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PI/PD Name: Kyle C Cavanaugh

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☐

Ethnicity Definition:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
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Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
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White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

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PI/PD Name: Jarrett Byrnes

Gender: ☐ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)
☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☒ White

Disability Status:
(Select one or more)
☐ Hearing Impairment
☐ Visual Impairment
☐ Mobility/Orthopedic Impairment
☐ Other
☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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PI/PD Name: Alison Haupt

Gender: ☐ Male ☒ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)

☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☒ White

Disability Status:
(Select one or more)

☐ Hearing Impairment
☐ Visual Impairment
☐ Mobility/Orthopedic Impairment
☐ Other
☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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PI/PD Name: Laura Trouille

Gender: ☐ Male ☒ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)

- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status:
(Select one or more)

- ☐ Hearing Impairment
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- ☒ None

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List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

Not for distribution

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 15-1

NSF 14-537 **09/03/15**

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

BCS - GEOGRAPHY AND SPATIAL SCIENCES

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1560975

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
09/03/2015	1	04040000 BCS	1352	092530369	09/04/2015 11:16am S

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)

956006143

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

University of California-Los Angeles

AWARDEE ORGANIZATION CODE (IF KNOWN)

0013151000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

11000 Kinross Avenue, Suite 211
Box 951406
LOS ANGELES, CA 90095-2000

NAME OF PRIMARY PLACE OF PERF

University of California-Los Angeles

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE

University of California-Los Angeles
1255 Bunche Hall, Box 951524
Los Angeles ,CA ,900951524 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)
☐ SMALL BUSINESS ☐ MINORITY BUSINESS
☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS

☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **Collaborative Research: Detecting 30 Years of Change in Global Kelp Forests via Remote Sensing and Citizen Science**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 411,055	24 months	05/01/16	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date
PHS Animal Welfare Assurance Number
☒ FUNDING MECHANISM **Research - other than RAPID or EAGER**

☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number
Exemption Subsection or IRB App. Date
☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)

☒ COLLABORATIVE STATUS
A collaborative proposal from one organization (GPG II.D.4.a)

PI/PD DEPARTMENT
Geography

PI/PD FAX NUMBER
310-206-5976

PI/PD POSTAL ADDRESS
1255 Bunche Hall
Box 951524
LOS ANGELES, CA 900952000
United States

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME Kyle C Cavanaugh	PhD	2011	310-794-0102	kcavanaugh@geog.ucla.edu
CO-PI/PD Jarrett Byrnes	PhD	2008	401-529-4104	jarrett.byrnes@umb.edu
CO-PI/PD Alison Haupt	PhD	2011	617-287-5370	ajhaupt@gmail.com
CO-PI/PD Laura Trouille	DPhil	2010	312-322-0820	ltrouille@adlerplanetarium.org
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide,Part I: the Grant Proposal Guide (GPG). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

Certification Regarding Conflict of Interest

The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of AAG Chapter IV.A.; that, to the best of his/her knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in FastLane.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:
(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR)
(This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research.
The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

Certification Regarding Federal Tax Obligations

When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations.
By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:
(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

Certification Regarding Unpaid Federal Tax Liability

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

Certification Regarding Criminal Convictions

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Criminal Convictions:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has not been convicted of a felony criminal violation under any Federal law within the 24 months preceding the date on which the certification is signed.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Tana Y Wong**	**Electronic Signature**	**Sep 3 2015 10:41AM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
310-825-8438	**tanawong@ucla.edu**	**310-206-4453**

PROJECT SUMMARY

Overview:

This project will build on an online interface the PIs recently developed called Floating Forests, which enables volunteers ("citizen scientists") to manually identify giant kelp forests on Landsat satellite imagery. The goal of Floating Forests is to document global changes in giant kelp abundance from 1984 to the present on monthly to seasonal timescales. This project will develop new methods to analyze user interpretations, validate this dataset, and use the data to understand how kelp forests ecosystems are responding to a changing climate. Our proposed research will build on the Floating Forests dataset to address the following questions:

1) How does the accuracy of citizen science based identification of giant kelp canopy compare to existing automated and semi-automated classification methods?

2) How do the abundance and population dynamics of giant kelp vary across its entire global range?

3) What are the primary drivers of variability in kelp forest abundance and how do the relative importance of these drivers vary in space?

Intellectual Merit :

In recent years the exchange of volunteered geographic information (VGI), geospatial data that are voluntarily created by citizens untrained in geography or spatial sciences, has increased exponentially. Examples of VGI include WikiTerra, Openstreetmap, analysis of Sloan Digital Sky Survey imagery, and a number of species occurrence mapping projects. However, these approaches have not been used extensively on the enormous resource of publically available earth observing satellite imagery such as Landsat. This project will develop methods for obtaining, validating, and analyzing volunteered analysis of Landsat imagery by citizen scientists. This work will provide a template for using citizen scientists to extract data from Landsat and other freely available satellite imagery sources (e.g. Google Earth) for a wide variety of applications.

Identifying the controls of giant kelp distributions and range limits will improve our ability to predict how global change will impact this important foundation species. This work will also test a number of general theoretical predictions on the patterns and processes behind species range limits. These empirical tests are made possible by the unprecedented spatial and temporal coverage provided by the Floating Forests data. Ultimately, this project will utilize a unique global timeseries to provide a better understanding of the processes that control the dynamics of an important coastal foundation species, giant kelp forests, across a range of spatial and temporal scales.

Broader Impacts :

The Floating Forests platform provides us with a unique tool to engage and inform the public about the importance of understanding how giant kelp forests are being impacted by global change. We will work with Zooniverse to further develop the outreach components of the platform, which will include tools to visualize giant kelp dynamics and analyze a user’s own classifications, information on giant kelp ecology and conservation, and online forums to promote discussion and interaction between users and the Floating Forests researchers. We also plan to develop a series of educational modules targeted to both K-12 students and undergraduates. These lesson plans will use Floating Forests in the classroom to teach students about satellite imagery analysis, global climate change, and kelp forest ecology. Last, we will work with Zooniverse to create a demonstration of how to create a citizen science project for the classification of large remote sensing imagery data sets by porting Floating Forests to their new open source citizen science project platform.

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Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

1. INTRODUCTION

Climate change is already impacting numerous ecosystems (Rosenzweig et al. 2008). For example, rising temperatures have shifted the abundance and distributions of hundreds of plant species towards higher latitudes and elevations (Chen et al. 2011). 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.

Characterizing these impacts on regional to global scales is often impractical using classic field sampling techniques. Luckily, recent increases in the availability of long-term satellite imagery with global coverage have made it possible to observe kelp forest ecosystems on larger space and time scales. However, extracting meaningful data from the massive amount of available imagery requires new methods and approaches. Many satellite imagery applications, including mapping giant kelp, cannot yet be fully automated, and so these analysis tasks can take large amounts of time and effort. **Here we propose to answer fundamental questions about the biogeography and population ecology of giant kelp at an unprecedented global scale using citizen science classifications of kelp forests from Landsat imagery via our online Floating Forests platform.**

1.1 Online Citizen Science and The Zooniverse

The problem of generating data from imagery that is resistant to computer classification is not unique to remote sensing and online citizen science has often been used to solve this problem. In particular, the online citizen science organization, The Zooniverse, has established a set of methods for high quality citizen science projects capable of collecting data from large sets of imagery.

The Zooniverse arose from an attempt to classify the 893,212 images of galaxies from the Sloan Digital Skies Survey using Hubble's morphological classification system (Hubble 1936). This proved impossible for computers and after two years; expert classifiers were only able to work through ~2% of the generated images. Project scientists created Galaxy Zoo (Lintott et al. 2008), allowing citizen scientists to walk through the simple steps of galaxy classification. The project ultimately generated 48 publications on the science, and numerous others on studying how citizen science works. Its success led to the creation of The Zooniverse, a nonprofit that works with scientists to create new online citizen science projects in disciplines ranging from astronomy to climate reconstruction to deep sea ecology.

In 2013, we approached The Zooniverse with our problem and worked together to create Floating Forests, an online citizen science platform to classify kelp forests from Landsat imagery. Since launching Floating Forests in August of 2014, we've worked with 5,577 citizen scientists who have made 2.14 million classifications of Landsat images of kelp forests in California and Tasmania. The Talk section of the website where project and citizen scientists to talk with each other has 6,871 comments from 237 users. Moreover, we are already been used in the classroom at both the second grade (Wilson 2015) and university level with free curricula provided at Zooteach (Zooniverse 2015a). The platform has also been translated into Spanish and Polish.

1.2 Patterns and processes underlying spatiotemporal patterns in species' abundance

Identifying the controls of species distributions and range limits will improve our ability to predict how global change will impact these distributions. There is a great deal of theoretical work on the controls of range limits, but many of the predictions from these studies remain untested as empirical research has lagged behind these theoretical developments (Gaston 2009, Sexton et al. 2009). It was long widely assumed that species are most abundant at the center of their range with abundance declining towards range edges (Hengeveld and Haeck 1982, Brown 1984, Brown et al. 1995). However, reviews have found limited support for such general patterns in abundance (Sagarin and Gaines 2002a, Sexton et al. 2009). It is unclear whether this lack of support is due to biology or methodological limitations of range limit studies. For example, most studies that empirically examined the abundant center hypothesis undersampled range edges (Sagarin and Gaines 2002a). Further, this pattern could depend on the spatial and temporal scales of observations. The density of local populations might not decrease towards range edges, but this decrease might be apparent at larger scales, representing declining occupancy (Gaston 2009). Abundance might also not decline gradually from range center to range edge. Instead, a drop in abundance might only be apparent at the very edge of the range. Gaston (2009) contrasts this 'rare-periphery' hypothesis with the more common 'abundant-center' hypothesis. However, few studies have empirically examined patterns of abundance across a species' entire range.

Temporal variability in population dynamics could make it difficult to detect spatial patterns of abundance across a species range from observations at a single time point (Sagarin and Gaines 2002b). These 'snapshot' observations might not represent true spatial patterns in abundance. Theoretically, populations near their range limit should experience more temporal variability when environmental fluctuations push these populations past their environmental tolerance limits, but Sexton et al. (2009) found only limited evidence of this pattern.

Theoretical work has demonstrated that gradients in extinction rates, colonization rates, or habitat availability can drive range limits (Lennon et al. 1997, Holt and Keitt 2000, Holt et al. 2005), but variability in these factors has not been observed empirically across a species's entire range. Theory predicts that these three routes to range limitation will produce distinct patterns in the abundance and dynamics of populations. For example, variability is expected to be higher at a range limit set by a gradient in extinction than it is at a limit set by a gradient in colonization (Holt and Keitt 2000). However, again, these predictions have not been tested empirically.

1.3 Giant kelp as a model system

Macrocystis pyrifera is an ideal system to test these theoretical predictions about how abundance and population dynamics varies across a species' range. *Macrocystis* is (1) widely distributed, (2) dynamic, (3) its range can be considered one-dimensional, simplifying the identification of range limits, and (4) its abundance can be monitored with satellite imagery.

Forests of *Macrocystis* are highly dynamic and widely distributed along temperate coastlines around the world. They experience a wide range of environmental conditions such as sea surface temperature (SST), nutrient concentrations, and wave disturbance. Winter storms and swell are an important annual source of plant mortality and recruitment (Dayton and Tegner 1984a, Ebeling et al. 1985, Graham et al. 2007), with variation with differences in depth, substrate and wave exposure (Dayton and Tegner 1984b, Graham et al. 1997). Prolonged periods of warm, nutrient-depleted water such as those associated with El Niño Southern Oscillation (ENSO) events can lead to local (Zimmerman and Robertson 1985, Reed et al. 1996) and widespread (Dayton et al. 1999) kelp loss, and prevent subsequent recovery. Finally, intensive grazing (most notably by sea urchins) can eliminate entire beds (reviewed in Dayton 1985, Foster and Schiel 1985, Harrold and Reed 1985). Individual kelp fronds live about 4-5 months and the entire *Macrocystis* plant has a lifespan of ~2.5 years (e.g., Reed et al 2008). The dynamic nature of kelp at the frond and plant level is illustrated even at regional scales (100s of km) where kelp biomass shows high variability at seasonal, interannual, and decadal scales (Cavanaugh et al. 2011). This high variability means that large fluctuations in range and multiple cycles of local extinction and recolonization can be observed over relatively short timescales (years to decades).

Macrocystis forests often experience cycles of local extinctions and recolonizations. Reed et al. (2006) estimated monthly extinction probabilities ranging from 0.005 to 0.292 (mean ± SD = 0.057 ± 0.063 and recolonization probabilities ranged from 0.023 to 0.200 (mean ± SD = 0.080 ± 0.040). These monthly rates agree with models and observations that suggest kelp forest patches are highly dynamic at the scale of months to years. A 5% monthly extinction rate implies that 60% of the occupied patches will become unoccupied within a year. These high extinction and recolonization rates, combined with the long-term, spatially extensive observations provided by Landsat imagery (see below), provide a unique opportunity to examine how these rates vary across the entire range. This will allow us to test theoretical predictions that link extinction/colonization dynamics to range limitation (Holt and Keitt 2000).

Macrocystis is restricted to shallow (generally < 30 m; Graham et al. 2007), nearshore areas. For practical purposes, its range can be considered one dimensional, simplifying the definition of range limits (Sagarin and Gaines 2002a). The edges of its range can be considered as 2 endpoints rather than a polygon. In a one-dimensional distribution, range area does not increase as a function of distance from range center, reducing bias when sampling the entire range.

An adult *Macrocystis* consists of a bundle of vine-like fronds buoyed by small gas bladders on individual blades and anchored to hard substrate by a common holdfast. Individual kelp fronds grow rapidly (up to 0.5 m/day), and once they reach the surface, fronds grow horizontally and create a dense surface canopy that can cover over 1250 hectares (Fig. 1; Parnell et al. 2006, Dayton 1985). The distinctive surface canopy of giant kelp forms a narrow band that fringes the shoreline and makes kelp forests distinctive when viewed from above, particularly in the infrared spectral region, and suitable for aerial mapping and satellite remote sensing (Jensen et al. 1980, Deysher 1993). We developed a technique to measure kelp canopy area and biomass from Landsat satellite imagery (Cavanaugh et al. 2011). The Landsat program has acquired 30 m spatial resolution, multispectral imagery over the entire globe nearly continuously from 1984 to the present every16-days, which. allows for resolution of giant kelp forests that range in area from 100s to 10000s of m^2. Landsat's repeat time sequence makes it suited to monitor the high frequency cycles of *Macrocystis*. With this dataset we can observe *Macrocystis* populations on seasonal to annual to decadal temporal scales and regional to global spatial scales. This will enable us to develop the most comprehensive dataset of global *Macrocystis* distributions to date, document changes in these distributions over the past 30 years, and monitor variability in the abundance of giant kelp forests across its entire global range.

Figure 1. Aerial view of giant kelp canopy near Santa Barbara, CA, with buoy in foreground and boat in background for scale. Photo credit: Santa Barbara LTER

<u>2. OBJECTIVE 1 – Process and validate Floating Forests citizen science *Macrocystis* data</u>

At its simplest level, Floating Forests is a website collecting coastal Landsat images that citizen scientists look at and circle kelp beds. To use of this data for analyses, we must validate (1) the accuracy of the kelp bed selection by citizen scientists and (2) that kelp identified in Landsat images accurately reflects the true abundance of kelp. While identified kelp is certainly present, issues of differences in satellites, post-processing, and local conditions could cause error in our abundance estimates. With Floating Forests data, we can model and correct for both sources of variation before analysis. We can also expand Floating Forests beyond *Macrocystis* so that we can evaluate the utility of remote sensing for other kelp species.

