I. Title Page

a. Type of Proposal: **Proposal Development**

b. Title of proposal: **Response of kelp forest communities to disturbance**

c. **Alison Haupt, Ph.D.**

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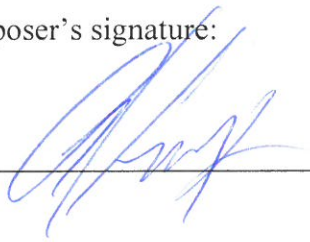
e. Project period of the proposal: award date through 5/31/2018

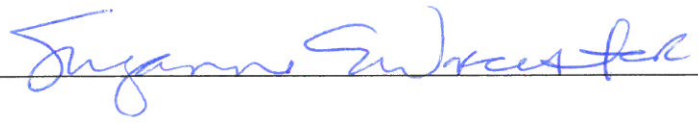
f. Amount of funding requested:

$8,892.66

g. Proposer's signature:



h. Department Chair signature:



i. Dean signature:

II. Abstract

Coastal communities rely on oceans for many vital ecosystem services. Local beaches provide recreation, supporting large economies based on tourism. However, increases in anthropogenic stressors, including climate change, is degrading these ecosystems and could be reducing the effectiveness of the services we depend on. Giant kelp (*Macrocystis pyrifera*), is a large canopy forming algae that creates an underwater structural habitat for a wide diversity of invertebrate, fish, and algal species. Not only are kelp forests the foundation for impressive biodiversity, but they also support extensive tourism and fishing economies in California. This project proposes to examine the response of kelp forests and associated communities to anthropogenic impacts and disturbances. This proposal will join a larger global network of kelp forest ecologists: the Kelp Ecosystem Ecology Network (KEEN) to examine the response to disturbance and raising temperatures, by implementing a standardized experimental kelp removal that will be replicated in kelp habitats globally. The data collected through the objectives will provide essential preliminary data for a larger NSF proposal for the global KEEN project. This project is ideal for the FIG program: 1) it is a tractable project that can be completed during the given timeframe but requires a small amount of seed funding to allow time for completion and funding for a CSUMB student, 2) favorable reviews from a previous NSF proposal for the larger global project pointed out the need for preliminary data from these kelp removals, and 3) to serve a larger number of CSUMB students I will also use data collected from this project to create an authentic data-driven module for my MSCI 340 Marine Ecology class that will provide 300-level students with an opportunity to cement the quantitative skills they've learned in previous classes.

III. Project Description

A. Introduction

Kelp forests are important foundational species that support a wealth of biodiversity and underlie coastal fishery and tourism economies (Graham 2004; Steneck et al. 2002). As a foundation species, kelps provide 3-D habitat in nearshore coastal ecosystems that support a wealth of species including abalone, rockfishes, sea otters, sea lions, among many others. Understanding how these important ecosystems will respond to future ocean conditions from climate change and other anthropogenic impacts will be paramount to effectively managing coastal resources. I am joining forces in a global network of kelp forest ecologists (Kelp Ecosystem Ecology Network: KEEN), to study how kelps respond to disturbance and changing temperatures across their entire range. Because we cannot locally manipulate coastal temperature, we will employ a standardized global sampling scheme and use geographic locations with different temperature regimes as a stand-in for warming temperatures to see how kelps will respond to warming waters and increasing levels of disturbance. Through standardized protocols, we will mimic disturbances by removing kelps and documenting how kelps and their associated communities recover post disturbance.

Through the Faculty Incentive Grant, I will work with collaborators to establish local experimental plots of the standardized KEEN protocols. This will allow me to explicitly test the response of kelps and their associated communities to large disturbances that cause the removal of kelp plants. Establishment of a KEEN site here in Monterey Bay will provide necessary preliminary data for a future NSF grant with other KEEN collaborators. Leveraging this global network will allow us to answer questions at a much larger spatial scale than what would be possible individually. The data garnered through the larger project is needed for effective and sustainable management of coastal kelp forest ecosystems in the face of climate change. FIG funds will help me develop an externally funded research program that will inform coastal management and involve CSUMB students at multiple levels: through classes like marine ecology, future capstone classes like kelp forest ecology, and also independent student projects.

