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Pedological and geological relationships with soil lichen and moss distribution in the eastern Mojave Desert, CA, USA

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A B S T R A C T

Biological soil crusts (biocrusts) are ubiquitous in drylands globally. Lichens and mosses are essential biocrust components and provide a variety of ecosystem services, making their conservation and management of interest. Accordingly, understanding what factors are correlated with their distribution is important to land managers. We hypothesized that cover would be related to geologic and pedologic factors. We sampled 32 sites throughout the eastern Mojave Desert, stratifying by parent material and the age of the geomorphic surfaces. The cover of lichens and mosses on 'available ground' ($L + M_{av}$; available ground excludes ground covered by rocks or plant stems) was higher on limestone and quartzite-derived soils than granite-derived soils. Cover was also higher on moderately younger-aged geomorphic surfaces (Qya2, Qya3, Qya4) and cutbanks than on very young (Qya1), older-aged surfaces (Qia1, Qia2), or soils associated with coppice mounds or animal burrowing under *Larrea tridentata*. When all sites and parent materials were combined, soil texture was the most important factor predicting the occurrence of $L + M_{av}$, with cover positively associated with higher silt, very fine sand, and fine sand fractions and negatively associated with the very coarse sand fraction. When parent materials were examined separately, nutrients such as available potassium, iron, and calcium became the most important predictors of $L + M_{av}$ cover.

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1. Introduction

Biological soil crusts (biocrusts) are communities of cyanobacteria, mosses, lichens, fungi, Archaea, and other bacteria that are commonly found on soil surfaces throughout the world, especially in dryland (arid and semi-arid) regions (Belnap and Lange, 2003). In these regions, they dominate soils in the large spaces between the sparse plants. Biocrusts can influence many aspects of dryland ecosystems, including soil fertility, stability, and hydrology. They can be the dominant source of nitrogen (N) for desert plant and soil communities (Evans and Belnap, 1999; Evans and Ehleringer, 1993). When wetted, they fix carbon (C) at a rate equivalent to vascular plant leaves (Lange, 2003). Organisms found within biocrusts (e.g., fungi) may increase the availability of many soil nutrients in the often high pH soils of deserts by secreting powerful metal chelators (Lange, 1974; McLean and Beveridge, 1990; for a review see; Belnap et al., 2003a). They also support below-ground decomposer communities (Darby et al., 2006). Biocrusts stabilize dryland soils by covering the soil surface and creating soil aggregates, hence reducing susceptibility to both wind and water erosion (Warren, 2003). In all but hyper-arid deserts, their presence roughens the soil surface, thus increasing the capture and retention of nutrient-rich dust (Reynolds et al., 2001), seeds, and organic matter (Rao and Burns, 1990; Rogers and Burns, 1994). Plant productivity, survivorship, and concentrations of most plant-essential nutrients are often higher in plants growing in crusted soils compared to adjacent, uncrusted soils (Harper and Belnap, 2001; for a review see; Belnap et al., 2003b). Biocrusts also influence many aspects of local hydrologic cycling (for a review see Belnap, 2006).

Biocrusts containing lichens and mosses have a greater influence on ecosystem processes compared to cyanobacterially-dominated biocrusts. Lichens fix more N, and mosses and lichens fix more C, per unit of soil surface area than cyanobacteria (Belnap and Lange, 2003). Lichens and mosses are darker than cyanobacteria, thus creating higher soil temperatures than cyanobacteria (Belnap et al., 2003b). Lichen-moss biocrusts have a rougher

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surface morphology than cyanobacteria biocrusts, thus enhancing capture of dust, water, and organic materials. Soil food webs are more complex and organisms more abundant under lichen-moss biocrusts than under cyanobacterial biocrusts (Darby et al., 2006; Rychert and Skujins, 1973; Yeates, 1979; for more references see; Belnap et al., 2003a). Therefore, the higher the cover of lichens and mosses, the greater the biocrust communities contribute to various ecosystem processes compared to bare or cyanobacterially-covered soils.

Given the importance of biocrusts, especially those containing lichens and mosses, to ecosystem function and services in dryland regions, their presence and well-being has become an important consideration in land management decisions, especially in face of the rising demand for recreation, military, energy production and mineral extraction activities on these lands. However, there is little information for managers, policy makers, or the public on what factors control lichen and moss distribution and as they are not mapped, there is almost no ability to take them into consideration for planning the placement and type, timing and amount of land use, including what lands to acquire for protection. To help fill this information gap, our study focused on what factors predict higher lichen and moss cover in the Mojave Desert.