2.1 How does Floating Forests work?

Floating Forests was built to identify giant kelp canopy from Landsat Thematic Mapper (TM) and Operational Land Imagery (OLI) satellite imagery. These sensors provide the spatial resolution to resolve giant kelp beds that range from 100s to 10000s of m^2 (Cavanaugh et al. 2011). Landsat's rapid repeat time makes it perfectly suited to monitor variability in giant kelp on seasonal to annual to decadal time scales.

We split each Landsat scene into 400 images of equal size along a 20 x 20 grid (~131 km^2 per image). When available, we record the angle of the sun hitting the water. Each image is put into the Floating Forests queue. When a user logs onto the site, they are shown a new randomly selected image. After a brief tutorial, users are asked to circle any kelp beds they see before going to the next image. Users also note whether clouds are present in the image and can skip the image if no kelp is visible.

Floating Forests uses consensus-based classification to ensure that we accurately detect kelp in images (Fig. 2). *Every image in Floating Forests is seen at least four times.* If after four, no one has noted any kelp, the image is retired. If any one of the first four viewers circles some kelp, the image is retained.

Images where kelp is seen by at least one user are seen by a total of fifteen users before being retired. Once an image is retired, we take the classifications by all users, overlay them, and generate a consensus map of what 30 x 30m pixels users would classify as kelp. This is the raw data we will transform into kelp areal cover for the image.

2.2 Objective 1A: Validation of Citizen Science Classifications

Our first question is how many users must identify a pixel as containing kelp before we are confident that pixel is kelp. Sometimes users will select clouds or other features, either on purpose or through a stray mouse click. Consensus identification is critical (Fig. 2C). Consensus thresholds may also change by region. Some regions contain either multiple canopy-forming species or the morphology of canopy formers may differ within the same species from region to region. To assess the proper user threshold needed to classify a pixel as kelp before estimating aerial coverage of kelp, we will compare user classifications to geospatial data provided by validated data sources for each region (Table 1).

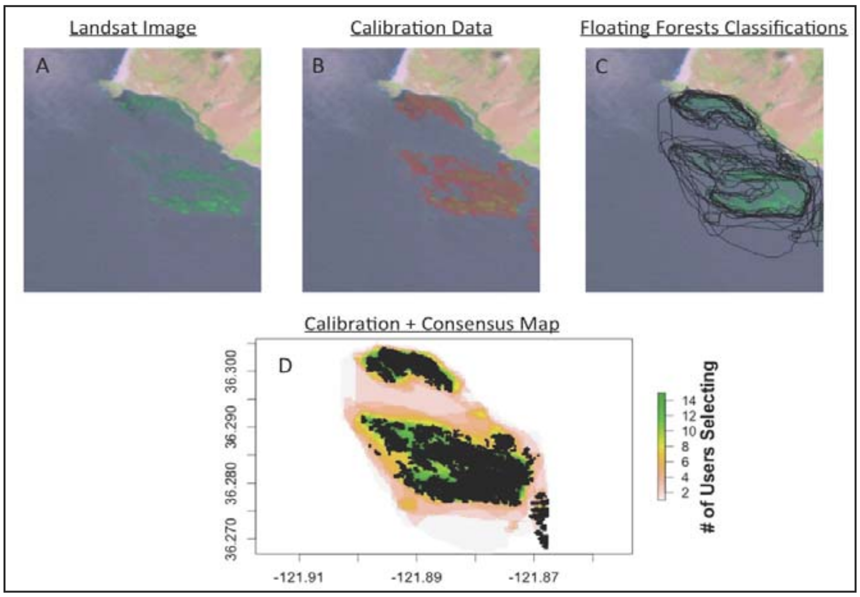

Figure 2. Comparison of calibration and Floating Forests data. A) Image taken from Landsat scene and used in Floating Forests. B) Image with calibration data from Cavanaugh et al 2011. C) All classifications from fifteen users from Floating Forests. D) Consensus map from Floating Forests (colors) overlaid with calibration data (black points).

To determine the threshold number of users, we will overlay classifications on calibration data and ask at what number of users classifying kelp (Fig. 2D) do we obtain a) the most similar estimate of kelp area as the calibration set (Figure 3A) and b) a >50% probability of a pixel actually containing kelp (i.e., better than random) using logistic regression (Figure 3B).

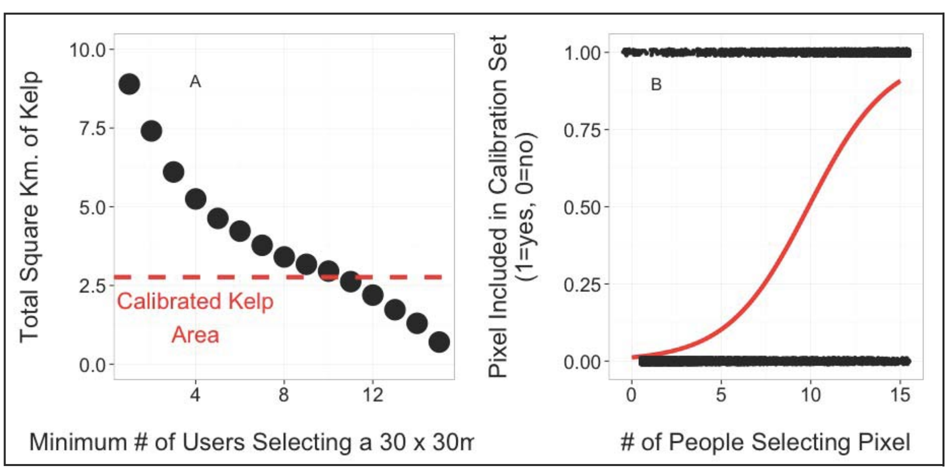

Figure 3. Performance of users in selecting kelp. A) Total square km of kelp selected at different user thresholds. Dashed red line shows true kelp cover from calibration data. B) Logistic regression of the relationship between number of people selecting a pixel and whether or not it was classified as kelp in the calibration data set.

2.2.1 Sources of Calibration Data

To calibrate data from Floating Forests, we will rely on multiple types of data sources that are reported either in the literature or by government agencies (Table 1). The first data source is previous efforts to use Landsat to classify kelp forests. These data, available for California (Cavanaugh et al. 2011) and soon for a subset of Tasmania from our collaborator Craig Johnson's group at the University of Tasmania and from Edyvane (2003), are already formatted as geospatial information and are directly comparable to the data generated by Floating Forests, as shown in the example in Figure 2D. The second data source is aerial surveys from planes or other aircraft. These data have been digitized into a variety of geospatial formats, but often at much finer resolution than Landsat data, such as the Alaska Department of Fish and Game's 1999 *Macrocystis* survey in southern Alaska (Tamelen and Woodby 2001). We will therefore need to downscale these datasets to the 30 x 30m resolution of Landsat, classifying a pixel as containing kelp if any pixels within it contain kelp. The third data source is historical maps, such as those around Tasmania collated by Edyvane (2003) for 1984-1999. These maps are often at a coarser resolution than Floating Forests imagery. We will therefore project these data sets on the 30 x 30m scale to match the Floating Forests data before calibration analysis.

Table 1. Validation data sets. All imagery and maps sets have been processed into geospatial file formats for analysis already according to the references listed.

Area	Source	Description of Data Source	Species Sampled
California	Cavanaugh et al. 2011, Bell et al. 2014	Expert Classifications of Landsat Imagery along the coast of California	*Macrocystis pyrifera*
Tasmania	Edyvane 2003	Historical maps, aerial photography and some select Landsat imagery covering 1984 - 1999	*Macrocystis pyrifera*
Sub-Antarctic Islands	Attwood et al 1991	Aerial photography of the Prince Edward Islands and Marion Islands in 1988-1989	*Macrocystis pyrifera*
New Zealand	Fyfe et al. 1999	Aerial photography of New Zealand kelp beds in the 1990s	*Macrocystis pyrifera*
Alaska	van Tamelen and Woodby	Aerial photography in 1999	*Macrocystis pyrifera*
South America	Torrusio 2009	Argetine satellite data from 2002-2004, Landsat data from 1999-2004 from kelp beds in Tierra del Fuego	*Macrocystis pyrifera*
Washington State	Berry and Mumford 2005	Aerial photography of kelp beds in Washington from 1989-2004	*Macrocystis and Nereocystis*
South Africa	Anderson et al. 2007	Ladsat 5 and 7 imagery of kelp canopies selected only at spring tides	*Ecklonia maxima*
Alaska	Stekoll et al. 2007	Aerial photography from 2002	*Eualaria fistulosa and Nereocystis leutkeana*
British Columbia	Mayne Island Conservancy Society 2012	Kayak-based mapping for 2009-2011	*Nereocystis leutkeana*
Washington State	Van Wagenen 2015	State agency aerial photography of kelp beds in Washington from 1989-2014	*Macrocystis and Nereocystis*

2.2.2 Methods to determine the threshold number of users across scenes with calibration data

To scale the single-image approach above to a whole calibration dataset to determine a threshold, we will model the number of users needed to accurately estimate kelp cover given properties of an image. This will allow us to determine the optimal number of users needed to classify any pixel as kelp for each image. This method will allow us to incorporate dynamic information about each image to obtain the most accurate classification. We will first ask what is the threshold of number of users that produced the closest areal coverage of kelp to the corresponding calibration data set closest in time to when the Landsat image was taken for all images (Figure 3A). We will then fit a generalized linear mixed model where for each image i from satellite j, some number of users who said an image was cloudy, the identity of the Landsat satellite taking the image, and the observed sun angle when recorded

$$\text{Observed optimal number of users}_{ij} \sim \text{Poisson}(\text{Fitted optimal number of users}_{ij})$$

$$\text{Fitted optimal number of users}_{ij} = b_1 + b_2 * \text{Clouds}_{ij} + b_3 * \text{Sun Angle}_{ij} + b_{4j}$$

$$b_{4j} \sim \text{Normal}(0, s_1)$$

where b_1 is the average number of users needed, b_2 is the cloud correction factor, b_3 is the correction for sun angle, and b_4 is the random effect of different satellites. If the error is over- or under- dispersed and/or exhibits nonlinearities, we will refit this model with the appropriate quasi- or negative binomial error distribution and/or nonlinear link function. From this model, for any image we can calculate the optimal number of users to calculate the area of kelp to ensure it is as close to calibration data as possible.

As a complementary approach, we will use logistic regression to model the number of users needed to classify an image under a given set of conditions for each image. For each 30 x 30m area in our calibration datasets corresponding to a pixel of a Landsat image, we can record whether that area contained kelp or not and model the number of classifications required for a good chance of accuracy (Figure 3D). We can then use a generalized linear mixed model with a binomial error and logit link function to model the probability that a pixel was correctly classified as a function of the number of users, the number of users stating the image contained clouds, the sun angle, and a random effects of satellite and image. We can then ask how many users are needed to have a reasonable confidence (i.e., >50%) that a given pixel has kelp. This answer should accord with the model for cover. If it does not, this will tell us that while Floating Forests is reasonable for the modeling of areal coverage of kelp, its utility at the scale of individual kelp pixels or for the analysis of bed morphology is not optimal.

Taking both methods together, we will be able to scan through all of the images in the Floating Forests database and calculate total area of kelp based on the number of pixels that were jointly classified by a model determined number of users.

2.3 Objective 1B: Determining local parameters that alter kelp detectability

Landsat does not take pictures of the earth according to the optimal conditions to detect the cover of kelps. In particular, imagery is not synched up with optimal environmental conditions for the detection of kelp canopies. Kelp can be difficult to detect via satellite if images are cloudy, if the tide is high leading to submerged canopies, if conditions are wavy, or if canopies have experienced seasonal dieback. All of this might be modified by the depth of the kelp bed, with shallower beds potentially creating denser longer canopies than deep-water populations. We can estimate how environmental factors influence the detectability of kelp using calibration datasets (Table 1) generated by aerial photography taken when conditions were optimal for kelp detection (i.e., at low tide on a cloudless calm day). For these data sets we can use the ETOPO1 Global Relief Model (Amante and Eakins 2009) to obtain the depth of water where beds were located in Floating Forests images, hindcasts from NOAA WaveWatch III to determine the local swell-height for an area, and the global tide database from OSU TOPEX/Poseidon Global Inverse Solution (Egbert et al. 1994) to determine the tide height when the Floating Forests image was captured. With this data we can model the true area covered by kelp forests based on these additional environmental parameters

2.3.1 Modeling kelp detectability and cover

To project the true kelp-cover outside of the calibration dataset, we will take individual calibration datasets matched with Floating Forests images where we have already determined the area covered by kelp using consensus counts as described above. We will use these observed kelp cover values along with the calibration kelp cover values and environmental data in a linear model where for observed kelp cover in image i taken in a given season (S=1 in the given season in the model below with summer as the intercept condition),

$$Observed\ Kelp\ Cover_i = Calibration\ Kelp\ Cover_i *(b_1 + b_2*Tide\ Height_i + b_3*Average\ Bed\ Depth_i + b_4* Swell\ Height_i + b_5*Tide_i*Depth_i + b_6*Tide_i*Swell_i + b_7*Tide_i*Swell_i*Depth_i + b_{8*}S_{fall} + b_{9*}S_{winterl} + b_{8*}S_{spring}) + e_i$$

$$e_i \sim Normal(0, s)$$

In this model, observations of the true kelp cover can be modified by all environmental factors that can alter kelp detectability and their interactions. Given the large amount of data, we will evaluate a) this model, b) a model with no three-way interactions, c) a model with no two or three-way interactions, and d) a model where observed kelp cover is only a function of calibrated kelp and compare them using an Akaike's Information Criteria to determine which model will best allow us to correct for environmental factors in determining the area covered by kelp in each image. We will use the AIC over the Baysien Information Criteria (BIC) as it has better properties for prediction outside of the dataset (Aho et al. 2014). Once we have fit this model, we can then project the amount of kelp in each Floating Forests image after correcting for environmental conditions.

2.4 Objective 1C: Determining the utility of Floating Forests and Landsat imagery for species other than Macrocystis pyrifera

While Floating Forests is currently used to examine *Macrocystis pyrifera* populations, *Macrocystis* is not the only kelp that forms surface canopies. In particular, *Nereocystis leutkeana* from Northern California to southern Alaska, *Eualiaria fistulosa* throughout Alaska, *Ecklonia maxima* in South Africa, and *Laminaria longissima* from Hokkaido to the Bering Sea all form surface canopies. Whether these canopies can be detected via Landsat imagery is unknown.

We will attempt to extend Floating Forests beyond giant kelp to these additional species and model their detectability as above for *Macrocystis* using additional data sources listed in Table 1. If we find they can be reliably detected, we will open up an entirely new source of long-term data on additional kelp species globally. This analysis is particularly crucial for *Nereocystis* as its range overlaps entirely with *Macrocystis*, although the two often are found under conditions of differing wave exposure (Utter and Denny 1996). Therefore, users will already be classifying images that could contain *Nereocystis* when from Northern California to Alaska. We will therefore treat this region separately from Central California to Baja in any analysis due to the difference in kelp forest species composition.