B. Literature review and background information

Coastal communities rely on oceans for many vital ecosystem services (Guerry et al. 2012). Local beaches provide recreation, supporting large economies based on tourism. Coastal fishermen depend on healthy ecosystems for fisheries. Coastal zones can even provide large-scale protection from storms and hurricanes (Barbier et al. 2008). However, increases in anthropogenic stressors, including climate change and development of coastal zones, is degrading these ecosystems and could be reducing the effectiveness of the services we depend on (Halpern et al. 2008; Halpern et al. 2009; Arkema et al. 2013; Jackson et al. 2001). **The objective of this project is to understand how kelp forests are affected by disturbance and climate change. This will enable me to participate in a global network of kelp ecologists: KEEN http://www.kelpecosystems.org/). Currently I am the KEEN regional coordinator for Central California and the Pacific Northwest and will be coordinating and leading standardized monitoring of kelp forests. This proposal will provide necessary preliminary data for an NSF proposal with J.E. Byrnes to provide funding for the larger KEEN project.**

Roughly 25% of the world's coastlines are dominated by kelps (Steneck et al 2002, Cavanaugh Unpublished Data). Kelps provide numerous ecosystem functions and services. On the east and west coasts of North America, kelps – seaweeds that form the foundation of many temperate rocky ecosystems – could be a useful ecosystem indicator to measure the effects of anthropogenic stressors on temperate marine ecosystems and the services they provide (Smale et al. 2013). Kelps provide many ecosystem functions and services: food for a wide variety of species (Duggins et al. 1989; Krumhansl and Scheibling 2012), alteration of water flow around shorelines (Gaylord et al. 2009), habitat to a variety of commercially important species (Carr and Syms 2006), influence marine nutrient cycling (Krumhansl and Scheibling 2012), and many others (see Dayton 1985 for a thorough review). Because of this service provision, changes in kelp abundance are likely to cause major changes to coastal ecosystems and the human communities who rely on them. Kelps also exhibit non-linear responses to disturbance and change (Steneck 2012; Steneck et al. 2002; Estes and Palmisano 1974), which further makes them an appropriate indicator for large-scale ecosystem change. Historically kelp forests have been negatively impacted by poor sewage treatment facilities during the 1950's in southern California (North 1964). Overfishing associated with proximity to coastal populations can also reduce apex predators and thus increase herbivory and lead to deforestation of kelp forests (Steneck et al. 2002). On the west coast of the United States kelp distribution and abundance shows a negative correlation with population density (B. Feist unpublished data).

Kelps are particularly susceptible to changes in ocean temperature due to their physiological and ecological dependence on cold water. Kelps equatorward range limits are set by a combination of physiological tolerance of adults (Lüning 1984, Hatcher et al. 1987), limits to reproduction, tolerance of gametophytes, failure of recruits (Ladah et al. 1999), and nutrient availability (Dayton 1985) which often correlates with temperature (Deysher and Dean 1986). Changes in temperature threaten to act on any and all of these. In particular, temperature induced decreases in growth and reproduction in kelps suggest that increases in temperature may inhibit kelps ability to recover from strong but local short-term disturbances (Wernberg et al. 2010). If kelps are not able to recover from a strong short-term disturbance, then the ecosystem may shift into one of several alternate states dominated by sea urchin barrens (Harrold and Reed 1985), algal turfs (Connell et al. 2008), foliose understory algae (Arkema et al. 2009), sessile suspension feeders (Rassweiler et al. 2010) and more. Each of these alternate community states has radical implications for all species in the kelp forest food web. Indeed, changes in the food web may help to force and maintain these new alternate states (Estes and Palmisano 1978).

We have already witnessed climate change related impacts on kelp forests in nearly every region of the globe. In Australia, climate change has hindered kelp recovery from heat waves (Wernberg et al 2010), caused range shifts in giant kelp (Merzouk and Johnson 2011), facilitated range shifts of urchin herbivores (Ling et al. 2009), and has been implicated to interact with urbanization to alter the relative competitive superiority of kelps and algal turfs (Connell et al. 2008). In Norway, warming waters have facilitated epibiont growth, a dominance of ephemeral algae and large-scale kelp die-offs (Moy and Christie 2012). Similarly, in the eastern North America, warmer waters have been linked to the success of epibionts (Krumhansl & Scheibling 2011) and increases in herbivore

grazing rates (Krumhansl & Scheibling 2011), which cause kelp canopy defoliation. Open space on the substratum may then be rapidly colonized by invasive algal species that prevent the recruitment of kelps (Levin et al. 2002, Scheibling & Gagnon 2006). We are also beginning to see range shifts in southern Europe as climate drives shifts in kelp biomass (Pehlke and Bartsch 2008, Fernandez 2011, Tuya et al. 2012) and reproduction. Last, in the exception that proves the rule, climate change has led to shifts in oceanography that have caused waters around South Africa to become colder, and thus actually has led to kelps marching towards the equator (Bolton et al. 2012). Climate-related impacts to foundation species, species that provide food and habitat for entire ecological communities, are likely to be especially consequential due to the critical influence these species have on ecosystem structure and function (Ellison et al. 2005). *Macrocystis pyrifera,* commonly known as giant kelp, is a classic example of a foundation species and supports one of the most productive and valuable coastal ecosystems in the world. However, giant kelp is particularly sensitive to changes in environmental conditions, and climate change has already impacted the abundance and distribution of giant kelp forests globally.

