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

SUGGESTED REVIEWERS:

Ken Sebens, University of Washington, <sebens@uw.edu>
Paul Dayton, UC San Diego <pdayton@ucsd.edu>
Inka Bartsch <Inka.Bartsch@awi.de>
Ken Dunton, dunton@utmsi.utexas.edu

REVIEWERS NOT TO INCLUDE:

Pursuant to PAPPG Chapter II.C.1.e., each PI, co-PI, and other senior project personnel identified on a proposal must provide collaborator and other affiliations information to help NSF identify appropriate reviewers.(v.4/21/2017)

Please complete this template (e.g., Excel, Google Sheets, LibreOffice), save as .xlsx or .xls, and upload directly as a Fastlane Collaborators and Other Affiliations single copy doc.
Do not upload .pdf.

There are five tables:
A: Your Name & Affiliation(s);
B: PhD Advisors/Advisees (all);
C: Collaborators;
D: Co-Editors;
E: Relationships

List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department (optional) to disambiguate common names.

Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and abbreviate, where necessary, to make the data fit.

To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows that enable sorting.
"Last active" dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.

Table A: List your Last Name, First Name, Middle Initial, and organizational affiliation (including considered affiliation) in the last 12 months.

A	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Byrnes, Jarrett E.K.	University of Massachusetts Boston	

Table B: List names as Last Name, First Name, Middle Initial, and provide organizational affiliations, if known, for the following.

G: Your PhD Advisor(s)
T: All your PhD Thesis Advisees
P: Your Graduate Advisors

to disambiguate common names

B	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Stachowicz, Jon J.	University of California Davis	jjstachowicz@ucdavis.edu
P:	Grosholz, Ted		
P:	Rosenheim, Jay		
P:			

Table C: List names as Last Name, First Name, Middle Initial, and provide organizational affiliations, if known, for the following.

A: Co-authors on any book, article, report, abstract or paper (with collaboration in last 48 months; publication date may be later).

C: Collaborators on projects, such as funded grants, graduate research or others (in last 48 months).

to disambiguate common names

C	Name:	Organizational Affiliation	Optional (email, Department)	Last Active

A:	Anderson, Robert	University of Tasmania		
A:	Balvanera , Patricia	UNAM		
A:	Barrett, Neville	University of Tasmania		
A:	Bolton , John	University of Cape Town		
A:	Bowen, Jennifer	Northeastern University		
A:	Buschmann, Alejandro	Universidad Catolica		
A:	Cardinale , Bradley J.	University of Michigan		
A:	Carr, Marc	University of California Santa Cruz		
A:	Caselle, Jenn	University of California Santa Barbara		
A:	Cavanaugh , Kyle	UCLA		
A:	Connell , Sean	University of Adelaide		
A:	Dee, Laura	University of Minnesota		
A:	Derrien-Courtel, Sandrinne	Muséum National d'Histoire Naturelle		
A:	Dijkstra, Jennifer	University of New Hampshire		
A:	Duffy , J. Emmett	Tannenbaum Marine Observatory Network		
A:	Edgar, Graham	University of Tasmania		
A:	Edwards, Matthew	San Diego State University		
A:	Elahi, Robin	Stanford University		
A:	Estes, James	UC Santa Cruz		
A:	Gamfeldt , Lars	University of Gothenburg		
A:	Gonzalez , Andrew	McGill University		
A:	Goodwin, Claire	National Museums of Northern Ireland		
A:	Grabowski, Jon	Northeastern University		
A:	Haupt , Alison	California State Monterey Bay		
A:	Hooper , David	Western Washington University		
A:	Isbell , Forest	University of Minnesota		
A:	Johnson , Craig	University of Tasmania		
A:	Kenner, Michael	UC Santa Cruz		
A:	Konar , Brenda	University of Alaska Fairbanks		
A:	Krumhansl , Kira	Simon Fraiser University		
A:	Kushner, David	National Park Service		
A:	Ling , Scott	University of Tasmania		
A:	Michaeli , Fiorenza	Stanford University		
A:	Norderhaug , Kjell-Magnus	Norwegian Institute for Water Research		
A:	Novak , Mark	Oregon State University		
A:	Nunn, Julia	National Museums of Northern Ireland		
A:	Okamoto, Daniel	Florida State University		
A:	Perez-Matus , Alejandro	Pontificia Universidad Católica de Chile		
A:	Ranganathan, Jai	NCEAS		
A:	Rassweiler, Andrew	Florida State University		
A:	Reed , Daniel C.	UC Santa Barbara		
A:	Salomon , Anne	Simon Fraiser University		
A:	Shears , Nick	University of Auckland		
A:	Sousa , Pinto, Isabel	University of Porto		
A:	Steneck, Robert	University of Maine		
A:	Witman, Jon	Brown University		
C:	Alsterberg, Christian	Lund University		
C:	Beas, Rodrigo	Universidad Autónoma de Baja California		
C:	Bik, Holly	UC Irvine		
C:	Deegan, Linda	Marine Biological Laboratory		
C:	Edwards , Kyle	University of Hawaii		
C:	Galloway, Aaron	University of Oregon		
C:	Giblin, Anne	Marine Biological Laboratory		
C:	Helm, Rebecca	Woods Hole Oceanographic Institute		