For species that do not overlap with *Macrocystis*, we will seed Floating Forests with images from areas where we have calibration data. If, after analyzing the results of against calibration data sets we find that we cannot reliably detect kelp forests, we will terminate data collection in these areas. If we do find reliable classification of kelp canopies, we will run the full Landsat data set for these regions. **This analysis represents a major expansion of Floating Forests and a dramatic expansion of our knowledge of kelp dynamics around the planet.**

3. OBJECTIVE 2 – Examine patterns and processes underlying spatiotemporal variability in *Macrocystis* abundance

We will use the dataset produced by the above activities to (1) examine spatiotemporal variability in *Macrocystis* abundance across its entire global range, and (2) identify the primary drivers of this variability. In the course of this research we will evaluate the following hypotheses:

1. Occupancy of *Macrocystis* (area of kelp per km of coastline) decreases from range center to range edge in a nonlinear pattern.
2. Variability in *Macrocystis* population dynamics increases towards equator-ward range limits as marginal populations are near the species' environmental tolerance limit.
3. There is a positive relationship between variability in abundance at a range limit and extinction rates at that limit.
4. Increasing SST has lead to a contraction in the global range of *Macrocystis* forests over the past 30 years. Regional variability in the magnitude of this contraction corresponds to regional variability in SST changes.

3.1. Hypothesis 1: Occupancy of *Macrocystis* (area of kelp per km of coastline) decreases from range center to range edge in a nonlinear pattern.

Rationale for Hypothesis 1: On large scales, the distribution limits of *Macrocystis* are thought to be set mainly by macroclimatic factors: poleward limits appear to be set by wave action and decreased insolation, while equatorward limits appear to be set by warm water and low nutrient conditions (reviewed in Graham et al. 2007). Since the distribution of *Macrocystis* appears to be coupled to environmental gradients, it is likely that conditions are optimal for *Macrocystis* near the center of its range. Environmental conditions are then expected to become less favorable near the range edge, which will lead to declines in abundance. The important macroclimatic drivers of *Macrocystis* distributions (wave disturbance, SST, and nutrients) are generally spatially autocorrelated at relatively large distances (10s-100s of km, Cavanaugh et al. 2013) and so we expect that distance from optimal habitat decreases the probability of a site being suitable for a *Macrocystis* population. However, wave disturbance and nutrient limitation have nonlinear effects on *Macrocystis* populations and so we expect that the decrease in occupancy of *Macrocystis* from range canter to range edge will be nonlinear. Our previous work in southern California demonstrated that increasing wave heights had a negative but saturating relationship with *Macrocystis* abundance (Cavanaugh et al. 2011). *Macrocystis* growth becomes nutrient limited below approximately 1µ*M* nitrate (Jackson 1977, Zimmerman and Robertson 1985), and prolonged periods below this threshold can lead to widespread mortality (Dayton and Tegner 1984a, Dayton et al. 1992, 1999, Tegner et al. 1997). Due to the threshold effects of waves and nutrient limitation on *Macrocystis* populations, we expect that abundance declines rapidly near the range edge (rare-periphery hypothesis) rather than declining linearly from range center to range edge (abundant-center hypothesis).

Proposed tasks – Assessing spatial variability in Macrocystis abundance
We will examine spatial variability in giant kelp abundance on regional to global scales using the global kelp canopy area dataset produced from Floating Forests. After the processing/validation steps described in Objective 1 are completed, we will create a map of the global distribution of *Macrocystis* by identifying all of the locations where *Macrocystis* was observed at any point during the Landsat time series (1984-present). This global dataset will then be separated in 7 regions: northeast Pacific (Aleutian Islands to Baja California), southeast Pacific (Peru and Chile), Argentina, South Africa, Southern Australia (including Tasmania), New Zealand, and the sub-Antarctic Islands (Fig 4). For each region we will identify the northern and southern range limits and define the range center as the latitudinal midpoint between range limits. Some regions will only have 1 limit (e.g. the southeast Pacific and Argentina do not have southern range limits as kelp extend around Cape Horn). In these cases the range center will be defined as the midpoint between the northern range limit and the southernmost kelp population. The sub-Antarctic islands will be excluded from the range limit analyses.

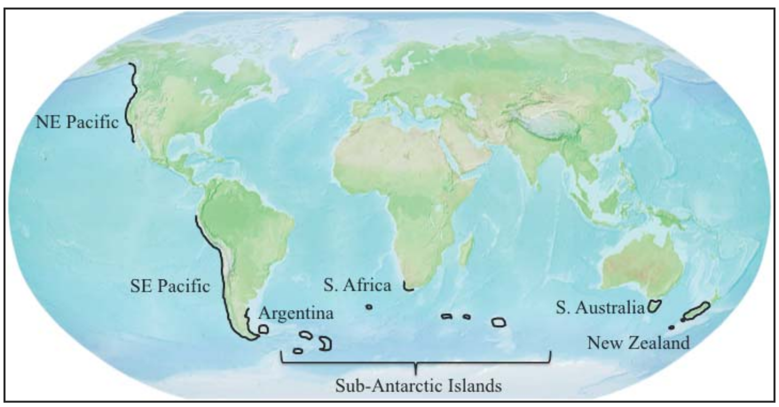

Figure 4. Global distribution of *Macrocystis pyrifera*. Adapted from Graham (2007).

For all of the subsequent analyses we will bin the kelp data into 5 km alongshore segments – the size of a Zooniverse image – by assigning each kelp canopy observation to the closest coastline segment and calculating the composite canopy area. Composite kelp canopy area will be calculated by summing the area of all the pixels that contained kelp canopy at any point during the time series. We will also calculate composite kelp canopy area in each coastline segment for the following time periods: 1985-1994, 1995-2004, and 2005-2014.

We will use the approach of Enquist et al. (1995) and Sagarin and Gaines (2002b) to find the shape that best fits the distribution of abundance from range center to range edge. This approach only examines whether observed abundance falls outside of the expected *bounds* on abundances set by a series of constraint curves (Fig. 5). As a result, it recognizes that there will likely be variability in suitability of habitat throughout the range, and some sites in the most optimal part of the range may have lowered abundance. Relative location in the range will be calculated using range index values (Enquist et al. 1995):

$$RI = 2(L - S)/R \qquad (1)$$

where L is the latitude of the sample, S is the latitude of the midpoint of the range, and R is the latitudinal extent of the range. RI ranges from -1 to 1 with values near 0 representing locations close to the center.

We will initially compare observed distributions in each region to the four constraint curves used in (Sagarin and Gaines 2002b). Linear constraint spaces (Fig. 6a-c) will be defined as:

$$CA_{max} = ax + b \qquad (2)$$

where a is the slope, x is the relative range index (RI), b is the maximum alongshore canopy area, and CA_{max} is the maximum canopy area expected at location x. The normal constraint space (Fig. 6d) will be defined following (Sagarin and Gaines 2002b) assuming that maximum relative canopy area at range center is 1 and 99.9% of all kelp canopy occurs between RI of -1 and 1. The normal maximum canopy area constraint curve is then defined as:

$$CA_{max}(x) = 1/[\sigma(2\pi^{0.5})]\exp[-0.5(x/\sigma)^2] \qquad (3)$$

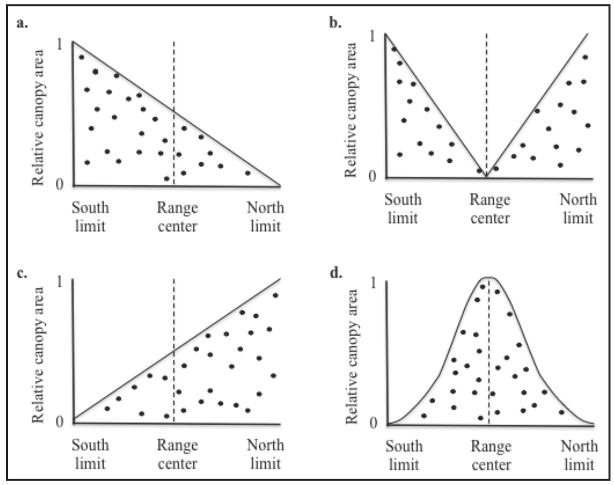

Figure 5. Shapes of the constraint curves used to examine the relationship between range index and relative canopy area. Hypothetical data points that fit inside of each curve are shown by the filled circles. Adapted from Sagarin and Gaines 2002b.

For each region, we will test whether the observed abundance patterns deviate significantly from the constraint boundaries using a bootstrap approach. We will create 10,000 simulated abundance patters by randomly rearranging the observed RI and canopy area (CA) values. We will calculate the sum of squared deviations (SS) for the observed data and each of the simulated data sets. The test of whether an observed distribution fits the constraint curve pattern will be considered significant if more than 95% of the simulated abundance patters have a higher SS than the observed data.

The comparisons described above test the abundant center hypothesis. To test the rare periphery hypothesis we will perform additional tests on regions that do not fit any of the 4 constraint curves described in Fig. 5. These are regions where there is no apparent relationship between abundance and RI when the entire range is examined. For these regions, we will analyze the area close to the range limit to see if relative abundance decreases rapidly at the very edge of the range. We will compare the data to the normal constraint curve (Fig 6d) again, but this time we will redefine our domain as the area within 100 km of the range limit and only use the half of the normal curve that goes from range center to range edge.

The above analyses will be performed using distribution data from 4 time periods: 1984-2014, 1985-1994, 1995-2004, and 2005-2014. This will allow us to examine the degree to which support for the abundant center and rare periphery hypotheses vary through time.

3.2. Hypothesis 2: Variability in *Macrocystis* population dynamics increases towards equator-ward range limits as marginal populations are near the species' environmental tolerance limit.

Rationale for Hypothesis 2: We expect that *Macrocystis* populations located near range limits are at the edge of their environmental tolerance limits. The environmental processes that set these limits (e.g. waves, nutrients, and SST) are highly variable in time, and so it is likely that these edge populations experience environmental fluctuations that periodically push them past their tolerance capabilities. On occasion, these types of disturbance can even extend well into the center of the range of *Macrocystis*. For example, during the 1983 and 1998 ENSOs many *Macrocystis* forests throughout Baja and southern

California experienced complete mortality (Dayton and Tegner 1984a, Dayton et al. 1992, 1999, Edwards 2004, Edwards and Hernández-Carmona 2005). Large-scale losses were observed as far north as Monterey Bay, ~1,500 km north of the southern range limit of *Macrocystis* in Baja California, Mexico (Edwards 2004). The southern range limit is itself highly dynamic – between 1982 and 2002 the range limit shifted back and forth over a distance of 120 km (Ladah et al. 1999, Edwards and Hernández-Carmona 2005). While *Macrocystis* forests in the northeast Pacific have been relatively well studied, the exact locations and dynamics of *Macrocystis* range limits in other parts of the world (e.g. southeast Pacific, Argentina, South Africa, Tasmania, New Zealand) are not well known.

Proposed tasks - Measuring variability in Macrocystis population dynamics across its range
Temporal variability in *Macrocystis* canopy area will be measured in each 5 km alongshore segment. *Macrocystis* populations are variable on intra-annual timescales due to seasonal cycles in SST, nutrient conditions, and wave disturbance (Bell et al. 2015) and inter-annual timescales due to longer scale variability in environmental conditions as well as biotic processes such as competition and herbivory (Dayton et al. 1999, Cavanaugh et al. 2011). We are most interested in variability that might affect the long-term persistence of *Macrocystis* populations, and so we will concentrate on characterizing variability on annual to decadal timescales. We will calculate annual maximum canopy area for each coastline segment for each year from 1984-2014.

We will characterize temporal variability by calculating the temporal coefficient of variation (CV) over the entire times series for each coastline segment. For each region, linear and nonlinear regression will be used to compare temporal variability to relative location in the range (RI) and to test whether temporal variability is significant higher at range edges than it is at range centers.

3.3. Hypothesis 3: There is a positive relationship between variability in abundance at a range limit and extinction rates at that limit.

Rationale for Hypothesis 3: No studies have examined how rates of extinction and recolonization in *Macrocystis* vary on large spatial scales, and so it is unclear how these rates will vary across its range. However, observations of delayed recovery of *Macrocystis* near its southern range limit in Baja California after ENSO events suggest that rates of recolonization decrease towards that range limit (Edwards and Hernández-Carmona 2005). On the other hand, the northern range limit of *Macrocystis* in the northeast Pacific is thought to be set by wave action (Graham et al. 2007), which would likely increase extinction rates. Theory suggests that range limits set by increased extinction rates will have higher turnover rates than limits set by decreased colonization (Holt and Keitt 2000), therefore we expect the northern range limit in the northeast Pacific to have higher turnover than the southern range limit. When comparing range limits across regions, we expect to see a positive relationship between extinction rates and temporal variability in abundance.

Proposed tasks - Measuring variability in Macrocystis extinction and recolonization rates across its range
We will calculate rates of occupancy, extinction, and recolonization over the entire time series for each coastal segment. For these calculations we will place all coastal segments on a consistent time scale (and account for differences in the number of observations among sites) by taking the maximum canopy area for each quarter (Jan-March, April-June, July-Sept, Oct-Dec). A coastal segment will be considered occupied if any canopy is observed in the segment during the quarter. A segment will be considered extinct if total canopy area is 0 for four or more quarters in a row. This 4-quarter (12-month) threshold will be used to reduce the likelihood that a segment that was considered extinct was actually populated by sub-surface juvenile plants. Under most conditions, sub-surface juveniles will reach the surface and form a canopy within six months (Foster and Schiel 1985).

Occupancy will be calculated as the fraction of semesters that a coastal segment was occupied by kelp canopy. Extinction rates will be calculated as the fraction of time that a coastal segment transitioned from occupied to extinct and colonization rates as the fraction of time that a segment transitioned from extinct to occupied. We will also calculate the mean amount of time a segment was continuously occupied and the mean length of extinction for each coastal segment.

We will use linear and nonlinear regression to compare extinction and colonization rates to relative location in the range (RI) and to test whether temporal variability is significant higher at range edges than it is at range centers. We will also look for a significant relationship between temporal variability in *Macrocystis* abundance and extinction and recolonization rates within and across regions.

3.4. Hypothesis 4: Increasing SST has lead to a contraction in the global range of *Macrocystis* forests over the past 30 years. Regional variability in the magnitude of this contraction corresponds to regional variability in SST changes.

Rationale for Hypothesis 4: Climate change impacts to kelp forests have been observed in nearly every region of the globe. In Australia, climate change has hindered kelp recovery from heat waves (Wernberg et al. 2010) 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 et al. 2011) and increases in herbivore grazing rates (Krumhansl and Scheibling 2011), which cause kelp canopy defoliation. We are also beginning to see range shifts in southern Europe as climate drives shifts in kelp biomass (Pehlke and Bartsch 2008, Fernández 2011, Tuya et al. 2012) and reproduction (Bartsch et al. 2013). In Tasmania dramatic declines in *Macrocystis* abundance (losses of > 90%) have been observed in recent years. These losses have been attributed to rapid warming of the waters around Tasmania (Johnson et al. 2011). In contrast, in central and southern California, there have not been any significant regional long-term trends towards increasing or decreasing *Macrocystis* abundance. A map of long-term changes in global SST from 1980-2010 shows that temperatures have increased in many regions that contain equator-ward *Macrocystis* range limits (e.g. red boxes in Fig. 6). We hypothesize that in recent years *Macrocystis* abundance has decreased and *Macrocystis* range limits have shifted poleward in these regions that have experienced warming.