KEEN is a global network of kelp biologists that seeks to answer the questions of how temperature affects the ability of kelps to respond to disturbance. To answer this question KEEN is implementing standardized experimental kelp removal plots to track recovery and response to disturbance of kelp forests and their associated communities across a wide range of temperature regimes that span the thermal tolerances of kelps. I helped to lead the first implementation of these experiments in the Gulf of Maine and will now implement, in coordination with collaborators at Moss Landing Marine Lab and Hopkins Marine Station, experimental plots in Monterey Bay California. **These experiments will provide experience for students through fieldwork, lab work, analysis, and will provide a platform for potential independent student projects and a future capstone (project-based) course at CSUMB.**

C. Statement of need and importance of project

This project will support collection of preliminary data about how kelp forest communities respond to disturbance. Previous submissions of this project with collaborators to the National Science Foundation, have received positive reviews, but reviewers pointed out the need for further preliminary data. To that end, regional collaborators are working to separately fund pilot projects to collect necessary preliminary data that would strengthen a future NSF proposal. The start-up funds I received from CSUMB have been used to purchase equipment needed for this project, but cannot be used for PI or student time required for this project. The FIG is crucial for me to support a student working on this project and to allow me the time to work on grant writing, which must happen during the semester when – in the absence of any buy-out – most of my time is dedicated to teaching.

With funding, I will contribute to global research program that examines the consequences of controlled and natural disturbance on kelp forests across thermal gradients within different biogeographic regions. This will enable us to build models to tease apart the role of temperature change *per se* versus local species-specific effects on

the response of kelps and their communities to disturbance to better understand the effects of future climate change on these important ecosystems. This project is also timely here in Monterey Bay: some local kelp forests are beginning transition to urchin urchin barrens has purple sea urchins have become more common on the central coast (Pers observation, Pearse, J and Watanabe, J pers comm).

D. Project goals and objective

The goals/objectives of this project are to:

1. Establish and monitor a standardized KEEN experimental removal and control plots in Monterey Bay in collaboration with Dr. Fiorenza Micheli at Hopkins Marine Station and Dr. Scott Hamilton at Moss Landing Marine Lab.
2. Contribute to a large global effort through the KEEN network to answer 3 questions:
    a. How will increases in mean temperature affect the ability of kelp forest communities to recover from disturbance?
    b. How will average temperature interact with disturbance common to all areas to affect kelps and associated communities?
    c. Are these effects system specific, or are they general across all global temperate rocky reefs?
3. Use these preliminary data to apply for NSF (deadline February 2018) and California Sea Grant (preproposal deadline March 2018).

E. Enhancing long-lasting scholarly professional growth

I am excited to lead an effort here in Monterey Bay to contribute to the understanding of how kelp forests will respond to and potentially recover from climate change and other disturbances. Currently, I serve as the regional coordinator for the KEEN program and work with other kelp forest ecologists locally and globally. By implementing these standardized removal experiments at a global scale, we will be able to test the response of kelp forest communities to disturbance across the range of kelp's thermal gradients, which will allow us to extrapolate potential response of kelp forest communities to warming ocean conditions. Not only will this project contribute to the larger global KEEN network, but it will also provide me with a platform for my future kelp forest ecology research program here in Monterey Bay. These removal experiments will be maintained long-term with local collaborators and will also be used to support other small independent projects for future undergraduate and graduate students. For example, a student could use these removals to test for how presence of kelp in rocky substrate affects recruitment of different invertebrates and fishes.

Additionally, balancing teaching with starting a research program is challenging, particularly when combined with being on maternity leave my 3rd semester at CSUMB. As a subtidal researcher, this problem is exacerbated because one cannot conduct subtidal research while pregnant and so I had to postpone starting this portion of my field research program before being on maternity leave. Funding through the FIG program will be essential for me as an early-career female researcher to overcome some of the biological barriers I have encountered to starting this project.