C:	Hepburn, Chris	University of Otago		
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C:	Martini, Kim	SeaBird Technologies		
C:	McClain, Craig	Louisiana University Marine Consortium		
C:	Miller , Luke	San Jose State University		
C:	Moore, Pippa	University of Abryswyth		
C:	O'Connor , Mary	University of British Columbia		
C:	Salvagno, Anthony	SciFund		
C:	Schmitt , Russ	UC Santa Barbara		
C:	Seavey, Jennifer	University of New Hampshire		
C:	Smale, Daniel	Marine Biological Association of the UK		
C:	Verges, Adriana	University of New South Wales		
C:	Walker, Barbara	UC Santa Barbara		
C:	Watson, Jane	University of Victoria		
C:	Watson, Jane	Vancouver Island University		
C:	Wernberg , Thomas	University of Western Australia		
A:	Lefcheck, Jon	Bigelow Labs		

Table D: List editorial board, editor-in-chief and co-editors with whom you interact. An editor-in-chief should list the entire editorial board.

B: Editorial board: Name(s) of editor-in-chief and journal (in past 24 months).

E: Other Co-Editors of journals or collections with whom you directly interacted (in past 24 months).

to disambiguate common names

D	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	Marshall, Dustin	Test University XYZ	Oikos	7/1/17
B:	Bonte, Dries	University of Ghent	Oikos	7/1/17
B:	De Deyn, Gerlinde	Wagenigen University	Oikos	7/1/17
B:	Moore, Allen	University of Georgia	Ecology and Evolution	7/1/17
B:	Beckerman, Andrew	University of Sheffield	Ecology and Evolution	7/1/17
B:	Firn, Jennifer	Queensland University of Technology	Ecology and Evolution	7/1/17

Table E: List persons for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

D	Name:	Organizational Affiliation	Optional (email, Department)	Last Active

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
NSF 17-537 **07/21/17**

☐ Special Exception to Deadline Date Policy

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1753246

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

OCE - BIOLOGICAL OCEANOGRAPHY

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
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043167352

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 Massachusetts Boston

AWARDEE ORGANIZATION CODE (IF KNOWN)
0022228000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
University of Massachusetts Boston
100 Morrissey Boulevard
Dorchester, MA. 021253300

NAME OF PRIMARY PLACE OF PERF
University of Massachusetts Boston

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
University of Massachusetts Boston
100 Morrissey Blvd
Boston ,MA ,021253300 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) ☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS

☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **CAREER:Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 1,109,944	60 months	06/01/18	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☒ TYPE OF PROPOSAL **Research**

☐ HUMAN SUBJECTS Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☒ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED **AS CI NZ UK HK**
☒ COLLABORATIVE STATUS **Not a collaborative proposal**

PI/PD DEPARTMENT
Biology Department

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CO-PI/PD				
CO-PI/PD				
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 (PAPPG). 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 PAPPG Chapter IX.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 Proposal & Award Policies & Procedures 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 ☒

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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.

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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, Chapter IX.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:

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Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Heather Carey**	**Electronic Signature**	**Jul 21 2017 4:38PM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
	heather.carey@umb.edu	

PROJECT SUMMARY

Overview:

As oceans continue to warm, we are confronted with the problem of assessing when and where climate change will cause ecosystems to rapidly shift states. These state shifts can be particularly pronounced when they affect species that serve as foundations for the entire ecosystem. This proposal will establish globally-replicated experiments to determine how slow changes in temperature - a press perturbation of climate change ? are likely to interact with the anticipated increased severity of pulsed disturbances to push kelp forest ecosystem past tipping points, engendering potential community state shifts. The proposed research asks the following questions:

1)How will global increases in water temperature affect the ability of kelp forest communities to recover from disturbance?
2)How does temperature interact with a common disturbance (storm waves) to affect kelps and their associated communities across the globe?

