

# Developing a Geospatial Model for Kelp Forest Management and Restoration

**Authors:** Jessica French, Masters in Environmental Data Science Student, University of California Santa Barbara (UCSB) Bren School of Environmental Science & Management  
Jfrench@bren.ucsb.edu | (541) 961-2472

Natalie Dornan, Ph.D. Student, UCSB Interdepartmental Graduate Program in Marine Science  
[nataliedornan@ucsb.edu](mailto:nataliedornan@ucsb.edu) | (805)-235-3135

**Project Clients:** Natalie Dornan, Ph.D. Student, UCSB Interdepartmental Graduate Program in Marine Science  
[nataliedornan@ucsb.edu](mailto:nataliedornan@ucsb.edu) | (805)-235-3135

Courtney Schatzman, Ocean Rainforest, Inc.  
[courtney@oceanrainforest.com](mailto:courtney@oceanrainforest.com) | (619) 886-2443

## Objectives:

Kelp forests are some of the most productive and biodiverse marine ecosystems in the world.<sup>1</sup> Unprecedented declines in kelp abundance and health since 2014 have increased the urgency in developing innovative management strategies and tools.<sup>2</sup> Understanding the conditions in which kelp survive and thrive is critical for both the management of natural kelp forests and increased understanding of kelp forest aquaculture farms..

**The goal of this project is to generate a management tool in the form of an interactive map that will link trends in water quality, oceanographic conditions, and nutrient biogeochemistry to kelp forest health,** ultimately identifying situations in which kelp health is promoted or inhibited. Ocean Rainforest, a local Santa Barbara seaweed aquaculture farm, is interested in developing such a tool to better understand the environmental conditions surrounding the growth of kelp for their business, and to identify other areas in the Santa Barbara Channel (SBC) that are suitable for restoration or citing of new farms. To create this tool, we will:

1. **Synthesize existing data** sets from the Santa Barbara Channel to analyze spatial and temporal patterns of water quality, climate, and kelp variables (e.g. areal density, growth, and primary production).
2. **Generate a dynamic, interactive, and open-source, geospatial model** to identify locations where kelp productivity and growth are optimized with the goal of identifying sites for kelp restoration in the future.

## Significance:

The ecosystem services provided by kelp forests are numerous. They create vertical habitat that support high biodiversity, complex food-webs, and benefit coastal communities economically and culturally.<sup>1,2</sup> A series of events on the west coast of North America between 2013 and 2017, including a historic marine heat wave in the midst of a severe El Niño (2015-2016) and mass mortality of sea stars from sea star wasting disease (2013 to present), led to dramatic declines in kelp canopy cover and an increase of urchin barrens in California.<sup>2-4</sup> These declines highlighted severe knowledge gaps in kelp forest ecosystem

dynamics including how spatial variation in bottom-up drivers impact kelp forest health and distribution for assessment and planning of kelp management and restoration, particularly in future climate scenarios.<sup>2-6</sup>

Kelp beds house the potential to help mitigate impacts felt by climate change through blue carbon storage. Vegetated coastal ecosystems (seagrass beds, mangroves, and salt marshes) sequester more carbon dioxide proportionally compared to terrestrial ecosystems.<sup>7</sup> There is additional evidence that suggests macroalgae ecosystems sequester carbon at a higher rate than traditional vegetated coastal ecosystems through the process of sedimentation and transport of organic carbon to the deep sea.<sup>8</sup>

With the myriad threats to kelp forests, their ecological importance and potential to mitigate impacts of climate change, kelp forest management and restoration is imperative. With limited resources available it is important to apply them where the impact will be greatest.<sup>2,9</sup> **The tool developed through this project will aid in identifying factors important for healthy kelp forests and areas that have the greatest potential for management and restoration resources.**

### **Background:**

Primary responsibility for management and monitoring of kelp forests in California rests with the California Department of Fish and Wildlife (CDFW) and the Ocean Protection Council (OPC) with additional support from academic institutions and non-profits.<sup>2</sup> Management strategies include implementation of marine reserves, limiting commercial kelp harvest, and long term monitoring. The Santa Barbara Channel is home to the Santa Barbara Long Term Ecological Monitoring (SB LTER) site, Channel Islands National Marine Sanctuary, and several state marine protected areas.

The Kelp Recovery Research Program supports numerous projects aimed at increasing understanding of kelp forest dynamics and the effectiveness of restoration methods.<sup>2</sup> One of these projects, *Where, when and how? A guide to kelp restoration in California using spatio-temporal models of kelp dynamics*, will create a restoration guide for resource managers but does not include the interactive mapping tool that we propose.<sup>10</sup> The Nature Conservancy, Woods Hole Oceanographic Institution, University of California, Los Angeles (UCLA), and University of California, Santa Barbara (UCSB) have developed a web map of kelp canopy cover, available at [kelpwatch.org](http://kelpwatch.org).<sup>11</sup> This groundbreaking project does not incorporate variables that impact kelp forest health or growth as we propose to do.

### **Equity:**

While this project does not directly address (in)equity, its potential to improve management and restoration outcomes for kelp forests would provide economic, cultural, and environmental benefits to all stakeholders.