F. Student involvement description

The FIG will fund one student who will contribute to field work and analysis of this project. This project will give a student an authentic research experience where they can contribute to a larger global project and also have the potential to implement their own smaller project. CSUMB has a large contingent of scientifically certified SCUBA divers, but there is a dearth of projects for these highly motivated students to work on. This project and future offshoots of this project would help fill this gap. Throughout my 2 years at CSUMB, I have successfully mentored undergraduates including UROC scholars, UROC researchers, students completing independent projects, and a CSUMB REU student. Nearly all of these students have gone on to present their projects at CSUMB research showcases and at regional marine ecology conferences. This project would give the student an opportunity to be involved with a project from the beginning through analysis and communication of results and I would encourage the student to present his/her results at a regional conference.

I will also use the preliminary results from this project to create a module for my MSCI 340 Marine Ecology class that will give students a chance to work with data in an ecological context. Many of our MSCI students at CSUMB struggle with quantitative and statistical skills. In the lab for MSCI 340, I place an emphasis on using data in a hands-on manner that gives students opportunities to practice skills learned in other classes including STAT 250 and MSCI 350. It's important that students practice skills learned in these statistics classes in their upper division courses to solidify their statistical foundations. This project will also serve as a pilot for a future group capstone class that I will develop centered on Kelp Forest Ecology. This will be another opportunity for students to make use of their scientific diving skills. Future proposals based on preliminary data from this project will also provide funding for more CSUMB undergraduates.

G. Reference List

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IV. Activity Plan/Methods/Project Design and Timeline.

The goal of this FIG grant is to establish one KEEN standardized removal site in Monterey Bay that will contribute to a larger global effort to examine the effect of disturbance on kelp forest communities. This effort will provide necessary preliminary data for a large collaborative NSF grant. The larger KEEN project will improve our understanding of how economically and ecologically important kelp forest ecosystems will respond to future climate change. This work will also solidify local collaborations with Hopkins Marine Station and Moss Landing Marine Lab.

Work plan

Site Selection:

Site will be selected to be of moderate wave exposure relative to the region and will have continuous kelp habitat between 8-12m. Sites will be selected that have relatively good initial kelp densities, although initial density will be used as a covariate. So that the process is comparable to the global KEEN network, we will use these standardization choices to make our results broadly comparable between regions without having to incorporate an excessive number of covariates. The CSUMB student funded through this project will work with me to do reconnaissance dives to identify a suitable site that has continuous rocky substrate and is large enough for the 3 control and 1 removal sites.

Site layout:

At a single site, we will locate four plots along a 60m transect (Figure 1). One of these plots will be chosen at random as the removal plot. The other three will serve as controls. The transect will run alongshore, with depth held relatively constant.

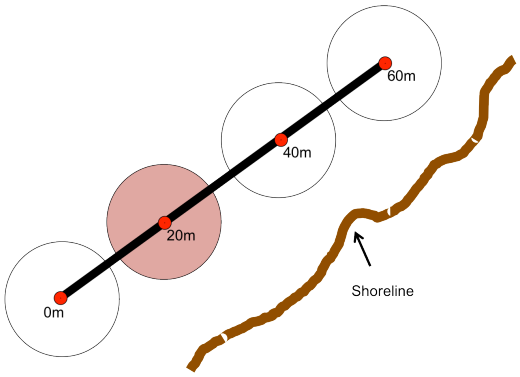

Figure 2: Layout of the experimental and control plots for the KEEN removal. For each replicate (3 controls and 1 experimental plot), location of the experimental plot will be chosen at random.

Pre and post removal sampling protocol:

We will sample twelve 1m^2 quadrats in the center of each plot (Figure 2). In each plot, we will count the abundance of kelps and estimate the cover (point-contact-method) of other large algae, and sessile invertebrates. We will also measure densities of mobile invertebrates. In experimental plots we will then remove the major structure-forming kelps in a circle 8m in radius (roughly 200m^2) by clipping them just above their holdfast, as kelps meristems are located just beneath their blades. This method will simulate kelp die back without leading to disturbance of other sessile species. A temperature logger will

be placed in the middle of the control plot. We will also sample in the same way (without removing kelp) in 3 control plots for each experimental plot. See Figure 2 for the experimental design layout. All plots will be resampled using the same methods every three months to track any changes.

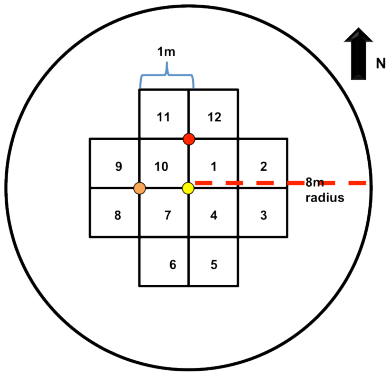

Figure 1: Sampling design for the removal and control plots for the KEEN project. Each square represents a $1m^2$ quadrat where mobile benthic invertebrates and fishes will be counted individually and algae and sessile invertebrates will be counted using Unit Point Contacts (UPCs). Each plot is a circle with an 8m diameter (note the figure is not to scale) to create a large buffer area between the experimental survey area and the edge of the removal because of shading effects from large canopy-forming kelp plants.

