Title: Effects of topographic complexity from crustose coralline algae to kelp forests
Keywords: habitat complexity, nearshore marine ecology, spatial spectral analysis
Background: Topographic complexity plays a critical role in settlement, recruitment, and maintenance of biodiversity in marine systems, yet its mechanistic role in these processes is poorly understood. The scale of topographic complexity relevant to ecological processes varies broadly and continuously from surface roughness (mm) to reef morphology (km), and the effect of topography on a given process is scale-dependent. Recruitment limitation is among the most important drivers of population dynamics; thus, factors influencing recruitment can have strong effects on population and community dynamics. Crustose coralline algae (CCA) may influence their community dynamics via topographic complexity at multiple scales.

Crustose coralline algae (CCA) are benthic algal species that form rugose $CaCO_3$ structures[23]. Their texture facilitates high larval settlement rates (e.g. stony aclonal cup coral, *Balanophyllia elegans*)[1], while other species preferentially settle where the presence of CCA is detected via chemical secretions[3, 19, 23]. Among these species are key grazers, such as urchins and abalone, that maintain benthic diversity and facilitate the growth of CCA[3, 19, 21]; thus, CCA are foundation species[8] that play a role in generating alternative urchin- or macroalgae-dominated states in temperate reefs[3]. Topographic complexity may have strong effects on CCA settlement and growth, and may subsequently affect the nearshore communities it inhabits. Understanding the role of CCA in community dynamics is now critically important, as ocean acidification threatens such biogenic carbonate structures.

I propose to quantify habitat complexity at nested scales in order to identify the scale of critical importance to ecosystem processes such as settlement and recruitment. Habitat complexity is most often quantified by measures of rugosity[9, 18], which is the ratio between the length of the contour surface profile and the linear distance between the end points[20], or fractal surface dimension[4, 7, 10, 12], which expresses the complexity of the structure's static geometry[16, 17]. While informative, these measures limit both the range of scale at which you can address and the transferability of these measurements to other scales, studies and systems[13]. Spatial spectral analysis applies the same method to each scale of measurements, so comparisons can easily be made across many scales. Spectral analysis is most commonly used to analyze time series data, however, applying this method to spatial data will broaden its application. I will conduct this work at Hopkins Marine Life Refuge (HMLR), where I previously created a geospatial habitat map of the subtidal environment. Temperate subtidal reefs such as those found in HMLR are one of the most productive and species-rich ecosystems, supporting a great variety of ecosystem services including CO_2 sequestration[22], shoreline wave protection[8, 11, 20], and nursery habitats[2, 5, 15] for ecologically and economically important species.

Proposal/Research Objectives: I propose to use subtidal measurement techniques and analytical tools to investigate the mechanistic linkages between habitat complexity and distributions of CCA, across several ecologically important scales.

<u>Question 1:</u> Is the distribution of CCA and its affiliated organisms correlated with habitat complexity and if so, at what scales? *Hypothesis 1:* I predict that the physical descriptors of habitat complexity will have disproportionate correlations with distributions of CCA and CCA affiliates, and further, smaller scales of topographic complexity will have strongest correlations. *<u>Methodology</u>:* I will collect spatially explicit data on the depth, slope, orientation, substrate type, and encrusting organisms (including CCA) using a modified Uniform Point Contact (UPC) method to estimate percent spatial cover. I will measure environmental parameters such as light, temperature, and wave exposure, in order to later account for them in my analyses. I will use spatial spectral analysis of topographic data to quantify habitat complexity across different scales, followed by a multiple regression of the physical parameter and CCA data. I will run a generalized linear model and additive model approach if the data is non-linear. Variance inflation factors will be used to account for co-linearity of the physical parameters.

Question 2: Is there a mechanistic link between habitat complexity and the recruitment and growth of CCA and its affiliates? *Hypothesis 2:* I predict that recruitment and growth of CCA will be greatest when complexity is greatest at multiple scales.

Methodology: I will use a spatially explicit randomized block design to test recruitment, growth and survival of CCA and other affiliated encrusting species. Four treatments will simulate three levels of habitat complexity: a smooth tile for no complexity, a rough tile for low complexity, a cleaned rock of known texture for high complexity, and a cast of the cleaned rock to simulate the same topographical features while controlling for factors such as chemical composition of the substrate. Replicate groups of these treatments will be deployed at many locations within my study site, and monitored for recruitment and growth of CCA and other encrusting species. I will deploy the treatments in a variety of microhabitats (e.g. horizontal and vertical rock faces, pinnacle tops, sand patches etc.) in order to make comparisons between larger scale features not accounted for in the tiles themselves.

Intellectual Merit and Broader Impacts: CCA play important roles in both temperate and tropical nearshore ecosystems, though its dependence on habitat complexity is poorly understood. A simple and accurate method to predict distributions of these algae would inform current management policies and contribute to the expectations of how they might change under predicted acidification regimes.

My previous work has fostered a strong relationship with Monterey Bay Aquarium (MBA) scientists, who have invited me to participate in existing outreach programs. Specifically, I will be involved with the two programs: The Underwater Explorers program, which introduces K-12 students to the underwater world through scuba diving, and Family Science Nights, MBA and Hopkins' bilingual program aimed to inform students from underserved schools and their families about ocean conservation. To further ensure that my research benefits others, local high school and undergraduate students will be involved in data collection and presentation of results, allowing future scientists to gain hands-on field and lab experience and develop essential professional relationships. Results from this study will be presented at the Pacific Ecology and Evolution Conference, Society for Integrative and Comparative Biology Conference, Western Society of Naturalists Conference, and marine spatial planning and management meetings to ensure communication to the broader scientific community and public.

Proposed institutions: I propose to complete this work under the mentorship of Drs. Fio Micheli and Mark Denny of Stanford University at Hopkins Marine Station. Stanford University offers the academic resources and institutional support necessary to complete this project and technical expertise to strengthen the study. Current fieldwork conducted by Dr. Micheli and Dr. Denny's labs provide the field support necessary for this project. HMLR's close proximity to both labs will minimize time and cost of transportation, facilitating involvement of other students and allowing me to spend more time incorporating my research and research interests into local outreach programs.

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