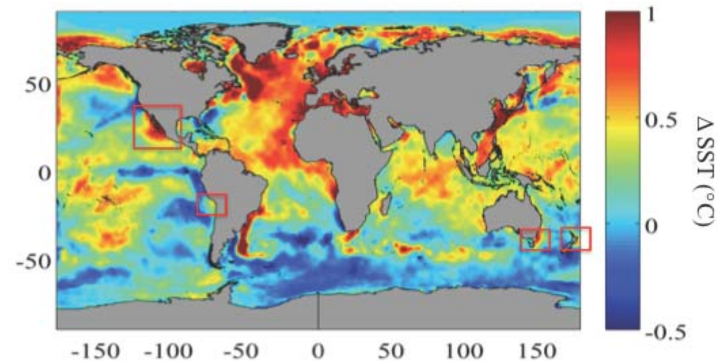

Figure 6. Change in average SST between 1980-1990 and 2000-2010. Data from the Hadley Centre Global Sea Ice and Sea Surface Temperature dataset (Rayner et al. 2003). Red boxes outline areas near the equatorward range limit of *Macrocystis* that have experienced significant warming.

Proposed tasks – Identifying trends in Macrocystis abundance and linking changes in abundance to environmental variability and anthropogenic factors

We will measure long-term trends in canopy area and the strength and timing of the seasonal cycles in canopy area using wavelet analysis and trend decomposition analysis. Seasonal cycles in *Macrocystis* abundance have been shown to vary substantially in space (Cavanaugh et al. 2011, Bell et al. 2015). Long-term changes in ecosystems do not always involve an increase or decrease in the mean state; they can also manifest themselves as shifts in variability or timing of seasonal cycles (Walther et al. 2002). We will use a time series analysis technique developed specifically for remotely sensed time series called Breaks for Additive Seasonal and Trend (BFAST; Verbesselt et al. 2010) to detect changes in the trend and seasonal components of our time series canopy abundance data. BFAST performs an iterative decomposition of time series into trend, seasonal, and noise components and then characterizes breakpoints within that time series. Trend, seasonal, and noise components are identified by iteratively fitting a piecewise linear trend and seasonal model to the data. Prior to the BFAST analysis we will identify subregions that are within 100 km of an equator-ward range limit. Canopy area will be summed across these subregions and the BFAST analysis will be performed on the entire subregion. Variation in trend slopes will be compared across subregions using ANOVA tests.

We will also track the specific location (i.e. latitude) of the equator-ward and pole-ward range limits in each region (northeast Pacific, southeast Pacific, Argentina, South Africa, Southern Australia, New Zealand). The BFAST analysis will then be performed on these time series of latitudes representing each range limit. We will calculate annual rates of migration for each range limit.

Once the seasonal and long-term trends in *Macrocystis* canopy cover have been described for each region, we will use contextual oceanographic data to describe the important physical drivers of *Macrocystis* variability. Our focus will be on the first order controls on kelp growth and survival (cf., waves, SST, and nutrient availability). Elevated temperatures are known to reduce giant kelp growth rates (Zimmerman and Robertson 1985, Graham et al. 2007) and surface waves are a major source of giant kelp forests losses (Reed et al. 2008, 2011). SST data will be acquired from 4 km resolution AVHRR Pathfinder satellite imagery (Reynolds et al. 2007). This dataset provides daily coverage of the entire globe from 1981 to the present. We will calculate daily SST for each coastal segment that contains *Macrocystis* canopy by identifying the AVHRR grid cell closest to that segment. NOAA's WAVEWATCH III model will be used to estimate wave disturbance in each coastal segment. WAVEWATCH III models significant wave height and period at approximately 50 km spatial resolution with nested regional domains of approximately 18 and 7 km resolution (Tolman 2009). Hindcast reanalysis data is available on monthly timescales from 1979 to 2007 (Chawla et al. 2012). Three oceanographic climate indices will also be used in this study: the North Pacific Gyre Oscillation (NPGO), Pacific Decadal Oscillation (PDO), and the Multivariate ENSO index (MEI). These climate oscillations fluctuate over interannual to decadal time-scales and are known to have large effects on *Macrocystis* populations in California and Baja California (Dayton and Tegner 1984a, Di Lorenzo et al. 2008, Parnell et al. 2010). However, the effects of these cycles on *Macrocystis* abundance in other regions is not well known (Graham et al. 2007).

Seasonal mean and maximum SST and wave height will be determined for each coastline segment from these gridded datasets. Seasonal means of the NPGO, PDO, and MEI will also be calculated. Generalized additive models (GAMs) will be used to model the relationship between *Macrocystis* canopy area and the environmental drivers. The general concept of GAMs is that a response variable (canopy area) can be modeled as the sum of non-linear functions of different predictor variables (Hastie and Tibshirani 1990). We will estimate standardized coefficients of each significant predictor is order to measure the relative importance of each variable. By examining plots of the nonlinear effects of each environmental variable, we will be able to identify environmental threshold associated with loss of *Macrocystis* canopy. The GAM analysis will be conducted on each 5 km coastline segment as well as on the 100 km range limit subregions. Finally, we will use regression analysis to compare variability in the latitude of *Macrocystis* equator-ward range limits to the environmental variables listed above.

Macrocystis is also affected by anthropogenic factors such as pollution and coastal development. Obtaining data on coastal development and urbanization in a standardized way across multiple countries may not be possible. We will take advantage of NASA's Earth Observatory Visible Infrared Imaging Radiometre Suite (VIIRS) project. The VIIRS project employs a low light sensor to specifically target nighttime city lights and obtain an understanding of the global human footprint. These images have had natural light-producing phenomena such as auroras and fires digitally removed. These satellite images provide an opportunity to create a standardized measure of coastal urban development globally. These images of publically available through NASA's website as geotiffs and can be easily analyzed using geographic information systems software and techniques. To groundtruth these data we can compare the brightness of lights in areas of known population density to get an estimate of the relationship of light brightness in the NASA VIIRS imaging to actual population density and measures of coastal development. We will use generalized linear mixed models to look for a relationship between kelp canopy cover and city light levels along the coast. We will also build a mixed model that incorporates information about physical and oceanographic parameters as well as our estimate of coastal development (estimated through the NASA imaging).

4. BROADER IMPACT ACTIVITIES

A key value in the proposal is a research and educational partnership between California State University, Monterey Bay (CSUMB), a Hispanic Serving Institution, University of California Los Angeles, and University of Massachusetts Boston, broadening the participation of underrepresented groups and first generation college students. Proposed activities will provide research opportunities for CSUMB undergraduates in science outreach and communication as well as kelp forest ecology. At CSUMB, funding will benefit a primarily undergraduate institution (PUI), an early career PI (Haupt), and underrepresented undergraduates who are primarily first generation college students. One research-based Kelp Forest Ecology field and lab-based course will be taught by PI Haupt at CSUMB specifically to prepare to engage students in the project. Additionally PI Haupt will teach a content-based Marine Ecology course with a lab that will focus on the tools and data developed by through the proposed project. Two undergraduates will be selected each year to conduct research internships that tie directly to the proposed project: one based in science communication and the other to examine potential effects of urban development on kelp. The Marine Science program at CSUMB specifically focuses on geospatial tools and undergrads at CSUMB are particularly well prepared to participate in this project. During the academic year, these two undergraduates will work in PI Haupt's lab. CSUMB's Undergraduate Research Opportunities Center (UROC), which hosts several minority participation programs, will provide students guidance and financial support (note: seven UROC-supported CSUMB undergraduates have received NSF GFRPs in the past two years). At UMB, the proposal will fund a graduate student for both years to participate in the work on citizen science validation as well as modeling the factors that alter kelp forest detectability. Co-PI Byrnes will also use Floating Forest teaching materials for university students into his marine biology class, a remote sensing class in the UMB School for the Environment, and incorporate it into a lab for the required freshman undergraduate biology sequence. At UMB's last assessment, 57% of students were women and 44% were minorities with ~50% as first generation college students. At UCLA, a graduate student will be funded to use the Floating Forests data to examine the patterns and drivers of spatiotemporal variability in *Macrocystis* abundance.

The Floating Forests platform provides us with a unique tool to engage and inform the public about the importance of understanding how giant kelp forests are being impacted by global change. We will work with Zooniverse to further develop the outreach components of the platform, which will include tools to visualize giant kelp dynamics and analyze a user's own classifications, information on giant kelp ecology and conservation, and online forums to promote discussion and interaction between users and the Floating Forests researchers. We also plan to develop a series of educational modules targeted to both K-12 students and undergraduates. We will also work directly with a high school teacher at a Title I school to develop lesson plans for an Ecology of the Monterey Bay class. These lesson plans will use Floating Forests in the classroom to teach students about satellite imagery analysis, global climate change, and kelp forest ecology and will be disseminated for use at other schools.

Collaboration with Zooniverse greatly enhances our ability to foster scientific outreach and increase scientific literacy through engagement with citizen science. Collectively, Zooniverse projects have engaged more than 1.3 million registered users and fostered a community of 15,000 volunteers who make classification contributions on a monthly basis and creating efficient automated classification of areal coverage of a particular species or features from enormous imagery databases is not unique to the remote sensing of kelps. We have had the good fortune to work intensively with the programmers and staff of Zooniverse to build Floating Forests. However, Zooniverse has recently created a platform, Panoptes, to enable scientists with large imagery datasets to create their own citizen science platforms with low to no input from Zooinverse staff (Zooniverse 2015b). To further the abilities of scientists to engage the public via citizen science and process these intractable imagery datasets, we will work with Zooniverse to port Floating Forests over to the Panoptes system. Led by Co-PI Trouille, Zooniverse will handle moving over all current data to a Panoptes-based system and aid in working with us to build an identical Panoptes-based Floating Forests. We will document the process of creating the site from start to finish, publish it as a guide for other scientists, and lead workshops at the Ecological Society of America and American Geophysical Union meetings.

5. PERSONNEL AND PROJECT MANAGEMENT PLAN

Kyle Cavanaugh will serve as lead PI and be responsible for overall project coordination, management, and reporting. He will coordinate and direct bimonthly meetings of all PIs to assess progress and conformance to timelines. He will also hold an annual "all-hands" in-person meeting or workshop to distribute responsibilities, share results, review progress, plan manuscripts, and establish deadlines. PI-Cavanaugh will lead the tasks associated with Objective 2 (analysis of spatiotemporal variability in global giant kelp abundance) and contribute to the activities associated with Objective 1 (development and validation of Floating Forests). PI-Cavanaugh will supervise a PhD student at UCLA whose dissertation will largely be based on the analysis of the Floating Forests data.

Co-PI Jarrett Byrnes will lead the tasks associated with Objective 1 (development and validation of Floating Forests). He will supervise a graduate student at UMass Boston. Co-PI Alison Haupt will lead all of the outreach and education activities. She will supervise two undergraduate interns each year. She will also lead our efforts to develop educational modules targeted towards K-12 students and undergraduates. Co-PI Laura Trouille from Zooniverse will lead the activities associated with customizing the Floating Forests website and creating a Landsat data pipeline, which will dramatically improve the efficiency of the Landsat data ingestion process.

PROJECT TIMELINE	**YEAR 1**				**YEAR 2**			
TASKS	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Migrate Floating Forests to Panoptes	■	■						
Build the Landsat data pipeline	■	■	■	■	■			
Validate citizen science user classification of giant kelp canopy		■	■	■	■	■		
Model giant kelp canopy detectability and cover				■	■	■		
Assess spatial variability in global giant kelp abundance				■	■	■		
Measure variability in giant kelp population dynamics				■	■	■	■	
Measure variability in giant kelp extinction and colonization dynamics					■	■	■	
Identify trends in giant kelp abundance and link those trends to environmental variability and anthropogenic factors					■	■	■	■
Develop new outreach tools for Floating Forests (visualization and data analysis tools, presentations on giant kelp ecology and conservation, online forums, etc.)		■	■	■	■	■	■	■
Develop educational modules for K-12 students and undergraduates		■	■	■	■	■	■	■
PI coordination and discussion	■		■		■		■	
Write manuscripts and present results at national conference							■	■

6. RESULTS FROM PRIOR NSF SUPPORT

Laura Trouille: SoCS #1211094, $395,902, 09/2012-08/2016, "Focusing Attention to Improve the Performance of Citizen Science Systems: Beautiful Images and Perceptive Observers". Intellectual Merit: We created a stable, mature solution providing researchers access to anonymized user data collected by the Zooniverse system. Through A/B split experiments, we have gained a deeper understanding of the effect of messaging, feedback, and other factors on user's performance. Finally, we are integrating machine learning algorithms in Zooniverse projects and developing an API to allow these algorithms to propose actions to the Zooniverse platform and to report the results of these actions. Broader Impacts:

Collectively, Zooniverse projects have engaged more than 1.3 million registered users, including students in formal and informal classroom environments, to participate in research. Their work has contributed to more than 60 published peer-reviewed papers. List of publications resulting from award:

Bowyer, A., Maidel, V., Lintott, C., Swanson, A., Miller, G., (2015). "This Image Intentionally Left Blank: Mundane Images Increase Citizen Science Participation", HCOMP, Works in Progress, submitted

Jackson, C., Osterlund, C., Maidel, V., Crowston, K., Mugar, G. (2015). "Which Way did they Go? Newcomer Movement through the Zooniverse", Computer Supported Cooperative Work and Social Computing, paper conditionally accepted pending final revisions.

Franzoni, C. & Sauermann, H., (2014). "Crowd Science: The Organization of Scientific Research in Open Collaborative Projects". Research Policy.

Research products: The project produced the following products: (1) Real-time generation of Zooniverse volunteers confusion matrixes, (2) Generalized reduction/consensus pipeline for Zooniverse projects, (3) Tracks user clicks and records them in Amazon's Dynamo DB service.

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Reed, D. C., A. Rassweiler, M. H. Carr, K. C. Cavanaugh, D. P. Malone, and D. A. Siegel. 2011. Wave disturbance overwhelms top-down and bottom-up control of primary production in California kelp forests. Ecology 92:2108–2116.

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Wernberg, T., M. S. Thomsen, F. Tuya, G. A. Kendrick, P. A. Staehr, and B. D. Toohey. 2010. Decreasing resilience of kelp beds along a latitudinal temperature gradient: potential implications for a warmer future. Ecology letters 13:685–694.
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Zimmerman, R. C., and D. L. Robertson. 1985. Effects of El Nino on local hydrography and growth of the giant kelp, Macrocystis pyrifera, at Santa Catalina Island, California. Limnology and Oceanography 30:1298–1302.
Zooniverse. 2015a. ZooTeach.
Zooniverse. 2015b. Zooniverse Project Builder.

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Professional Preparation

Trinity University, San Antonio, TX, Geosciences & History, B.S., 2003
University of California, Santa Barbara, CA, Marine Science, Ph.D., 2011
Smithsonian Environmental Research Center, Edgewater, MD, Postdoctoral Fellow, 2012-2014

Appointments and Positions

Assistant Professor, University of California Los Angeles, Department of Geography, 2014-present
Remote Sensing/GIS Analyst, Earth Satellite Corporation, Rockville, MD 2004-2006

5 most relevant publications

Cavanaugh K.C., Siegel D.A., Kinlan B.P., Reed D.C. (2010) Scaling giant kelp field measurements to regional scales using satellite observations. *Marine Ecology Progress Series* 403:13-27.

