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# Challenges in assessing color and spatial distribution of bacterial mats in lava cavities

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Microorganisms that live in extreme environments, such as volcanic cavities, often opt for a biofilm lifestyle to enhance their survival possibilities [1, 2]. Cave-dwelling microbial biofilms (bacterial mats) are functionally complex ecosystems, comprehending several evolutionarily distant bacterial phylotypes [3, 4, 5]. Bacterial mats are important not only because of their role in cave ecology, but they have also been demonstrated to hold promise as potential sources for industrially valuable compounds, such as antibiotics [6, 7]. Bacterial mats form colorful patches on the walls and ceilings of caves. Their colors range from white, or gray to tan, several shades of yellow and sometimes pink [3]. Recent studies suggest differences between mat colors, both at structural [8] and bacterial consortium composition levels [9, 10, 11]. Little is still known on the spatial distribution of the differently colored mats and its representation in caves, but the available data, obtained in carbonate caves, seem to indicate that each type of community is housed in different ecological niches, where the influx of organic matter and microclimatic parameters vary [8, 12]. It would be important to elucidate spatial distribution of the colored mats in volcanic cavities as well, in order to gain a better understanding of the ecology of these subterranean extreme environments. This poses several challenges. Consistent visual evaluation of mat color, on itself, is subjective and assessing the degree of coverage by each mat color is difficult. Microbial mats sometimes juxtapose, making this task even harder. Instrumental, objective methods are lacking that could help with the task of determining which microbial mats grow where in volcanic cavities.

Color pattern recognition is an old topic with much recent development, partly due to the extensive use of photo-editing software. This task has been accomplished in many ways, but is usually optimal only with evenly lit subjects in controlled environments. A cave environment, with uneven walls covered by different bacterial mats in varying concentration, leading to very different hue and saturation of similar mats, represents a real challenge for any algorithm intending to properly separate and quantify the surface covered by such mats. Developing either supervised or unsupervised classification systems that can handle dozens or hundreds of bacterial mat pictures in a batch process may be a difficult task and prompts the following questions: