MEDS Group Project Proposal

A web-based application for visualizing spatial and temporal patterns of anthropogenic stressors on coral reefs in the lagoons of Moorea, French Polynesia

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Project Clients: Moorea Coral Reef Long Term Ecological Research project (MCR LTER)

Objectives

The objective of this project is to build an interactive web-based application for data visualization and analysis to advance understanding of spatial patterns of benthic community dynamics on shallow coral reefs. The interactive web-based application will be used by MCR LTER researchers to quickly visualize and analyze data. The application will also be used as an educational tool for UCSB undergraduate courses and MCR LTER outreach activities. Finally, the application will serve as a tool for the local community in Moorea to visualize spatial data that can inform local management decisions.

We will create a flexible web-based platform to visualize spatially explicit biological and physical data collected as part of the ongoing Moorea Coral Reef Long Term Ecological Research project (MCR LTER) in Moorea, French Polynesia. Data layers will include a range of physical and biological variables, including seawater temperature, nutrients, benthic communities (corals, fish, algae, etc.), and coral bleaching collected across a grid of approximately 200 sites in the ~ 40 km^2 lagoons surrounding the island. The application will allow for visualization of the spatio-temporal patterns of variables from individual datasets as well as correlations among variables from multiple datasets at multiple spatial scales.

Significance

Coral reefs are highly diverse and productive ecosystems that provide numerous ecosystem services to coastal populations. Yet these ecosystems are also among the most threatened on the planet. Rising ocean temperatures are causing mass coral bleaching events worldwide. At the same time, many tropical coastal zones are experiencing population growth, with accompanying coastal development, agricultural intensification, and increased fishing pressure. These global and local drivers can act in concert to drive coral decline and prevent coral recovery.

The stressors that interactively cause coral decline and prevent coral recovery can be spatially heterogeneous within a reef system. For example, nutrient pollution can decline with increasing distance from agricultural or urban sources and fishing pressure can be concentrated in the most accessible locations near human settlement. Similarly, temperature stress associated with marine heat waves that result in coral bleaching can vary across reef habitats and depths. Understanding spatial patterns in these drivers is critical for predicting how coral reef ecosystems will respond to disturbances and local anthropogenic stressors and is important for developing management plans to mitigate negative impacts.

In addition to advancing MCR LTER research goals, the interactive web-based application will be an invaluable tool for the local community in Moorea. The application will also serve as an educational tool by allowing us to easily distribute nearly two decades of MCR LTER data to a large number of students across the world. The interactive nature of the application will allow students across a range of education levels to easily visualize and understand the changes occurring to the reefs of Moorea.

Background

The NSF-funded Moorea Coral Reef LTER project (mcr.lternet.edu) has been collecting biological and physical data on the shallow reefs surrounding Moorea, French Polynesia since 2005. Since the inception of the program, the reef ecosystem has experienced several ecological shocks, most notably an outbreak of coral-eating seastars and a major cyclone that greatly reduced coral cover in 2007-2010 (Adam et al. 2011). The impact of and response to these disturbances was highly spatially heterogeneous, with some reefs recovering coral cover rapidly, others more slowly, and still others experiencing a period of protracted coral decline with corals being replaced by persistent stands of macroalgae (Holbrook et al. 2018, Schmitt et al. 2019, Adam et al. 2021). More recently, many corals were killed during a major coral bleaching event associated with a marine heat wave in 2019 (Burgess and Edmunds 2021). The response to this last disturbance was also spatially heterogeneous, with some reefs experiencing very high levels of coral mortality and other reefs experiencing minimal mortality. Variation in the responses of reefs to these disturbances is linked to spatial heterogeneity in factors driving the decline and recovery of corals, including seawater temperature, nutrient pollution, and the availability of coral larvae to reseed the reef. However, patterns are complex and a better understanding of the spatial patterning of coral decline and recovery and the multiple interacting factors driving coral dynamics is needed. To further this goal, we seek to develop a platform where multiple different datasets can be integrated and visualized to better understand spatial heterogeneity in benthic community dynamics and environmental drivers on the reefs of Moorea.

