, I.A. Garibotti, and A. Atencio. 2012. "Biological soil crust recovery after long-term grazing exclusion in the Monte Desert (Argentina). Changes in coverage, spatial distribution, and soil nitrogen." *Acta Oecologica* 38:33–40.

Harper, K.T., and J. Belnap. 2001. "The influence of biological soil crusts on mineral uptake by associated vascular plants." *Journal of Arid Environments* 47:347–357.

Hernandez, R.R., and D.R. Sandquist. 2011. "Disturbance of biological soil crust increases emergence of vascular plants in California sage scrub." *Plant Ecology* 212:1709–1721.

Langhans, T.M., C. Storm, and A. Schwabe. 2009. "Community assembly of biological soil crusts of different successional stages in a temperature sand ecosystem, as assessed by direct determination and enrichment techniques. *Microbial Ecology* 58:394–407.

Li, X.R., F. Tian, R.L. Jia, Z.S. Zhang, and L.C. Liu. 2010. "Do biological soil crusts determine vegetation changes in sandy deserts? Implications for managing artificial vegetation." *Hydrological Processes* 24:3621–3630.

Li, X.R., P. Zhang, Y.G. Su, and R.L. Jia. 2012. "Carbon fixation by biological soil crusts following revegetation of sand dunes in arid desert regions of China: A four-year field study". *Catena* 97:119–126.

Root, H.T., J.C. Brinda, and E.K. Dodson. 2017. "Recovery of biological soil crust richness and cover 12–16 years after wildfires in Idaho, USA." *Biogeosciences* 14:3957–3969.

Song, G., X. Li, and R. Hui. 2017. "Effect of biological soil crusts on seed germination and growth of an exotic and two native plant species in an arid ecosystem." *PLoS ONE:* 12(10): e0185839.

Wu, L., S. Lan, D. Zhang, and C. Hu. 2013. "Recovery of chlorophyll fluorescence and CO_2 exchange in lichen soil crusts after rehydration. *European Journal of Soil Biology* 55:77–82.

Zhao, Y., Z. Zhang, Y. Hu, and Y. Chen. 2016. "The seasonal and successional variation of carbon release from biological soil crust-covered soil." *Journal of Arid Environments* 127:148–153.