2. Methods

2.1. Site selection and description

Our study sites were located within the eastern Mojave Desert of eastern California where surficial geologic maps were available (Fig. 1; Bedford et al., 2010; Miller et al., 2009; Schmidt and McMackin, 2006). Average annual rainfall in this region is 247 mm/year, but as common in deserts, is highly variable, ranging from 77 to 580 mm/year. The average annual temperature ranges from 15.5 to 18.2 °C (Hereford et al., 2006). Our study was limited to alluvial fan deposits which make up the majority of surfaces found in the Mojave Desert. We controlled for several soil-forming factors, including parent material, elevation, and soil age. The parent materials studied were quartzite, limestone, and two of three main granite types. The weathering styles of granite vary to produce grus-rich fans and rocky fans; we focused on rocky fans, as grus-rich fans are uncommon in most areas of the Mojave. Of those granites that weather into rocky fans, some contain a range of apatite, monazite and phosphate minerals relatively high in

Table 1
Parent material, elevation, and number of transects for each site.

Parent material	Zone	Average elevation, *m*	Number of sites	Total transect length, *m*
Limestone	Clark Mts.	1094	3	
	Providence Mts.	708	2	
	Spring Mts.	837	3	
				5810
Quartzite	Mesquite Mts.	1044	2	
	Kingston Range	860	3	
	McClain Peak	547	3	
				4642
High P Granite	Ivanpah Mts.	1383	1	
	New York Mts. North	1458	3	
	New York Mts. South	899	3	
				3392
Low P Granite	Ivanpah Mts. North	1001	3	
	Ivanpah Mts. South	1257	3	
	Nipton South	975	3	
				16300

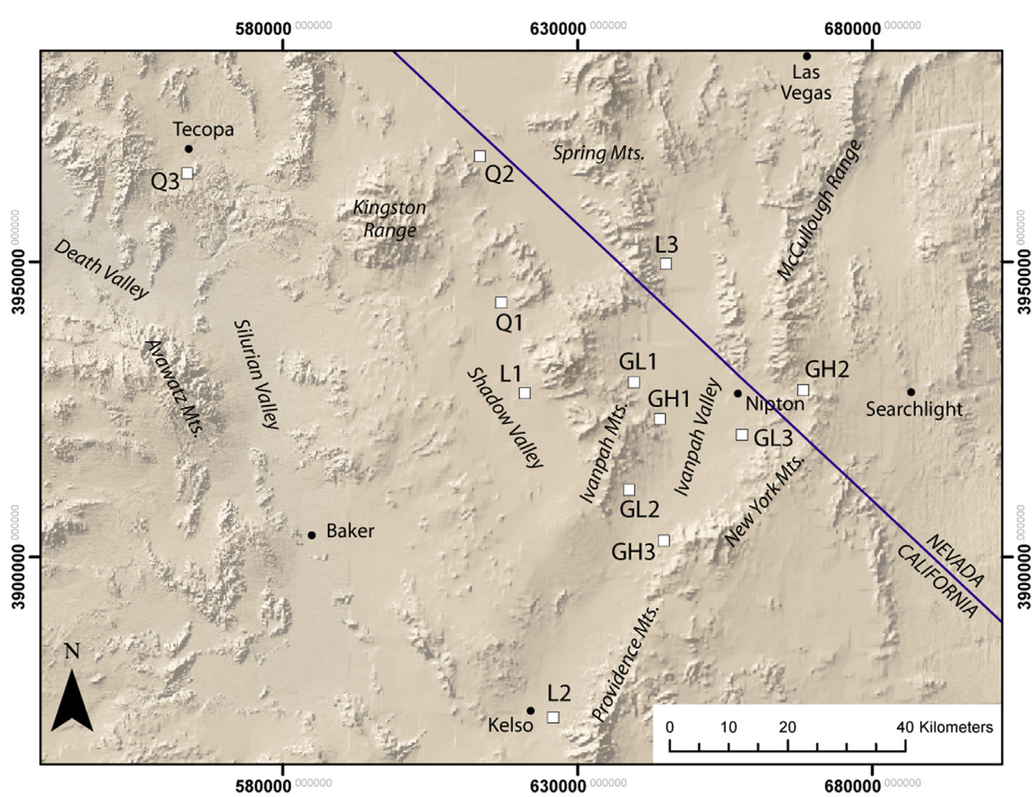

Fig. 1. Map of the study sites in the eastern Mojave Desert, California. Sites are indicated by white boxes, and substrates for fans are given by the following letters: Q = quartzite, L = limestone, GH = granite high in phosphorus, GL = granite low in phosphorus.