Cavanaugh K.C., Siegel D.A., Reed D.C., Dennison P.E. (2011) Environmental controls on giant kelp biomass in the Santa Barbara Channel, CA. *Marine Ecology Progress Series* 429:1-17

Byrnes, J.E.K., **Cavanaugh, K.C**., Haupt, Bell, T.W., Harder, B., A.J., Rassweiller, A., Pérez-Matus, A., Assis, J., and The Zooniverse. 2014. Floating Forests. http://floatingforests.org. See also http://blog.floatingforests.org/ and http://talk.floatingforests.org/ for more.

Bell, T. W[†]., **Cavanaugh, K. C.**, [†] & Siegel, D. A. (2015). Remote monitoring of giant kelp biomass and physiological condition: An evaluation of the potential for the Hyperspectral Infrared Imager (HyspIRI) mission. *Remote Sensing of Environment*. *[†]Authors contributed equality to this work*

Cavanaugh K.C, Kendall B.E, Siegel D.A., Reed D.C., Alberto, F., Assis J. (2013) Synchrony in dynamics of southern California giant kelp forests is driven by both local recruitment and regional environmental controls. *Ecology* 94:499-509

5 other publications

Byrnes J.E., Reed D.C., Cardinale B.J., **Cavanaugh K.C.**, Holbrook S.J, Schmitt R.J., (2011) Increases in winter storms simplify kelp forest food webs. *Global Change Biology* 17:2513-2524

Reed D.C., Rassweiler A., Carr M.H., **Cavanaugh K.C.**, Malone D., Siegel D.A. (2011) Wave disturbance overwhelms top-down and bottom-up control of primary production in California kelp forests. *Ecology* 92:2108-2116

Bell, T. W., **Cavanaugh, K. C.**, Reed, D. C., & Siegel, D. A. (2015). Geographical variability in the controls of giant kelp biomass dynamics. *Journal of Biogeography*.

Cavanaugh K.C, Kellner J.R., Forde A.J., Gruner D.S., Parker J.D., Rodriguez W., Feller I.C. (2014) Poleward expansion of mangroves is a threshold response to decreased frequency of extreme cold events. *Proceedings of the National Academy of Sciences* 111(2):723-727

Cavanaugh K.C, Kellner J.R., Cook-Patton S., Feller I.C., Williams A.P., Parker J.D. (2015) Integrating physiological threshold experiments with climate modeling to project mangrove species' range expansion. *Global Change Biology* 21(5), 1928-2938

Synergistic Activities

Citizen Science: Developed the crowdsourcing science project Floating Forests (http://www.floatingforests.org). Floating Forests is an online interface which allows volunteers (citizen scientists) to track kelp forest dynamics on satellite imagery. There is also a large education/outreach component on the website.

Mentoring, Undergraduate/Graduate: 3 graduate and 11 undergraduate students (2010-present), Mentor to the 2011 NASA Student Airborne Research Program, Mentor to 2013 NASA DEVELOP student program, Organizer and mentor to the LTER Santa Barbara Schoolyard Program

Grant Panels: NASA Ecological Forecasting for Conservation and Natural Resource Management program (2013), NSF Biological Oceanography (2013)

Symposium and Meeting organizer, Organizer, Santa Barbara Coastal, Moorea Coral Reef, and California Current LTER Graduate Student Symposium

Graduate Students Supervised

Rémi Bardou (UCLA), Cheryl Dougherty (UCLA), Daniel Jensen (UCLA)

Recent Collaborators

J Assis (U Algarve), T Bell (UCSB), J Byrnes (U Mass), M Carr (UC Santa Cruz), S Cook-Patton (Smithsonian), S Davis (UC Santa Barbara), P Dennison (U of Utah), A Forde (U of Maryland), S Gosnell (FSU), D Gruner (U Maryland), T Konotchick (J. Craig Venter Institute), Heather Leslie (Brown University), J Parker (Smithsonian), C Patrick (Smithsonian), P Raimondi (UC Santa Cruz), A. Rassweiler (UC Santa Barbara), W Rodriguez (Smithsonian), AP Williams (Colombia U), M Young (UC Santa Cruz)

Graduate and Postdoctoral Advisors

David Siegel (UC Santa Barbara), Bruce Kendall (UC Santa Barbara), Phaedon Kyriakidis (UC Santa Barbara), Dan Reed (UC Santa Barbara), Libe Washburn (UC Santa Barbara), Candy Feller (Smithsonian), Jim Kellner (Brown U)

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(a) Professional Preparation

Brown University, Providence RI Bachelor of Science in Biology 1997-2001

UC Davis, Davis CA Population Biology, M.S. 2003, Ph.D. 2002-2008

Santa Barbara Long Term Ecological Research Project Santa Barbara CA Postdoctoral Fellow, 2008 - 2010

National Center for Ecological Analysis and Synthesis Santa Barbara CA Postdoctoral Fellow, 2010 - 2012

(b) Appointments

Assistant Professor. University of Massachusetts Boston, Department of Biology 2012 – Present

(c) Products
(i) List of Five Relevant Products

1. Witman, J.E., Lamb, R., **Byrnes, J.E.K.** In Press. Towards an integration of scale and complexity in marine ecology. *Ecological Monographs.*

2. Byrnes, J.E.K., Cavanaugh, K.C., Haupt, Bell, T.W., Harder, B., A.J., Rassweiller, A., Pérez-Matus, A., Assis, J., and The Zooniverse. 2014. Floating Forests. http://floatingforests.org. See also http://blog.floatingforests.org/ and http://talk.floatingforests.org/ for more.

3. Byrnes, J.E.K., J. Ranganathan, J., Walker, B.L.E., and Faulkes, Z. 2014. To Crowdfund research, scientists must build an audience for their work. PloS one 9:e110329. [doi]

4. Byrnes, J. E. K., L. Gamfeldt, F. Isbell, J. S. Lefcheck, J. N. Griffin, A. Hector, B. J. Cardinale, D. U. Hooper, L. E. Dee, and J. E. Duffy. 2014. Investigating the relationship between biodiversity and ecosystem multifunctionality: Challenges and solutions. *Methods in Ecology and Evolution* 5: 111-124. [doi] [R package]

5. Byrnes, J.E., Reed, D.C., Cardinale, B.J., Cavanaugh, K.C., Holbrook, S.J., and Schmitt, R.J. 2011. Climate driven increases in storm frequency simplify kelp forest food webs. *Global Change Biology*. 17: 2513-2524. [doi]

(ii) List of Five Additional Products

1. Elahi, R., O'Connor, M.I., **Byrnes, J.E.K.,** Dunic, J., Eriksson, B.K., Hensel, M.J.S., Kearns, P.J. 2015. Recent Trends in Local-Scale Marine Biodiversity Reflect Community Structure and Human Impacts. Current Biology. 25: 1938–1943. [doi]

2. Byrnes, J.E.K. 2015. hadsstR: An R pcakge to utilize Met Office Hadley Centre Sea Surface Temperature datasets for analyses in R. https://github.com/jebyrnes/hadsstR

3. Lefcheck, J.S., **Byrnes, J.E.K.,** Isbell, F., Gamfeldt, L., Griffin, J.N., Eisenhauer, N., Hensel, M.J.S., Hector, A., Cardinale, B.J., Duffy, J.E., 2015. Biodiversity enhances ecosystem multifunctionality across trophic levels and habitats. Nature Communications 6, 6936. [doi]

4. Byrnes J.E., Johnson L.E., Connell S.D. et al. 2013. The sea urchin – the ultimate herbivore and biogeographic variability in its ability to deforest kelp ecosystems. PeerJ PrePrints, 1, e174v1. [doi]

5. Byrnes, J.E.K., Cardinale, B.J., and Reed, D.R. 2013. Sea urchin grazing increases with prey diversity on temperate rocky reefs. *Ecology*. 94:1636-1646. [doi]

(d) List of Five Synergistic Activities

1. Coordinator for the international Kelp Ecosystem Ecology Network. http://kelpecosystems.org

2. Contributing Developer to *lavaan*, *sem*, and *semTools*- Libraries for the analysis of Structural Equation Models in R http://lavaan.org, https://github.com/simsem/semTools/wiki

3. Marshlife.org http://marshlife.org - A blog part of a MIT SeaGrant on salt marsh food web structure where researchers tell stories of life in the field and current advances in salt marsh research.

4. Global Impacts of Climate Change on Kelp Forests. Leader, National Center for Ecological Analysis and Synthesis working group.

5. SciFund Challenge, co-founder and board president. SciFund Challenge is a nonprofit organization that empowers scientists to shrink the gap between science and society. We train scientists how to connect to the public, back scientists in their outreach, and crowdfund to support research.

(e) Collaborators and Co-Authors: Balvanera, Patricia, UNAM; Bolton, John, University of Cape Town; Cavanaugh, Kyle, Smithsonian Environmental Research Center; Connell, Sean, University of Adelaide; Duffy, J. Emmett, Virginia Institute of Marine Sciences; Edwards, Kyle, University of Michigan; Gamfeldt, Lars, University of Gothenburg, Sweden; Gonzalez, Andrew, McGill University; Holbrook, Sally, University of California Santa Barbara; Hooper, David, Western Washington University; Hughes, A. Randall, Northeastern University; Isbell, Forest, University of Minnesota; Johnson, Craig, University of Tasmania; Kimbro, David, Northeastern University; Konar, Brenda, University of Alaska Fairbanks; Krumhansl, Kira, Simon Frasier University; Ling, Scott, University of Tasmania; Michaeli, Fiorenza, Stanford University; Norderhaug, Kjell-Magnus, Norwegian Institute for Water Research; Novak, Mark, Oregon State University; O'Connor, Mary, University of British Columbia; Perez-Matus, Alejandro. Pontificia Universidad Católica de Chile; Reynolds, Pamela, Virginia Institute of Marine Sciences; Salomon, Anne, Simon Frasier University; Schmitt, Russ, University of California Santa Barbara; Shears, Nick, University of Auckland; Sousa Pinto, Isabel, University of Porto; Wernberg, Thomas, University of Western Australia. (28)

Graduate Advisors (1) and Postdoctoral Sponsors (2): John J. Stachowicz, UC Davis. Bradley J. Cardinale, University of Michigan; Daniel C. Reed; UC Santa Barbara.

Thesis Advisor and Post-Graduate Scholar Sponsor: Alison Haupt, California State Monterey Bay, Postdoctoral Mentee. (1)

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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.

5 MOST RELEVANT PRODUCTS:
Byrnes, JEK, Cavanaugh, KC, Haupt AJ, Bell, TW, Harder, B, Rassweiller, A, Pérez-Matus, A, Assis, J, and The Zooniverse. 2014. Floating Forests. http://floatingforests.org. See also http://blog.floatingforests.org/ and http://talk.floatingforests.org/ for more.
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.
Haupt, AJ. 2013. Ocean acidification as a West Coast Governors Alliance on Ocean Health priority area. Technical Report for WCGA.
Iles, AC, TC Gouhier, BA Menge, JS Stewart, AJ Haupt, MC Lynch. 2011. Climate-driven trends and ecological implications of event-scale upwelling in the California Current System. Global Change Biology 18:783-796.
Micheli, F, AO Shelton, SM Bushinsky, AL Chiu, AJ Haupt, KW Heiman, CV Kappel, MC Lynch, RG Martone, and J Watanabe. 2008. Persistence and recovery of depleted marine invertebrates in marine reserves of Central California. Biological Conservation. 141:1078-1090.

OTHER PRODUCTS:
Haupt, AJ, F Micheli, and SR Palumbi. 2013. Dispersal at a snail's pace: historical processes affect contemporary genetic structure in an exploited marine snail. Journal of Heredity 104:327-340.
Woodson, B, JA Barth, OM Cheriton, MA McManus, JP Ryan, L Washburn, KN Carden, BS Cheng, J. Fernandez, LE Garske, TC Gouhier, **AJ Haupt**, KT Honey, MF Hubbard, A Illes, L. Kara, MC Lynch, B Mahoney, M. Pfaff, ML Pinsky, MJ Robert, JS Stewart, SJ Teck, A True. Observations of internal wave packets propagating along-shelf in northern Monterey Bay. 2011. Geophysical Research Letters. 38
Logan, CA, SE Alter, **AJ Haupt,** K Tomalty and SR Palumbi. 2008. An impediment to consumer choice: overfished species are sold as Pacific red snapper. Biological Conservation. 141:1591-1599.

O'Connell CS, **Haupt AJ**, Palumbi SR. 2008. Molecular and morphological characterization of two species of sea cucumber, *Parastichopus parvimensis* and *Parastichopus Californicus*, in Monterey, CA. Stanford Undergraduate Research Journal 7 36-40.

Ruttenberg, BI, **AJ Haupt**, A Chiriboga, and RR Warner. 2005. Patterns, causes and consequences of regional variation in the ecology and life history of a reef fish. Oecologia. 145: 394-403.

SYNERGISTIC ACTIVITIES:

Project leader National Center for Ecological Analysis and Synthesis project: Evaluation of the use of cumulative impact indices as proxies for ecosystem status of the California Current ecosystem.

Science team member Floating Forests (floatingforests.org) a citizen science to quantify kelp cover globally through Landsat satellite technology through zooniverse.

Regional coordinator for California and the Pacific Northwest for the Kelp Ecosystem Ecology Network. KEEN is a global network of kelp forest ecologists created to study the response of kelps to climate change and disturbance globally.

Ocean HEROES science outreach program for underserved student groups working with the Seaside, CA Boys and Girls Club. Founder, teacher and curriculum developer.

Participant NSF-funded Baja Biocomplexity Project: active stakeholder engagement with small-scale Mexican fishermen in Baja California, Mexico.

COLLABORATORS LAST 4 YEARS (30) AND CO-EDITORS LAST 2 YEARS (0):

Jorge Assis (Univerdade do Algarve Portugal), Sharon Baruch-Mordo (The Nature Conservancy), Tom Bell (UCSB), Jarrett Byrnes (University of Massachusetts Boston), Jill Bourque (USGS), Kyle Cavanaugh (UCLA), Chris Costello (UC Santa Barbara), Matt Edwards (CSU SD), Laura Gonzalez (UT Austin), Ashley Greenley (Fishwise), Sergio Guzman del Proo (UNAM Mexico), Scott Hamilton (CSU MLML), Catherine Kulman (CA OPC), Phil Levin (NOAA NWFSC) Jason Link (NOAA), Megan Mach (Center for Ocean Solutions Stanford), Rebecca Martone (Center for Ocean Solutions Stanford), Bonnie McCay (Rutgers), Fiorenza Micheli (Stanford), Stephen Palumbi (Stanford), Alejandro Perez-Matus (ECIM Universidad Catolica de Chile), Andrew Rassweiler (UCSB), Jameal Samhouri (NOAA NWFSC), Elisa Serviere Zaragoza (CIBNOR Mexico), Geoff Shester (Oceana), Rebecca Shuford, (NOAA), Sigrid Smith (University of Michigan), Wendy Wiseman (Rutgers), Brock Woodson (University of Georgia) Amy Vierra (CA OPC).

GRADUATE ADVISORS AND POSTDOCTORAL SPONSORS (3):

Graduate: Fiorenza Micheli, Stephen Palumbi, Stanford University. Post-Doctoral: Jarrett Byrnes University of Massachusetts Boston.