Equity

Coral reefs in Moorea provide numerous ecosystem services to the local community and are a culturally significant resource to the Polynesian people (Rassweiler et al. 2020, Hunter & Lauer 2021, Nassiri et al 2021). For example, two thirds of the households report engagement in the local-scale lagoon fishery (Rassweiler et al. 2020). However, the Polynesian community in Moorea has been historically marginalized from local marine management decision-making (Hunter, 2017, Hunter et al. 2018). This is changing, with local environmental groups and fishing cooperatives increasingly engaged in marine management decisions. For example, local fishing associations on Moorea (and elsewhere in French Polynesia, Filous et al. 2021) are spearheading rotating fishery closures, or rahui, a form of traditional fisheries management employed by Polynesian societies. Our interactive web-based application can empower these local groups by helping community members visualize areas that may be more or less vulnerable to climate-associated threats like heat waves and coral bleaching, as well as areas that may be most vulnerable to local stressors such as nutrient input, or overharvesting of herbivorous fish. By helping identify potentially vulnerable and resilient reefs, our web-based application will help facilitate

community-based, bottom-up management of coral reef ecosystems in Moorea to the benefit of a historically marginalized population.

Data

To advance understanding of the multiple interacting factors driving coral dynamics in Moorea, in 2016 the MCR LTER established a spatially intensive sampling regime across a grid of approximately 200 sites in the shallow lagoons surrounding the island. This undertaking has produced a number of spatially-rich datasets (Burkepile and Adam 2019, Donovan et al. 2020, Adam et al. 2021) that describe, for example, nutrient enrichment and coral bleaching (Figure 1). The MCR LTER also has a rich time series, dating back to 2005, for a large number of different biological and physical variables collected at 18 sites around the island. These data are publicly available via the MCR LTER data catalog (http://mcr.lternet.edu/data), the Environmental Data Initiative data portal (https://portal.edirepository.org/nis/home.jsp), and the DataONE data portal (https://search.dataone.org/data).

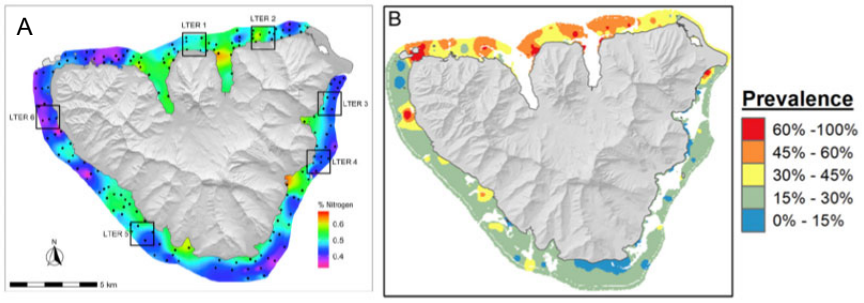

Figure 1. Interpolations showing spatial patterns of (A) nitrogen enrichment and (B) coral bleaching in the shallow lagoons surrounding Moorea, based on samples from 180 sites.

Possible Approaches

A possible approach is to create an interactive web app from R using R Shiny (https://shiny.rstudio.com/) and/or leaflet (https://rstudio.github.io/leaflet/). R Leaflet can be used to create interactive heat maps of spatially explicit data. R Shiny can be used to create interactive data visualizations of temporal data. Both packages can be used to combine results to create an all-encompassing interactive web-based platform that can be used as a tool for data visualization.

Another possible approach is to use ArcGIS Field Maps platform (https://www.esri.com/en-us/arcgis/products/arcgis-field-maps/overview)

Deliverables

We will develop a flexible platform for visualizing geo-spatial data from the lagoons of Moorea. The project will initially be tailored to visualize data on nutrients and coral bleaching from a sampling grid of ~ 200 sites, with the potential for future iterations to build on this platform by including more data layers and additional functionality. Future iterations would include the ability to incorporate and display additional ecological and environmental time series data streams collected by MCR researchers, tools for visualizing correlations among variables collected at different spatial and temporal scales, and the ability to interface with a mobile device. A design and implementation plan, technical documentation, and two presentations will be completed during this project.

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Budget

Funding for the project beyond what is provided by the Bren School to the participating students should not be needed for the project. However, the MCR LTER project would cover any additional incidental costs such as for software acquisition, computer supplies, etc. if needed.

Timeline

This project will last for five months, beginning at the start of the winter quarter in January 2022. Anticipated timing of project milestones is shown below

Project Milestone	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022
Refine project objectives					
Develop design and implementation plan					
Present design plan to Bren faculty					
Create and document web-based application					
Review progress with MCR client					
Refine application based on feedback from client					
Present final product to the public, MCR client, and Bren community					