To answer these questions, our global network of kelp forest ecologists will conduct identical manipulative and observational experiments using standardized protocols in the kelp forests of four biogeographic regions across the globe. Results will be analyzed using nonlinear mixed models and Structural Equation Modeling (SEM) to quantify the interactions among temperature, disturbance, and kelp forest persistence.

Intellectual Merit:

Kelp loss is being documented around the world. Loss often correlates with areas exhibiting ocean warming that show water temperatures exceeding kelps? thermal limits. However, the size and type of disturbance that actually causes loss varies from location to location; whether temperature is actually implicated in the subsequent lack of recovery is unclear. This research will take a global-scale approach to ask whether kelp forests and their associated communities will change due to interactions between the long-term press of climate change and the short-term agents of more local disturbance.

Broader Impacts:

As part of this research, undergraduates from UMass Boston will be trained in the techniques of underwater research using SCUBA. This is a unique opportunity for many UMB students. The university?s demographics draw heavily from traditionally underrepresented groups in marine science. Many, even here in coastal Boston, have no experience with SCUBA or life underwater. This project will build a program introducing them to the underwater world while making them a vital part of conducting this research. High performing students will be given further opportunities to participate in research, both here and abroad. Additionally, this proposal will provide for the training of one graduate student, one postdoc, and enable multiple undergraduates to shape their senior thesis projects.

This project also forms the backbone of the collaborative Kelp Ecosystem Ecology Network (KEEN). The research I propose utilizes this nascent international collaborative network that I have spent the last four years building, creating common standards, protocols, and governance. It will give us the resources needed to perform the work and facilitate communication and collaboration across the network. We also plan to reach outside of the network, immediately opening our data to other kelp forest researchers and NGOs, and provide an example of how to create a global Biodiversity Observation Network for kelp forests.

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Current and Pending Support	1	
Facilities, Equipment and Other Resources	2	
Special Information/Supplementary Documents (Data Management Plan, Mentoring Plan and Other Supplementary Documents)	3	
Appendix (List below.) **(Include only if allowed by a specific program announcement/ solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)**		
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.

CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales

Results of Previous NSF Support - LTER Plum Island Ecosystems: Dynamics of coastal systems in a region of rapid climate change, sea-level rise, and human impacts, Ref Award# OCE-1637630, $256,720 over five years for PI Byrnes: PI Byrnes is currently a new member of the Plum Island LTER. This is the first year of his participation, and field operations are underway. Currently, he is supporting one graduate student, one technician, two students to sort samples, and is mentoring an REU.

1. Career Context Statement

1.1. Career Goals: My research and teaching focus on the effects of global change in coastal ecosystems. I focus on its cascading effects via changes in foundation species using kelp forests and, more recently, salt marshes as model systems. I emphasize exploring mechanism with local experiments and global data synthesis to evaluate generality. This has led me to focus much of my early career build a global collaborative kelp forest research network that is already yielding novel results. This proposal will allow me to build a strong foundation for the next decade of this work, focusing on the kelp forest systems I have studied for the last decade. ***This proposal will enable me to advance our understanding of global change in kelp forest ecosystems via local fieldwork, international collaboration, and involving students in research they otherwise might never have considered.***

1.2. Connecting Students to the Oceans Around Them: ***This proposal will enable me to create a dynamic program connecting students to life in the ocean in their own back yard.*** The campus of UMass Boston (UMB) is right on the water. However, most of our students have little experience with the sea around them. Even fewer have seen life on the seafloor firsthand. If funded, this proposal will expand students' horizons and give them first-hand experience of life in the sea. My work will connect UMB students to the biological richness of the subtidal kelp forests of Gulf of Maine. I have already begun to lay the necessary groundwork to involve students by developing a SCUBA-oriented subtidal research capability at UMB and creating a formal dive-safety board, working towards AAUS admission, and building a dive-training program. *This proposal will enable me to bring students into subtidal research that otherwise would never get the opportunity to understand these systems first-hand.*