THESIS ADVISOR AND POSTGRADUATE-SCHOLAR SPONSOR (0)

Biographical Sketch

Dr. Laura Trouille
Director of Citizen Science at the Adler Planetarium
312-322-0820; ltrouille@adlerplanetarium.org

A. PROFESSIONAL PREPARATION

College/University	Location	Major	Degree &Year
Dartmouth College	Hanover, NH	Physics	B.A., 2003
University of Wisconsin – Madison	Madison, WI	Astronomy	Ph.D., 2010
Northwestern University (NU)	Evanston, IL	Astronomy	Postdoc, 2010-2013

B. ACADEMIC/PROFESSIONAL APPOINTMENTS

Director of Citizen Science at the Adler Planetarium, 2015+
NU CIERA Postdoctoral Fellow and Astronomer at the Adler Planetarium (joint appointment), 2013-2015
CIERA Postdoctoral Fellow, Northwestern University, 2010-2013
Astronomy Adjunct Faculty, Chicago State University, Spring 2011
Research Assistant, UW-Madison, Ph.D. Thesis Advisor: Dr. A. Barger, 2004-2010
National Science Foundation Graduate Research Fellow, UW-Madison, 2006-2009
CIRTL DELTA Education Research Intern, UW-Madison, 2009-2010
NASA International Year of Astronomy Outreach Ambassador, 2009
Instructor for Undergraduate Intro to Astronomy, UW-Madison, 2007
Computer & ESL Secondary School Teacher, Czech Republic & India, 2003-2004
Research Assistant (Senior Thesis), SwRI, Advisor: Dr. E. Young, 2002-2003
Research Assistant, L'Observatoire de Paris, Advisor: Dr. J. P. Zahn, 2002

C. PRODUCTS

– Hainline, K., Hickox, R. DiPompeo, M, & Trouille, L. A Spectroscopic Survey of WISE-selected Obscured Quasars with the Southern African Large Telescope, ApJ, 795, 124, 2014
– Trouille, L., Barger, A. J., & Tremonti, C. The OPTX Project V: Identifying AGNs, ApJ, 742, 46. 2011
– Trouille, L. & Barger, A. J. The OPTX Project IV: How Reliable is [OIII] as a Measure of AGN Activity? ApJ, 722, 212, 2010
– Trouille, L., Barger, A. J., Cowie, L. L., Yang, Y. & Mushotzky, R. F. The OPTX Project III: X-ray versus Optical Spectral Type for AGNs. ApJ, 703, 2160, 2009
– Trouille, L., Barger, A. J., Cowie, L. L., Yang, Y. & Mushotzky, R. F. The OPTX Project I: Flux and Redshift Catalogs for the CLANS, CLASXS, and CDF-N Fields, ApJS, 179, 1. 2008

Other Significant Products

– Weintrop, D., Beheshti, E., Horn, M.S., Orton, K., Trouille, L., Jona, K., & Wilensky, U. Interactive Assessment Tools for Computational Thinking in High School STEM Classrooms. INTETAIN 2014, Springer International Publishing, 22-25, 2014
– Trouille, L., Beheshti, E., Horn, M., Jona, K., Weintrop, D., & Wilensky, U. Computational Thinking in High School Science and Math Classroom. Am. Astronomical Society Meeting 221, #201.09, 2013
– Morscher, M. & Trouille, L. Astrostatistics: Probabilities - The Drake Equation and Life on Other Worlds. The Classroom Astronomer, 2, 31-35. 2013
– Coble, K., Camarillo, C., Trouille, L., Bailey, J., Cochran, G., Cominsky. L. Investigating Student Ideas about Cosmology I: Distances and Structure. Astronomy Education Review, 12, 1, 2013
– Farr, B., Mathias, G., & Trouille, L., Gravitational Wave Science in the High School Classroom, American Journal of Physics, 80, 10, 898, 2012

D. SYNERGISTIC ACTIVITIES

– *Co-I for NSF $1million Computing Education for the 21st Century grant*. With an interdisciplinary team of learning sciences, STEM, and computer science faculty, graduate students, and postdoctoral fellows, developing computational thinking and modeling curricula for the high-school STEM classroom and providing teacher professional development workshops during the summer and throughout the academic year for Chicago area teachers, 2012-present

– *Teaching Certificate through the UW-Madison Center for the Integration of Research, Teaching, and Learning (CIRTL) DELTA Program*. Pedagogy coursework and internships; developing and assessing astronomy curricular materials for the undergraduate and K-12 level. Also attended a semester-long seminar on how to be an effective, supportive, and responsible research mentor, 2004-2010.

– *Lead Scientist for Galaxy Zoo: Quench*. With the Zooniverse.org team, developed the infrastructure and support materials to enable the public to experience the entire process of science through an online research experience. 2500 people participated in the galaxy morphology classification, 250 worked with the data in our online data analysis platform and posted in the online discussion forum, and now twenty are involved in writing the article, to be submitted to a peer-reviewed professional journal, 2013-present.

– *Research Mentor,* mentor for three graduate students, five undergraduate students, and four high school students in research projects using computational approaches to identify trends in galaxy evolution as well as education research in assessing the impact of computational thinking learning materials and identifying undergraduates' alternate conceptions in cosmology, 2006-present.
Note: Two of my high school students won $20K college scholarships for 3rd place in the 2012 SIEMENS Talent Competition and one won first place in the 2014 Northeastern Science and Engineering Fair.

– *Member of the American Astronomical Society Committee on the Status of Women in Astronomy and liaison to the AAS Employment Committee*. Developing and disseminating resources to the community to provide an inclusive culture/climate and supportive practices for women and minorities at all levels (undergraduates, graduate students, postdocs, researchers, faculty, and staff), 2010-2014

COLLABORATORS AND OTHER AFFILIATIONS

Collaborators & Co-Editors (Total: 22):
J. Bailey (Nevada State Univ.), A. Barger (UW-Madison), E. Beheshti (Northwestern Univ.), C. Camarillo (Chicago State Univ.), Y. Chen (Nanjing Univ.), K. Coble (Chicago State Univ.), G. Cochran (Florida International Univ.), D. Haggard (Northwestern Univ.), R. Hickox (Dartmouth College), M. Horn (Northwestern Univ.), K. Jona (Northwestern Univ.), V. Kalogera (Northwestern Univ.), R. Keenan (ASIAA), M. Nickerson (Chicago State Univ.), K. Orton (Northwestern Univ.), B. Simmons (Oxford), R. Taam (Northwestern Univ.), C. Tremonti (UW-Madison), J. Wang (Northwestern Univ.), D. Weintrop (Northwestern Univ.), U. Wilensky (Northwestern Univ.), K. Willett (UMN)

Graduate and Postdoctoral Advisors
Graduate Advisors: Barger, A. (UW-Madison); Cowie, L. (U. of Hawaii); Mushotzky, R. (GSFC)
Postdoctoral Sponsors: Kalogera, V. & Taam, R. (CIERA)
Thesis Advisor over the Last Five Years:
Graduate Students: David Weintrop (Northwestern University Learning Sciences); Elham Beheshti (Northwestern University Computer Science), Carmen Camarillo (Chicago State University Education)
Total Number of Graduate Students Advised: 3
Total Number of Postdoctoral Scholars Supervised: 0

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **University of California-Los Angeles**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Kyle Cavanaugh**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Kyle C Cavanaugh - Principal Investigator**	0.00	0.00	1.00	**10,756**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**10,756**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**23,328**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**34,084**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**1,768**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**35,852**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **High performance computer** $ **5,000**					
TOTAL EQUIPMENT				**5,000**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**3,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**134,413**	
6. OTHER				**16,104**	
TOTAL OTHER DIRECT COSTS				**150,517**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**194,369**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified indirect cost (Rate: 54.0000, Base: 100932)**					
TOTAL INDIRECT COSTS (F&A)				**54,503**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**248,872**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**248,872**	
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Kyle Cavanaugh**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Tana Wong**	Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION: **University of California-Los Angeles**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months): Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Kyle Cavanaugh**	AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Kyle C Cavanaugh - Principal Investigator**	0.00	0.00	1.00	11,293	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	11,293	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (1) GRADUATE STUDENTS				24,028	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				35,321	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				1,849	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				37,170	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				2,500	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				74,898	
6. OTHER				16,587	
TOTAL OTHER DIRECT COSTS				93,485	
H. TOTAL DIRECT COSTS (A THROUGH G)				133,155	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified indirect cost (Rate: 54.0000, Base: 53756)**					
TOTAL INDIRECT COSTS (F&A)				29,028	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				162,183	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				162,183	

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $
PI/PD NAME: **Kyle Cavanaugh**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION
ORG. REP. NAME*: **Tana Wong**	Date Checked / Date Of Rate Sheet / Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Los Angeles

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Kyle Cavanaugh

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Kyle C Cavanaugh - Principal Investigator	0.00	0.00	2.00	22,049	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.00	22,049	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (2) GRADUATE STUDENTS				47,356	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				69,405	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				3,617	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				73,022	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 5,000					
TOTAL EQUIPMENT				5,000	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				5,500	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				209,311	
6. OTHER				32,691	
TOTAL OTHER DIRECT COSTS				244,002	
H. TOTAL DIRECT COSTS (A THROUGH G)				327,524	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				83,531	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				411,055	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				411,055	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Kyle Cavanaugh

ORG. REP. NAME*
Tana Wong

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

BUDGET JUSTIFICATION

Senior Personnel

PI Cavanaugh requests 1.0-month summer salary for each of three years. PI Cavanaugh will lead the project and supervise the graduate student, and perform the analyses of spatiotemporal variability in global giant kelp abundance. He will prepare scientific papers and present the outputs of this project at national conferences.

Other Personnel

PIs Cavanaugh requests salary to support a Graduate Student Researcher (GSR) at 50% time during the academic year and summer (12 months) of the first and second years. The GSR, supervised by Cavanaugh, will use the Floating Forests data to analyze spatiotemporal variability in giant kelp abundance. His/her PhD dissertation will be based primarily on this project.

Fringe Benefits

Fringe benefits are estimated using figures approved by the University of California Systemwide Administration. Academic summer employment is 12.7%, Graduate student researcher is 1.3% for Academic year and 3% for Summer.

Equipment

In year 1 we have budgeted $5,000 for a high performance computer for the graduate student at UCLA. This cost is based on a quote from Apple for a Mac Pro with 3.5 Ghz 6-core with 32 GB of memory and 1TB PCIe-based flash storage. A high performance computer is necessary to perform the proposed analysis on the extremely large data sets (many TBs) that will be generated by Floating Forests. We will use it to develop global maps of giant kelp canopy area and perform all of the analysis activities described in Section 2 of the proposal. This computer will only be used for work related to this project. We have access to a scientific computing cluster through the UCLA Division of Social Sciences, however this is a shared resource and so availability is sometimes limited. Because we will be downloading and processing satellite imagery almost continuously during the length of this project, we need a dedicated machine for this work.

Travel (Domestic)

<u>Year 1</u>

To enable direct collaboration and completion of project, we ask for support for the graduate student and PI to travel to Boston, MA to meet with Co-PI Byrnes, Co-PI Haupt, and their groups in year 1. We estimate $1,000 for airfare, $1,500 for hotel, and $500 for food ($50/person/day for 5 days).

<u>Year 2</u>

We request $2,500 in year 2 for PI Cavanaugh to attend one conference in the United States to present findings from the proposed work. For the conference, flight costs are estimated at $500, registration costs at $500, lodging at $1000, and food costs are estimated at $500.

Other Direct Costs
Dissemination and Publication Costs
Page charges for one publication in an open-access journal ($2,000) for the final year of the project.

Subaward to Adler Planetarium (aka Zooniverse)
Total: $65,000; Year 1: $62,520; Year 2: $2,480
See attached justification for Adler Planetarium

Subaward to University of Massachusetts, Boston
Total: $120,551; Year 1: $60,013; Year 2: $60,538
See attached justification for University of Massachusetts, Boston

Subaward to CSU Monterey Bay
Total: $23,760; Year 1: $11,880; Year 2: $11,880
See attached justification for CSU Monterey Bay

Other: Technology Infrastructure Fee
The Technology Infrastructure Fee (TIF) is a consistently-applied direct charge that is assessed to each and every campus activity unit, regardless of funding source, including units identified as individual grant and contract awards. The TIF pays for campus communication services on the basis of a monthly accounting of actual usage data. These costs are charged as direct costs and are not recovered as indirect costs. The charge is $33.28/FTE.

Other: Mandatory Health Benefits and Fee Remissions
Health insurance and fee remissions are mandatory for the hiring of graduate student researcher at 25% or greater during the academic term. These fees are exempt from indirect cost.

Indirect Cost (F&A)
On April 27, 2011, the University of California and the United States Department of Health and Human Services (the responsible Federal audit agency) entered into a new facilities and administrative (F+A) cost rate agreement for the Los Angeles campus. This agreement establishes facilities and administrative cost rates for the period of July 1, 2010, through June 30, 2016. The on-campus Research rate currently in effect is 54%. Indirect Costs are calculated at 54% of Modified Total Direct Costs (total costs – minus student tuition fees, equipment, fabrication costs, subcontracts and participant supports costs.). See: http://www.research.ucla.edu/ocga/sr2/idcinfo.htm#FA1

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **Adler Planetarium**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Laura Trouille**				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1.	0.00	0.00	0.00			
2.						
3.						
4.						
5.						
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0		
2. (2) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	7.25	0.00	0.00	33,302		
3. (0) GRADUATE STUDENTS				0		
4. (0) UNDERGRADUATE STUDENTS				0		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6. (0) OTHER				0		
TOTAL SALARIES AND WAGES (A + B)				33,302		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				5,994		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				39,296		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)						
TOTAL EQUIPMENT				0		
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				0		
2. FOREIGN				0		
F. PARTICIPANT SUPPORT COSTS						
1. STIPENDS $ 0						
2. TRAVEL 0						
3. SUBSISTENCE 0						
4. OTHER 0						
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				0		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0		
3. CONSULTANT SERVICES				0		
4. COMPUTER SERVICES				1,500		
5. SUBAWARDS				0		
6. OTHER				0		
TOTAL OTHER DIRECT COSTS				1,500		
H. TOTAL DIRECT COSTS (A THROUGH G)				40,796		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Cost (Rate: 53.2500, Base: 40796)**						
TOTAL INDIRECT COSTS (F&A)				21,724		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				62,520		
K. SMALL BUSINESS FEE				0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				62,520		
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $					
PI/PD NAME **Laura Trouille**				FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Tana Wong**				Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
Adler Planetarium

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Laura Trouille

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.25	0.00	0.00	1,183	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				1,183	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				213	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				1,396	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				0	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				222	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				222	
H. TOTAL DIRECT COSTS (A THROUGH G)				1,618	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Cost (Rate: 53.2500, Base: 1618)**					
TOTAL INDIRECT COSTS (F&A)				862	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				2,480	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				2,480	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Laura Trouille

ORG. REP. NAME*
Tana Wong

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET
Cumulative

				FOR NSF USE ONLY	
ORGANIZATION **Adler Planetarium**				PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Laura Trouille**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (0) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (3) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	7.50	0.00	0.00	34,485	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				34,485	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				6,207	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				40,692	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				0	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				1,722	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				1,722	
H. TOTAL DIRECT COSTS (A THROUGH G)				42,414	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				22,586	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				65,000	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				65,000	

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $	
PI/PD NAME **Laura Trouille**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION	
ORG. REP. NAME* **Tana Wong**	Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

Budget Justification
Adler Planetarium

A. Senior Personnel – ($0)

1. Laura Trouille, PI – No salary support is requested for this proposal.

B. Other Personnel – ($34,485)

2. Other Professionals

1) Citizen Science Developer – 6 months of salary support requested in Year 1 and 0.25 months in Year 2 with a 3% annual increase.
2) Citizen Science Designer – 1.25 months salary support requested in Year 1 only.