### **Available Data:**

Data for this project is available through a variety of long term monitoring projects including [Santa Barbara LTER](#), [National Center for Environmental Information](#), and [Kelp Forest Community Monitoring through the National Parks Service](#). Through these data portals we will have access to a range of

oceanographic (temperature, salinity, chlorophyll a, turbidity, etc.), climate (Southern Oscillation Index), and kelp variables (areal density, growth, and primary production) in the Santa Barbara Channel.

### **Computational Tools and Needs:**

- Data will be stored on a UCSB Box Folder shared with the group. This will ensure all group members have access and there is adequate storage space.
- Data processing and wrangling will be handled in R as it provides a great deal of functionality and tools for working with different data types from different organizations.
- Analysis and geospatial modeling will also be carried out in R as it provides many different mapping tools and packages. Additionally, R has the capability to be used with Maxent which would broaden our ability to model environmental niches.
- The repository for the project will be hosted on GitHub which will allow for collaboration and maintenance of the open source ShinyApp resulting from this project.

### **Possible Approaches:**

- The first stage of this project will be identifying the exact data sets to use that can be synthesized to provide information on a range of variables that impact kelp forest health.
- Following data set identification, we will need to develop a workflow for wrangling the data into a common format that can be represented in a geospatial model.
- Analyses of how different variables impact the potential for an area to support healthy kelp forests could be carried using maxent.
- Additional mapping tasks including an interactive map could be accomplished using a geospatial analysis package in R such as leaflet or tmap.

### **Deliverables:**

Through this project we will produce a **synthesized data-set of variables that influence kelp forest health** (including oceanographic, climactic, and ecological variables) from existing data in the Santa Barbara Channel. Additionally, we will create a **geospatial model** in the form of an interactive map that visualizes these factors in the Santa Barbara Channel, providing insight into how they interact, and how their geographic distribution can be used to guide management and conservation decisions surrounding California's invaluable kelp forests.

### **Audience:**

The target audience of this tool will primarily be the clients, Ocean Rainforest and Natalie Dornan. The tool developed through this project will aid Ocean Rainforest in demonstrating the feasibility of kelp aquaculture in the SB Channel and increase understanding of kelp forest dynamics, benefiting Natalie Dornan's research. Secondly, it will be designed for resource managers and stakeholder groups working on kelp restoration and management in the Santa Barbara Channel. We will design the end product to be readily available to relevant audiences in the form of an R ShinyApp, made publicly available on GitHub and Natalie Dornan's personal webpage.

## Citations

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October 13, 2022

Bren School of Environmental Science & Management  
University of California, Santa Barbara  
2439 Bren Hall, Santa Barbara, CA 93106-5131

Greetings, Bren Group Project Review Commission —

This letter intends to affirm Ocean Rainforest's commitment to engage a Master of Environmental Data Science team for a proposed project. Ocean Rainforest would like to provide additional information, guidance, and support necessary for these students to successfully engage with the proposed project.

As a brief background, Ocean Rainforest, Inc. is the prime contractor for a multi-year contract funded through the U.S. Department of Energy's Advanced Research Projects Agency - Energy (ARPA-E) [MARINER](#) Program. Under the project heading "MacroSystems," Ocean Rainforest intends to demonstrate the feasibility of cultivating *Macrocystis pyrifera* in the Santa Barbara Channel. Ocean Rainforest, Inc. is a recently formed subsidiary of the parent company – Ocean Rainforest, Sp/F (ORF). Based in the Faroe Islands, ORF brings nearly ten years of experience in offshore cultivation of kelp and other seaweed species. By applying science, innovation, and expertise in growing premium quality seaweed for sale and for research, ORF is internationally recognized as a key pioneer in the developing industry.

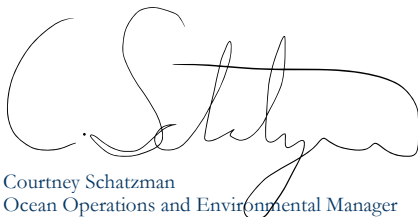
Given ORF's expertise in offshore cultivation, processing, sales, and distribution, Ocean Rainforest, Inc. is well positioned to lead the MacroSystems team in helping build the sustainable seaweed cultivation industry in California. Over the course of the project, our team intends to:

- Support the traditional fishing industry by creating fish habitat and therefore increasing local fish populations
- Improve the health of the marine environment by reducing the amount of excess nutrients in the water
- Reduce ocean acidification by capturing CO<sub>2</sub>
- Encourage economic development in the local community by creating sustainable and reliable jobs

In the context of the Bren MEDS Group Project, Ocean Rainforest, Inc. small team of highly skilled, dedicated, and passionate individuals could provide a transformative foundation for a Bren student interested in supporting the development of the industry.

For now, we appreciate the opportunity to be considered as a client for the group project proposed herein. The Ocean Rainforest team has enjoyed working with Jessica French and Natalie Dornan and hopes to continue our collaboration in the weeks and months ahead.

Sincerely,



Courtney Schatzman  
Ocean Operations and Environmental Manager  
[Ocean Rainforest, Inc.](#)  
1117 State St, Santa Barbara, CA 93101  
[courtney@oceanrainforest.com](mailto:courtney@oceanrainforest.com) | (619) 886-2443