Ecology and spatial pattern of cyanobacterial community island patches in the Atacama Desert, Chile

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[1] Plant landscape ecology studies have been carried out for decades and are fundamental to biological research. In contrast, few corollary spatial landscape studies exist for microorganisms, particularly in extreme environments. To address this gap, we mapped the abundance and spatial distribution of photoautotrophs colonizing translucent rocks in several sites in the Atacama Desert, including the hyperarid core. Cyanobacterial communities at all sites are predominantly (>75%) ‘perilithic’ (confined to the periphery of rocks) and occur in non-random spatial patterns (“island patches”) at multiple scales. Cyanobacterial patches typically contain 1-5 colonized rocks but in some cases support much higher numbers. A high resolution mapping of a single 18-m2 rock cluster at the Aguas Calientes study site (25°S, 69°W) revealed colonization of 5.2% (49 of 948 quartz rocks) and showed colonized rocks to be much larger (~2X) than the available mean rock size. Ripley’s K and point pattern analyses show that quartz rocks are not “selected” or occupied by cyanobacteria randomly, but that non-random processes distinct from those creating the background rock pattern must be invoked to explain microbial patchiness in the Atacama Desert. These processes include physical controls (rock size/orientation, microtopography) that reflect resource (water) limitations, and biological dispersal via rainfall, fog and wind.


1. Introduction

[2] Deserts and arid lands cover approximately one-third of the Earth’s land surface, making them important ecosystems worldwide. Within these environments, desert pavements (gravels that mantle surface soils) extend for several meters to thousands of kilometers and are a predominant habitat for microbial life. In particular, “lithic” (lithobiotic, lithophytic) cyanobacterial communities (LCC), comprised of co-occurring cyanobacteria and heterotrophic bacteria, colonize the cracks (chasmo-liths), pore spaces (endoliths) and undersides (hypoliths) of translucent rocks (e.g., quartz, gypsum, calcite) in the pavement to gain protection from the harsh external environment [Friedmann et al., 1967; Friedmann and Galun, 1974; Golubic et al., 1981]. In the world’s driest deserts, these communities may harbor the few primary producers within the larger landscape [Friedmann, 1980; Allen, 1997; Warren-Rhodes et al., 2006; Wierzchos et al., 2006].

[3] A wealth of studies have characterized LCC ecology, including community composition, metabolic activity, photosynthesis, and microclimate [Friedmann et al., 1967, 1993; Nienow et al., 1988a, 1988b, 2003; Cockell and Stokes, 2004; Omelon et al., 2006]. Few studies, however, have explicitly examined the spatial component of LCC ecology—particularly at extents greater than a few mm [Broady, 1981; Nienow et al., 1988a, 1988b; Cockell and Stokes, 2004; Green and Bohannan, 2006; Omelon et al., 2006]. For higher plants, such studies have yielded fundamental insights into concepts and models such as self-organization, patch dynamics, hierarchical scale, biogeography, positive biological feedback and ecohydrology [Peterson, 2000; Urban et al., 2002; Barrett et al., 2004; Rietkerk et al., 2004; Belnap et al., 2005; Ludwig et al., 2005].

[4] Pioneering work in adapting plant ecology to the study of cyanobacterial soil crusts has recently been undertaken in arid environments [Belnap et al., 2005; Bowker et al., 2005, 2006]. This paper seeks to extend such work to LCC in hyperarid deserts. To that end, we use available data from earlier LCC ecological studies in the Atacama Desert,