	Year 1	Year 2
Developer	$27,560	$1,183
Designer	$5,742	$0
Total	$33,302	$1,183

C. Fringe Benefits – ($6,207)
Calculated at Adler's average rate of 18% of salaries and wages.

	Year 1	Year 2
Salaries	$33,302	$1,183
Fringe 18%	$5,994	$213

D. Equipment – (None)

E. Travel – (None)

F. Participant Support Costs – (None)

G. Other Direct Costs – ($1,722)

4. Computer Services – The average annual cost of web hosting services for the project period is projected to be $1,500 per project. We request $1,500 for Year 1 and $222 for Year 2 due to budget constraints.

H. Total Direct Costs – ($42,414)

I. Indirect Costs – ($22,586)
Adler Planetarium's negotiated federal rate is 53.25% of modified total direct costs. Base for calculation is A+B+C+G = $42,414.

J. Total Direct and Indirect Costs – ($65,000)

K. Residual Funds – (None)

L. Amount of This Request – ($65,000)

M. Cost Sharing – (None)

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University Corporation at Monterey Bay

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Alison Haupt

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Alison Haupt - Co-PI**	0.00	0.60	0.00	4,667	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.60	0.00	4,667	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				4,667	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				2,333	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				7,000	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				1,137	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				0	
H. TOTAL DIRECT COSTS (A THROUGH G)				8,137	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Cost (Rate: 46.0000, Base: 8137)**					
TOTAL INDIRECT COSTS (F&A)				3,743	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				11,880	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				11,880	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Alison Haupt

ORG. REP. NAME*
Tana Wong

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University Corporation at Monterey Bay

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Alison Haupt

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Alison Haupt - Co-PI**	0.00	0.60	0.00	4,667	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.60	0.00	4,667	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				4,667	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				2,333	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				7,000	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				1,137	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				0	
H. TOTAL DIRECT COSTS (A THROUGH G)				8,137	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Cost (Rate: 46.0000, Base: 8137)**					
TOTAL INDIRECT COSTS (F&A)				3,743	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				11,880	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				11,880	

M. COST SHARING PROPOSED LEVEL $ 0 | AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Alison Haupt

ORG. REP. NAME*
Tana Wong

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University Corporation at Monterey Bay

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Alison Haupt

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Alison Haupt - Co-PI	0.00	1.20	0.00	9,334	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	1.20	0.00	9,334	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				9,334	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				4,666	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				14,000	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				2,274	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				0	
H. TOTAL DIRECT COSTS (A THROUGH G)				16,274	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				7,486	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				23,760	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				23,760	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Alison Haupt

ORG. REP. NAME*
Tana Wong

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

University Corporation at Monterey Bay
On behalf of California State University, Monterey Bay

Budget Justification

A. Senior Personnel:

PI Haupt (0.6 academic year months) will analyze data collected through the Zooniverse *Floating Forests* project to investigate the effects of urban environments on kelp forests globally and incorporate *Floating Forests* research into undergraduate courses at California State University, Monterey Bay. Dr. Haupt will also mentor one part-time undergraduate research assistant, sponsored by the CSUMB Undergraduate Research Opportunities Center, who will be responsible for engaging the public through the Zooniverse website and blog as well as assisting with data analysis.

Year 1 = $4,667; Year 2 = $4,667; Total = $9,334

B. Fringe Benefits:

The University Corporation and CSUMB charge actual benefit rates which vary by individual. The benefit rates for full-time faculty include retirement, dental, health, life/LTD, vision, FICA, Medicare, SUI and Workers' Compensation. Fringe benefits are estimated at the university's average faculty benefit rate of 50%; the grant will be charged at the rate in effect at the time the salary is charged.

Year 1 = $2,333; Year 2 = $2,333; Total = $4,666

C. Travel:
Funds are budgeted to partially support travel to one regional conference per year, such as the Western Society of Naturalists (e.g., $250/night lodging; $350 RT airfare; $55/day per diem x 2 = $110; $350 registration; $60 ground transport; $7/day incidentals x 2 = $14). Additional funding will be sought from external and internal sources as needed.

Year 1 = $1,137; Year 2 = $1,137; Total = $2,274

D. Total Direct Costs:

Year 1 = $8,137; Year 2= $8,137; Total = $16,274

E. Indirect Costs:

The federally negotiated indirect cost rate for the University Corporation at Monterey Bay is 46% Modified Total Direct Costs (MTDC). This is a predetermined rate through 6/30/16 and provisional though 6/30/2017. The cognizant agency for the campus is the U.S. Department of Health & Human Services.

Year 1 = $3,743; Year 2 = $3,743 Total = $7,486

F. Total Amount of this Request: $23,760

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **University of Massachusetts Boston**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Jarrett Byrnes**				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1. Jarrett Byrnes - Co-PI	0.00	0.00	0.50	4,321		
2.						
3.						
4.						
5.						
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	4,321		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0		
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0		
3. (1) GRADUATE STUDENTS				31,500		
4. (0) UNDERGRADUATE STUDENTS				0		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6. (0) OTHER				0		
TOTAL SALARIES AND WAGES (A + B)				35,821		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				253		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				36,074		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) High performance computing system $ 5,000						
TOTAL EQUIPMENT				5,000		
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				0		
2. FOREIGN				0		
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0						
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				0		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0		
3. CONSULTANT SERVICES				0		
4. COMPUTER SERVICES				0		
5. SUBAWARDS				0		
6. OTHER				0		
TOTAL OTHER DIRECT COSTS				0		
H. TOTAL DIRECT COSTS (A THROUGH G)				41,074		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Modified indirect cost (Rate: 52.5000, Base: 36074)						
TOTAL INDIRECT COSTS (F&A)				18,939		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				60,013		
K. SMALL BUSINESS FEE				0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				60,013		
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $					
PI/PD NAME **Jarrett Byrnes**				FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Tana Wong**				Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Massachusetts Boston

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Jarrett Byrnes

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Jarrett Byrnes - Co-PI	0.00	0.00	0.50	4,451	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	4,451	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (1) GRADUATE STUDENTS				31,500	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				35,951	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				255	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				36,206	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				3,491	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				0	
H. TOTAL DIRECT COSTS (A THROUGH G)				39,697	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Modified indirect cost (Rate: 52.5000, Base: 39697)					
TOTAL INDIRECT COSTS (F&A)				20,841	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				60,538	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				60,538	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*
Tana Wong

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Massachusetts Boston

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Jarrett Byrnes

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Jarrett Byrnes - Co-PI	0.00	0.00	1.00	8,772	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	8,772	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (2) GRADUATE STUDENTS				63,000	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				71,772	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				508	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				72,280	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 5,000					
TOTAL EQUIPMENT				5,000	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				3,491	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				0	
H. TOTAL DIRECT COSTS (A THROUGH G)				80,771	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				39,780	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				120,551	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				120,551	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*
Tana Wong

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

Co-PI Byrnes Budget and Justification

A. Senior Personnel: We also ask for support for Co-PI Dr. Byrnes for half a month of support at $4,321 in year 1 and $4,451 in year 2 (includes 3% salary escalation).

B. Other Personnel: We ask for support ($21,000 academic and $10,500 summer) for a graduate student at UMass Boston for both years to participate in the work on citizen science validation as well as modeling the factors that alter kelp forest detectability.

C. Fringe: Fringe is calculated at 1.84% for the Co-PI for $80 and 1.65% for the graduate student in summer for $173 in 2017 and again in 2018.

D. IT Equipment: We ask for $5,000 for a high performance computing setup for the graduate student at UMB to facilitate rapid data analysis with the large data sets being generated by Floating Forests.

E. Domestic Travel: To enable direct collaboration and completion of projects, we ask for support for the graduate student and co-PI to travel to either Los Angeles or Monterey, CA to meet with PI Cavanaugh, Co-PI Haupt, and their groups in year 2. We estimate $2,000 for airfare, $1,000 for hotel housing, and a $491 per diem.

I. Indirect Costs: F&A Rate of 52.5% is negotiated between DHHS and the University of Massachusetts Boston. This brings it to $18,939 in year 1 and $20,841 in year 2.

J. Total Direct: 2016-2017: $41,074 2017-2018: $39,697
Total: 2016-2017: $60,013 2017-2018: $60,537

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Kyle Cavanaugh

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Using HyspIRI to Identify Benthic Composition and Bleaching in Shallow Coral Reef Ecosystems

Source of Support: NASA
Total Award Amount: $ 195,108 Total Award Period Covered: 08/19/15 - 08/18/17
Location of Project: UCLA
Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 1.00

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: CalM3: California Marine Modeling and Management

Source of Support: UC Research Initiatives
Total Award Amount: $ 80,566 Total Award Period Covered: 01/01/16 - 12/31/18
Location of Project: UCLA
Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.50 Sumr: 0.00

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Integrating physiological threshold experiments, remote sensing, and climate modeling to characterize the sensitivity of coastal ecosystems to climate change

Source of Support: NASA
Total Award Amount: $ 280,954 Total Award Period Covered: 04/01/16 - 03/31/19
Location of Project: UCLA
Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 1.00

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Collaborative Research: Detecting 30 Years of Change in Global Kelp Forests via Remote Sensing and Citizen Science (this proposal)

Source of Support: National Science Foundation
Total Award Amount: $ 411,055 Total Award Period Covered: 05/01/16 - 04/30/18
Location of Project: UCLA, UMB, CSUMB, Adler Planetarium
Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 1.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Jarrett Byrnes

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Detecting thirty years of change in global kelp forests via remote sensing and citizen science

Source of Support: UCLA subcontract /NSF

Total Award Amount: $ 411,055 Total Award Period Covered: 05/01/16 - 04/30/18

Location of Project: Boston, MA

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 0.50

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Collaborative Research: Multi-stressor effects of ocean acidification and eutrophication on food chain efficiency in a natural food web

Source of Support: WHOI/NSF

Total Award Amount: $ 95,905 Total Award Period Covered: 04/01/16 - 03/31/19

Location of Project: Boston, MA

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 0.50

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Evaluating the relationship between kelp forest ecosystems and water temperature in the Southern Gulf of Maine

Source of Support: WHOI SeaGrant

Total Award Amount: $ 99,186 Total Award Period Covered: 02/01/16 - 01/31/18

Location of Project: Boston, MA

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 0.75

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Feedbacks between coastal New England kelp beds and wave disturbance

Source of Support: MIT SeaGrant #NA140AR4170077

Total Award Amount: $ 124,181 Total Award Period Covered: 02/01/15 - 01/31/17

Location of Project: Boston, MA

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 1.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Food web structure as a driver of multiple ecosystem functions

Source of Support: MIT SeaGrant #5710003602 (Prime NA14OAR4170077)

Total Award Amount: $ 154,835 Total Award Period Covered: 02/01/14 - 01/31/16

Location of Project: Boston, MA

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Summ: 1.00

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

 USE ADDITIONAL SHEETS AS NECESSARY

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Alison Haupt

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Collaborative Research: Detecting 30 Years of Change in Global Kelp Forests via Remote Sensing and Citizen Science (this proposal)

Source of Support: National Science Foundation

Total Award Amount: $ 411,055 Total Award Period Covered: 05/01/16 - 04/30/18

Location of Project: California State University, Monterey Bay

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.60 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support
DR. LAURA TROUILLE
Director of Citizen Science, Adler Planetarium

CURRENT SUPPORT

Title: SOCS: Collaborative Research: Focusing Attention to Improve the Performance of Citizen Science Systems: Beautiful Images and Perceptive Observers
Type: Federal Award
Program/Sponsoring Agency: IIS Social Computational Systems/NSF
Lead Organization: Adler Planetarium
Adler PI: Laura Trouille
Performance Start: 7/1/12 **Performance End:** 8/31/16
Adler Award Amount: $395,902 **Cal-Months:** 0.0

Title: Zooniverse: Live Science Development
Type: Corporate Subaward
Program/Sponsoring Agency: Google Impact Awards**,** Google Foundation
Lead PI, Organization: Chris Lintott, University of Oxford
Adler PI: Laura Trouille
Performance Start: 10/1/13 **Performance End:** 9/30/16
Adler Award Amount: $449,569 **Cal-Months:** 1.2/year

Title: Asteroid Zoo
Type: Corporate Agreement
Program/Sponsoring Agency: Planetary Resource, Inc.
Lead Organization: Adler Planetarium
Adler PI: Laura Trouille
Performance Start: 12/6/13 **Performance End:** 12/5/16
Adler Award Amount: $60,000 **Cal-Months:** 0.0

Title: REU Site: Preparing a Diverse Workforce through Interdisciplinary Astrophysics Research
Type: Federal Subaward
Program/Sponsoring Agency: Research Experiences for Undergraduates/NSF
Lead PI, Organization: Vicky Kalogera, Northwestern University
Adler PI: Laura Trouille
Performance Start: 2/1/14 **Performance End:** 1/31/17
Adler Award Amount: $0 **Cal-Months:** 0.0

Title: Pathways: Using Citizen Science to Study the Social Behavior of a Charismatic Rare Bat Species at Mammoth Caves National Park
Type: Federal Subcontract
Program/Sponsoring Agency: Advancing Informal STEM Learning (AISL)/NSF
Lead PI, Organization: Shannon Trimboli, Western Kentucky University Research Foundation
Adler PI: Laura Trouille
Performance Start: 4/10/14 **Performance End:** 12/31/15
Adler Award Amount: $36,458 **Cal-Months:** 0.0

Title: To support sustainable future for the rapidly expanding Zooniverse platform through an engaged and empowered community of citizen scientists

Type: Foundation Grant
Program/Sponsoring Agency: Alfred P. Sloan Foundation
Lead Organization: Adler Planetarium
Adler PI: Laura Trouille
Performance Start: 7/1/14 **Performance End:** 6/30/16
Award Amount: $707,648 **Cal-Months:** 0.0

Title: Disk Detective: Finding Circumstellar Disks with WISE and 100,000 New Colleagues
Type: Federal Subcontract
Program/Sponsoring Agency: Astrophysics Data Analysis Program/NASA
Lead PI, Organization: Marc J. Kuchner, Goddard Space Flight Center
Adler PI: Laura Trouille
Performance Start: 7/1/15 **Performance End:** 12/31/15
Adler Award Amount: $52,481 **Cal-Months:** 0.0

Title: Tree Zoo Proto-type
Type: Federal Subcontract
Program/Sponsoring Agency: NSF
Lead PI, Organization: James R. Kellner, Brown University
Adler PI: Laura Trouille
Performance Start: 7/1/15 **Performance End:** 6/30/16
Adler Award Amount: $10,000 **Cal-Months:** 0.0

Title: A citizen science mediated Optical Character Recognition (OCR) module for large-scale data rescue
Type: Federal Award
Program/Sponsoring Agency: North Pacific Research Board
Lead PI, Organization: Kevin R. Wood, National Oceanic and Atmospheric Administration
Adler PI: Laura Trouille
Performance Start: 7/1/15 **Performance End:** 1/31/16
Adler Award Amount: $25,134 **Cal-Months:** 0.26/year

