Introduction: Scleractinian corals are foundational in supporting the incredibly high biological diversity in coral reef environments and providing ecosystem services that are intrinsic to the longevity of society. The diverse microhabitats provided by the elaborate morphologies of corals function as predation refuge and are essential for supporting the low trophic level (LTL) fish community.[1] Specialist fish species will live within one coral colony (or others of similar morphology) for much of their lives, whereas generalist fish can associate with a wider variety of microhabitats. Trophic cascading of the LTL fish community results in flourishing commercial fisheries, which are estimated to be globally valued at $5.7 billion USD annually.[2] Yet, the existence of coral dominated tropical reefs is largely threatened by global scale, anthropogenic warming-induced coral bleaching events—which has in part contributed to a 50-75% decline in worldwide coral cover over the last ~35 years.[3,4] The loss of microhabitat often leads to drastic declines in the reef fish community[5] and can crash commercial fishery markets. To mitigate against the further decline of coral reefs and the fisheries they support, restoration strategists in-part rely on large-scale coral propagation and outplanting—involving the artificial fragmentation of reef-obtained donor colonies and returning the clonal population back to the reef.[6] Often, studies attempting to describe coral reef environments solely focus on percent coral cover and fail to capture the complex nature of coral reef ecosystems.[7] It remains unclear how reef fish community assemblages are directly affected by bleaching-induced changes in microhabitat availability. Understanding fish-microhabitat associations is essential for devising targeted, efficient fisheries restoration efforts. The proposed research aims to elucidate the unique fish-microhabitat associations to better inform outplanting-based fisheries restoration efforts. Revealing fish-microhabitat associations would lead to the development of a comprehensive Coral Outplanting for Fisheries Guide (COFG) to be leveraged by coral restoration and fisheries managers. This research also aims to capture changes in the population levels and spatial distributions of commercially valuable high trophic level (HTL) populations while under the presumed pressure of depleted LTL prey populations following a bleaching event.

Hypotheses: I hypothesize that (1) bleaching events will induce the largest decreases in specialist, LTL fish populations relative to generalist fish populations (H1), (2) bleaching events drive HTL predator populations to relocate to less-affected regions of the reef where food sources are sufficient, or in more extreme cases, recruit to nearby reefs owing to the reductions of LTL fishes associated with H1 (H2), and (3) outplanting of fisheries-specific coral taxa will facilitate the recovery of the fishery stock (H3).

Experimental Approach: *Timeseries Density Maps*: The framework of one entire reef would be imaged before and after a single bleaching event, which would be scheduled according to existing local degree heating week (DHW) data. DHW is a measure of accumulated thermal stress obtained by the 12-week time-integration of sea surface temperature data exceeding the local bleaching threshold and is a reliable bleaching predictor.[8] The onset of bleaching is expected when DHW values reach 4 °C-weeks, whereas mass bleaching and mortality is expected at 8 °C-weeks.[9] The framework would be characterized by generating high taxonomic resolution photomosaics[10] of the benthic coral community coupled with ArcGIS-generated density maps of coral colony microhabitat volume approximated using structure-from-motion (SfM). SfM is a computationally intensive software that would allow me to digitally reconstruct the reef and extract microhabitat volume data from each colony. The movements of lower and higher trophic level fish populations would be continuously monitored utilizing size-specific acoustic telemetry transmitters and receivers to create 3D population density maps in ArcGIS. It is imperative to implant size-specific transmitters to minimize potential adverse health impacts to best isolate for tracking the natural movements of the fish.[11] Fish populations would be estimated for all implanted fish taxa using well-established tag-recapture techniques and the appropriate stock assessment model according to the species-specific life history traits.

Statistics: To determine specific fish-microhabitat associations and build the COFG, colony location and taxonomic classification will be tested against the time-based location density of the tagged LTL fish. To test for potential reef-level population reduction differences in LTL fish species (specialists vs. generalists) (H1), I would linearly model the tag-recapture-obtained population abundance data and evaluate whether species, time, and the interaction of species and time are significant predictors of mean abundance. To test for potential significant changes in the movements of HTL predator populations (H2), I would model the time-based location density of tagged LTL fish populations paired with the time-based location density of tagged HTL predators. I would encourage future studies to utilize the COFG produced by this research to answer H3. These studies would require quantifying the background recruitment rates of LTL fish populations and the new recruitment rates following a large-scale outplanting effort. I would also overlay the microhabitat volume density maps with the fish population density maps to allow for better visual interpretation of the data.

Resources: I am applying to be advised by Dr. Sandin who is a leading expert in coral reef ecology at the Scripps Institution of Oceanography (SIO). Dr. Sandin's team is comprised of many individuals with years of experience who would assist me in reliably imaging the reef and identifying coral colonies. I hope to also receive guidance from Dr. Brice Semmens (SIO), who often uses telemetry techniques in his research, to safely implant fish with acoustic transmitters and reliably track their movements. This study would rely on the resources available to SIO, especially the use of custom-framed, study-optimized cameras[12] and SfM to digitally reconstruct the reef from imagery and perform the colony microhabitat volume calculations. The spatial monitoring of LTL populations would require surgically implanting fish with Juvenile Salmon Acoustic Telemetry System (JSATS)[13] microacoustic transmitters and installing JSATS N201 receivers around the perimeter of the reef. The spatial monitoring of HTL populations would follow the same methods but require Vemco™ V16p-4H transmitters and VR2 receivers.

Intellectual Merit: This research would provide valuable insight to ecologist's holistic understanding of successional reef fish communities. Although previous work has evaluated the role of decreased reef framework on fish community composition using transect based methods,[14] it remains unknown how shifts in specific coral species alter the population level and distribution of specific fish species. This research aims to reveal these mysteries with the increased quantized framework resolution from SfM and the paired monitoring of fish movements. This project would provide great predictive value to infer what reef-associated fish communities may look like in the future if the current frequency of bleaching events continues. Particularly, which fish species we might expect to decline at a given reef site if targeted conservation efforts, such as those that would be made possible by the COFG, are not enacted.

Broader Impacts: The COFG developed from this research could guide the decisions of coral restoration and fisheries managers by detailing which coral species serve as primary microhabitat for a particular LTL fish population—enabling managers to easily identify which coral species to outplant to maximize the available microhabitat for LTL prey species for a specific fishery. In theory, increased microhabitat availability and trophic cascading would result in increased LTL prey population(s) and the HTL fishery stock. However, the world's leading coral outplanting organization, the Coral Restoration Foundation (CRF), has only optimized the large-scale propagation and outplanting of 4 coral species. The fisheries-relevant coral species identified by this research that are not currently being outplanted would provide reason to increase funding for the development of new programs working to optimize the large-scale propagation of these species. The realization of this optimized restoration strategy would require a collaborative effort between SIO, CRF, and fisheries managers around the world to outplant the specific coral taxa that provide the most relevant microhabitat for prey of target fisheries. This innovative restoration optimization would be a valuable strategy to help work towards sustainable fisheries and maintaining their incredible economic value for future generations. I intend to disseminate the findings from this project via publications in peer-reviewed journals to drive similar studies that would build upon my findings and broaden the geographic relevancy of the COFG. I will present my findings to students at nearby institutions to inform aspiring ecologists of the problems our worlds reefs are facing, hopefully inspiring them to pursue related careers and research.

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