Analysis:

For our analyses, we will examine the relationship between temperature relative to thermal limit of the kelp species removed and three variables: 1) response of kelp abundance to manipulation relative to control, 2) response of non-kelp algal percent cover, and 3) response of sessile invertebrate cover. We will also examine change in mobile invertebrate abundance.

Timeline

Month	Task
April 2017	Identify undergraduate student that will be supported by this project. Schedule sampling days Create data sheets specific to Monterey Bay
May 2017	Train students. Field work to identify location of experimental plots Refine data sheets post dives
June 2017	Initial sampling of experimental removal plots for baseline data Removal of kelp from removal plot
July 2017	Re-evaluate data sheets and species lists Enter data and create workflow for analysis Start conversations with collaborators about NSF Grant
September 2017	Resample plots 3 months post kelp removal Start introduction for NSF grant with collaborators
October 2016	Enter data and preliminary analyses of changes Create module for MSCI 340 based on collected data Write budget for NSF proposal
November 2016	Begin preproposal process for CA Sea Grant Write methods for NSF proposal
December 2016	Resample plots 6 months post kelp removal Write broader impacts for proposal
January 2016	Send drafts of CA SG proposal and NSF proposal to outside readers for feedback
February 2016	Submit proposal to National Science Foundation Biological Oceanography program and pre-proposal to California Sea Grant.

V. Likelihood of External Funding

I am a third-year tenure-track Assistant Professor in Marine Science at CSUMB and am working to establish a research program here at CSUMB. Currently I have one successful externally funded grant through the NASA NSPIRES program that is funding a collaborative project with University of Massachusetts Boston, UC Los Angeles, and the Zooniverse (zooniverse.org). This project will establish a work flow for improving access to NASA landsat data and strengthen our citizen science work through Floating Forests (floatingforests.org) and creation of curricula for high school and college students. I also have a collaborative NSF grant that is currently pending. This proposal is with collaborators at University of Washington and UC San Diego and would fund a project to use population genetics to assess the response of parasite populations to changes in biodiversity. This project would fund 5-6 CSUMB undergraduates to complete Research Internships in Molecular Ecology, which will provide these students with fundamental skills that will enhance opportunities for graduate school and jobs post graduation.

Additionally, a previous version of this proposal was submitted to NSF with collaborator Dr. Jarrett Byrnes (University of Massachusetts Boston) and the proposal was well received. However, reviewers wanted to see more preliminary data as a proof of concept that the KEEN network would be able to establish experimental plots. **Thus, the collection of preliminary data funded through this FIG grant is essential to support a successful larger NSF grant with these collaborators.** These data would also support a proposal to CA Sea Grant with collaborators at Moss Landing Marine Lab, CSU San Diego, and Stanford University to separately fund local KEEN work.

External Funding Opportunities:
Sponsor name: National Science Foundation
Program title: Biological Oceanography Program
RFP web address: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=11696
Deadline: February 15, 2018
Date range: 3 years after award is made (~Summer/Fall 2018 - 2021)
Funding range: ~$100K-$900K

Sponsor name: California Sea Grant College Program
Program title: Special Focus Awards for New Faculty Members
RFP web address: (from previous deadline) https://caseagrant.ucsd.edu/grants-and-funding/call-for-preliminary-proposals-2018#preproposal-guidelines
Deadline: Preproposal date March 2018
Date range: February 1, 2019 – February 1, 2020
Funding range: $125,000

Biosketch

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PROFESSIONAL PREPARATION:

Undergraduate: University of California, Santa Barbara, Santa Barbara, CA, Biology, B.A., 2003.

Graduate: Stanford University, Stanford, CA, Biological Sciences, Ph.D., 2011.

Postdoctoral: West Coast Governors Alliance on Ocean Health Sea Grant Fellow, 2011-2013; University of Massachusetts Boston, Boston, MA, community ecology of kelp forests, 2013-2015.

APPOINTMENTS:

Assistant Professor, California State University Monterey Bay, 2015-present.

SELECTED PUBLICATIONS:

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Samhouri, JF, AJ Haupt, PS Levin, JS Link, R Shufford. 2013. Lessons learned from developing integrated ecosystem assessments to inform marine ecosystem-based management in the USA. ICES Journal of Marine Science 71:1205-1215.

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