Title: Broadening Participation in a Computational Future: Casting a wide net
Type: Foundation Subaward
Program/Sponsoring Agency: Lyle Spencer Research Awards/The Spencer Foundation
Lead PI, Organization: Laura Trouille, Northwestern University
Adler PI: Laura Trouille
Performance Start: 8/1/15 **Performance End:** 7/31/18
Adler Award Amount: $0 **Cal-Months:** 0.0

PENDING SUPPORT

Title: ADBC Proposal: Digitization TCN: Collaborative Research: The Key to the Cabinets: Building and sustaining a research database for a global biodiversity hotspot
Type: Federal Subcontract
Program/Sponsoring Agency: Advancing Digitization of Biodiversity Collections/NSF
Lead PI, Organization: Zack Murrell, Appalachian State University
Adler PI: Laura Trouille
Performance Start: 6/1/14 **Performance End:** 5/31/18

Adler Award Amount: $40,000 **Cal-Months:** 0.75/year

Title: Bringing Wildlife Management into Focus: Integrating Camera Traps, Remote Sensing and Citizen Science to Improve Population Modeling
Type: Supplemental Funding, Federal Subaward
Program/Sponsoring Agency: ROSES 2012 A.36/NASA
Lead PI, Organization: Phil Townsend**,** University of Wisconsin
Adler PI: Laura Trouille
Performance Start: 1/6/15 **Performance End:** 1/5/18
Adler Award Amount: $139,821 **Cal-Months:** 0.28 Year 2, 0.14 Year 3, 0.09 Year 4

Title: Collaborative Research: ABI Development: Notes from Nature: Advancing a Next Generation Citizen Science Platform for Biocollection Transcription
Type: Federal Subaward
Program/Sponsoring Agency: Advancing Digitization of Biodiversity Collections/NSF
Lead PI, Organization: Robert Guralnick, University of Florida/Florida Museum of Natural History
Adler PI: Laura Trouille
Performance Start: 3/11/15 **Performance End:** 2/28/18
Adler Award Amount: $145,561 **Cal-Months:** 0.05/year

Title: Collaborative Research: Engaging Introductory Astronomy Students in Authentic Research through Citizen Science
Type: Federal Award
Program/Sponsoring Agency: Improving Undergraduate STEM Education (IUSE: EHR)/NSF
Adler PI: Laura Trouille
Performance Start: 9/1/15 **Performance End:** 8/31/18
Award Amount: $137,513 **Cal-Months:** 0.2/year

Title: GlitchZoo: Teaming Citizen Science with Machine Learning to Deepen LIGO's View of the Cosmos
Type: Federal Subaward
Program/Sponsoring Agency: INSPIRE/NSF
Lead PI, Organization: Vicky Kalogera, Northwestern University
Adler PI: Laura Trouille
Performance Start: 9/1/15 **Performance End:** 8/31/18
Adler Award Amount: $194,818 **Cal-Months:** 0.2/year

Title: Annie: Annotation of Biological Collections with Help from Citizens
Type: Subaward
Program/Sponsoring Agency: Belgian Research Action
Lead PI, Organization: Robert Guralnick, University of Florida
Adler PI: Laura Trouille
Performance Start: 10/1/15 **Performance End:** 9/30/17
Adler Award Amount: $13,336 **Cal-Months:** 0.0

Title: Astrophysics Education at NASA Goddard: Enhancing Teacher Preparedness, Increasing Student Scientific Literacy, and Engaging Lifelong Learners Through Connections to Goddard-Unique Science and Technology
Type: Federal Subaward

Program/Sponsoring Agency: Science Mission Directorate Science Education Cooperative Agreement Notice/NASA
Lead PI, Organization: Barbara Mattson, NASA Goddard Space Flight Center/Universities Space Research Association
Adler PI: Laura Trouille
Performance Start: 10/1/15 **Performance End:** 9/30/20
Adler Award Amount: $869,550 **Cal-Months:** 0.28 Year 1, 0.97 Year 2, 1.15 Year 3, 0.71 Year 4, 0.05 Year 5

Title: Detecting 30 Years of Change in Global Kelp Forests via Remote Sensing and Citizen Science
Type: Federal Subaward
Program/Sponsoring Agency: Geography and Spatial Sciences Program/NSF
Lead PI, Organization: Kyle Cavanaugh, University of California Los Angeles
Adler PI: Laura Trouille
Performance Start: 5/1/16 **Performance End:** 4/30/18
Adler Award Amount: $65,000 **Cal-Months:** 0.0
Total Award Amount: $411,055

Title: Quantifying the response of canopy photosynthesis to climate forcings in a Neotropical forest using dense time series of chlorophyll fluorescence
Type: Federal Subaward
Program/Sponsoring Agency: NSF
Lead PI, Organization: James R. Kellner, Brown University
Adler PI: Laura Trouille
Performance Start: 7/1/16 **Performance End:** 6/30/17
Adler Award Amount: $45,006 **Cal-Months:** 0.1

FACILITIES, SOFTWARE, AND EQUIPMENT – UCLA

The UCLA Department of Geography is well equipped to perform the necessary data analysis tasks described in the proposal. PI Cavanaugh has access to a 100TB data storage server, which will be used to store and manage datasets produced by this project. The PIs also have access to personal computers (PC and Mac) and a high performance scientific computing cluster managed by the UCLA Division of Social Sciences. UCLA has access to a variety of satellite imagery analysis, GIS, and scientific computing software including ArcGIS 10, ENVI/IDL 5.0, MODTRAN, and Matlab.

FACILITIES, SOFTWARE, AND EQUIPMENT – **UMass Boston**

UMB Laboratory: On the UMB campus, students will be housed in the PI's fully equipped research laboratory in the new UMB Integrated Sciences Complex. The lab is fully supplied with multiple Apple computers, a fume hood for sample processing, and sample freezer, a full range of shop tools, dissecting scopes, and other equipment for lab work.

UMB Computer: UMass Boston has extensive computer resources for this project. Each research lab has an array of internet- connected Macs and PCs. UMB has 10 computer labs with over 250 PCs and printers available for student use, as well as specialty computer facilities and computer teaching laboratories. The University has licenses for all necessary software beyond use of open source tools (i.e., MATLAB, ArcGIS) although open source tools (R, Python) are prefered. The PI will provide computer facilities in his lab for student work. We also have access to a Ravana, a 128 core server for High Performance Computing where necessary.

UMB Office Support: The Program Coordinator has dedicated office space with computer equipment as well as access to a full array of support equipment such as copy and fax machines. The Directors and all participating faculty have appropriate office space. The offices of the Biology Department and the Dean of the College of Science and Mathematics have staff and supplies that support this project for any shipping needs.

FACILITIES, SOFTWARE, AND EQUIPMENT – California State University Monterey Bay

PI Haupt is a new faculty member who received startup support to establish a research program. The shared lab space is equipped with lab bench space, fume hood, chemical storage space, and desk space for students. In progress or recently completed lab purchases include 2 Leica Stereomicroscopes with light sources with 1 Leica HD camera attachment; Leica S8 APO Series Microscope (B-Stand Package); Garmin GPS; Canon Digital Rebel T3i + Backscatter Sea & Sea RDX-600D underwater housing, and 10 Onset temperature loggers.

Computing facilities are available to CSUMB students and technicians for use in data entry, word processing, and data analysis (R, MATLAB). The PIs also have licenses for all software necessary to analyze (MATLAB) and display data (Excel, Matlab) and write manuscripts (MS Office).

All PIs offices are equipped with a Macintosh desktop computer with Microsoft software, and have access to shared printers, copiers, and other supplies.

The Chapman Science Center contains faculty office space, teaching and research labs, student and administrative workspace that will be utilized for mentoring and research activities. The eight laboratory classrooms hold at least 24 students, some up to 40. Carts with 24 wireless Apple Mac Powerbook laptops or 24 wireless Hewlett-Packard PC laptops are used to convert classrooms to computer labs. Two to three additional computer work stations are permanently situated in each laboratory classroom for student use. The teaching labs are fully equipped, including a geology laboratory, a physics laboratory, three biology laboratories, two chemistry laboratories, and one organic chemistry laboratory. The instructional laboratory equipment includes microscopes, centrifuges, power supplies, gel boxes, pcr machines, spectrophotometers, digital cameras, and much else. Venier LabPro Software and Technology is utilized in the general chemistry laboratories to provide students hands on experience with the most recent technologies.

Undergraduate Research Opportunities Center (UROC) – is a cross-campus center that trains, supports, and engages students in undergraduate research. UROC students work on relevant and innovative research projects at CSU Monterey Bay and at regional research institutions. Their work is guided by a research mentor and is supported by extensive training in research proposal writing, presentation skills, communication skills, professionalism, and graduate school preparedness. Students are also given the opportunity to communicate their work to the academic community through presentations and publications. UROC will collaborate on the recruitment, selection, and training of student research assistants.

FACILITIES, SOFTWARE, AND EQUIPMENT – Adler Planetarium

The Adler Planetarium Citizen Science department is host to the majority of the web development and education efforts for the collection of online citizen science projects know as the Zooniverse (zooniverse.org). Working in collaboration with science teams across the world, with volunteers in almost every country, the team takes large data sets that cannot be adequately analyzed by computers and puts them online. Volunteers are asked to perform simple tasks, such as counting, identification or measurement and the resulting data is fed back to science teams who use it to further their research. As well as performing a simple analysis task on behalf of the science teams, volunteers can participate in discussions with other volunteers and scientist (e.g. talk.galaxyzoo.org).

Dr. Trouille, the software developer, and the designer have access to the necessary computing equipment, office space, Internet access, and programming software necessary for this project through the Adler. The Adler also provides the required server space to store and manage the data and to perform the computational tasks.

Data Management Plan

Data management will be coordinated by the Principal Investigators, and carried out by all project participants. PI Cavanaugh will take ultimate responsibility for organizing the data files and ensuring their availability.

1. Types of data

Raw data from the Floating Forests project will consist of .csv files that describe the image coordinates of the polygons users use to delineate kelp canopy. We will process these data to create maps of the number of users that have identified a given pixel of kelp. After the calibration and validation activities have been performed, our final data product will be maps of kelp canopy for every Landsat image. These data will be processed into a geographical information system format such as GeoTiffs and/or shapefiles.

2. Data and metadata standards

Metadata will be comprised of two formats - contextual information about the data in a text based document and ISO 19115 standard metadata in an xml file.

Analysis scripts will be commented extensively, and the workflow for each analysis will be documented in an accompanying text file.

3. Policies for access and sharing

All data will be deposited at Temperate Reef Base http://temperatereefbase.imas.utas.edu.au/static/landing.html. Co-PI Byrnes is currently working on a project to develop this database. Code for all analyses will be shared publicly at https://github.com/jebyrnes/floatingForests and be assigned a DOI for permanent archiving via Zenodo https://zenodo.org/. When possible, data will also accompany published paper as appendices (e.g., for PLoS One). Data will be fully open access with the only requirement being citation to the data product.

4. Policies and provisions for re-use, re-distribution

The giant kelp canopy area data will be made available as soon as data is quality controlled. This data will be published as a data product, and will require only citation of the data product itself. While future authors will be encouraged to contact the PI and co-authors with questions about the data, no requirements or restrictions will be placed on the use of the data.

5. Plans for archiving and preservation of access

Short-term

In the short-term, data and scripts will be stored on laboratory computers and backed up nightly to a hard drive. Additionally, the lab will use the Dropbox service (https://www.dropbox.com/) to persistently backup the data as it is entered.

Long-term

Long-term archiving will be via Temperate Reef Base as described in the policies for access and sharing. If Temperate Reef Base should fail, we will move data to another member node of the Data One project to ensure that it is fully searchable and accessible to the general public.

Undergraduate Research Opportunities Center
UROC
California State University, Monterey Bay

September 1, 2015

To: NSF Geography and Spatial Sciences (GSS) Program
From: Dr. Holly Unruh, Associate Director, Undergraduate Research Opportunities Center (UROC)

By signing below or by transmitting this message electronically, I acknowledge that the Undergraduate Research Opportunities Center is listed as a collaborator on the proposal, titled "Detecting 30 Years of Change in Global Kelp Forests via Remote Sensing and Citizen Science," with Dr. Alison Haupt as California State University, Monterey Bay's Principal Investigator and Dr. Kyle Cavanaugh, Principal Investigator at the lead institution, University of California, Los Angeles.

I commit to provide or make available the resources designated in the project description of the proposal that seeks support for this project.

Signed: ______________________

Holly Unruh, Associate Director

Organization: Undergraduate Research Opportunities Center, California State University, Monterey Bay

Date: 9/1/15

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

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DAN REED
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UNIVERSITY OF CALIFORNIA
MARINE SCIENCE INSTITUTE
SANTA BARBARA, CALIFORNIA

2 September 2015

Dr. Kyle Cavanaugh
1255 Bunche Hall
University of California, Los Angeles
Box 951524
Los Angeles, CA 90095

Dear Kyle,

I am writing on behalf of the Santa Barbara Coastal Ecosystem LTER (SBC LTER) to express our strong interest in collaborating with you on your proposal to the NSF Geography and Spatial Sciences Program entitled, "Detecting 30 Years of Change In Global Kelp Forests via Remote Sensing and Citizen Science". Developing an improved understanding of the processes that drive spatiotemporal variability in giant kelp abundance on global scales is directly relevant to SBC LTER's goal of determining the effects of climate change on the structure and function of kelp forests.

As a collaborator on your project SBC LTER will provide you with diver, aerial, and satellite derived data on giant kelp abundance for use in your Floating Forests calibration and validation activities. Floating Forests represents a unique tool both for extracting data from vast amounts of satellite imagery and for engaging the public about the importance of giant kelp ecology and conservation.

We wish you the best of luck with your proposal. Your prior research in this area has been extremely successful and influential, and we look forward to continuing our productive and valuable collaboration.

Sincerely,

Dan Reed
Lead Principle Investigator
Santa Barbara, Coastal Long Term Ecological Research project

FACULTAD DE CIENCIAS BIOLÓGICAS
PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE

Las Cruces, September 2, 2015

Letter of support

NSF Panel
Dear Review Committee,

Firstly I would like to thank you for inviting me to be part of this network. I am writing this letter of collaboration for the proposal, “Detecting 30 Years of Change In Global Kelp Forests via Remote Sensing and Citizen Science” led by Dr. Kyle Cavanaugh and Dr. Jarrent Byrnes. I am subtidal ecologist in Chile, where the coastal environment is mainly kelp dominated. Chile is a leading country in export of kelp in the world (ca~300.000 tons year^{-1}). I currently positioned as research associate at ECIM (Marine Coastal Research Station) from Pontificia Universidad Católica de Chile with an active field program (state funded) in central-northern Chile focusing on the understanding of mechanisms of positive interactions between these habitat forming species and fish on latitudinal gradients.

Regarding Floating Forest initiative, my lab and I will be using the data generated. I am excited to be collaborating with other kelp forest researchers in comprehend the long-term patterns and novel research initiative.
Please feel free to contact me if you have any questions.

Alejandro Perez Matus
SUBELAB (Subtidal Ecology Laboratory)
Estación Costera de Investigaciones Marinas
Pontificia Universidad Católica de Chile