1.3 The Kelp Ecosystem Ecology Network & Response to Previous Reviews: I have spent the last four years building The Kelp Ecosystem Ecology Network (KEEN), a network of kelp forest ecologists performing coordinated experiments and monitoring. My first research effort as new faculty was leading an NCEAS working group to look at long-term effects of kelps and climate change. We assembled the first-ever global database of kelp time series and found that, rather than showing uniform trends, kelp trajectories were highly variable the world over (Krumhansl et al. 2016) Ongoing work from the group shows this variability is possibly linked to climate (see preliminary data below). However, data coverage was haphazard, utilized wildly different protocols, and was not well-positioned to answer questions about concomitant community shifts and mechanisms beyond speculation. I concluded that a coordinated effort was needed to truly disentangle the general mechanisms linking kelp forest communities and climate, and so at the International Temperate Reef Symposium in 2014, I assembled a team and we launched KEEN. The goal of the current network is assess the effects of global change on the world's kelp forests via coordinated activities along latitudinal gradients in different ecoregions. Previous NSF reviews asked for proof of the viability of the network and whether it could actually be done. The answer is yes. We have:

1) Acquired three years of data across the network which is now publically available.
2) Aided in building a formal data management system, Temperate ReefBase which hosts KEEN and other temperate reef data at http://temperatereefbase.imas.utas.edu.au.
3) Focused on developing a single regional network – KEEN Of New England (KEEN ONE) in detail to create a model for other regions to enable KEEN to scale up.

4) Developed a handbook of methodologies and data management practices for all members.
5) Built a formal governance structure with regional coordinators.
In addition, KEEN has partnered with the Adler Planetarium to create the citizen science platform Floating Forests (http://floatingforests.org) to built a 30+ year dataset of global canopy kelp coverage. This proposal will allow me to transform this nascent international research network into a long-term success for years to come.

1.4. Project Overview & Connection to Career Development: The central objective of this project is to understand how change in ocean climate – temperature, wave disturbance, etc. – will affect kelp forests around the globe. It will do so via experimental removals of kelps in different ecoregions along environmental gradients – a space for time substitution approach – alongside an observational study of how interannual variability of the world's kelp forests responds to changing thermal and wave regimes. Global work will be accomplished via collaboration with a pre-existing network of kelp forest ecologists. Local work here in the New England will focus on getting undergraduates into the water and involved in subtidal research. Getting funded for this proposal will enable me to cement a career-long connection to this vital ecosystem, locally and globally, both in my research and teaching.

2. Introduction & Motivation for Work

2.1 Overview

As humans continue to alter the environment around us, so-called global change, we have witnessed multiple examples of rapid changes in the state of ecosystems and ecosystems (Hughes et al. 2013). Many state shifts are triggered by the interaction of long-term press perturbations with a sudden pulsed disturbance event. Climate change presents an opportunity to study the interaction between these multiple types of disturbance in ocean ecosystems (Harley et al. 2006). Classically, researchers have tried to understand the effect of long-term press perturbations, such as climate change's slow rise in temperature (Roemmich et al. 2012, Gleckler et al. 2012) or short-term pulse disturbances, such as a heat-wave (Wernberg et al. 2012, 2016) or storm (Byrnes et al. 2011), in isolation. I propose that we can understand many of these state shifts as interactions between press and pulse perturbations (Bender et al. 1984, Scheffer et al. 2001).

Climate change presents a wide variety of examples of the dramatic consequences of the interaction between the long-term press of temperature increases and a short-term additional disturbance. Consider, for example, coral die offs in already warming areas subjected to heat waves (McWilliams et al. 2005) or the denuding of forests when climate driven decreased tree health coincides with likewise range and phenology shifts in pest outbreaks (Williams and Liebhold 2002, Bentz et al. 2010). Is this interaction between temperature change and locally pulsed disturbances general? In what types of ecosystems will this press-pulse interaction have its strongest effect? How can we better understand the interaction between press and pulse disturbance for communities and ecosystems using climate change as a backdrop?

The loss of dominant habitat forming foundation species (sensu Dayton 1972) can set off a cascade of indirect changes within an ecosystem (Dunne and Williams 2009, Novak et al. 2011). Climate change could have its strongest effects where temperature alters recovery of foundation species from local pulsed disturbances. Temperate marine ecosystems dominated by large structure forming brown macroalgae – kelp forests - present a perfect system to understand the effects of climate change via shifts in the ecology of foundation species. Moreover, given their variability across the globe, and variability in their long-term population trends (Krumhansl et al. 2016), they provide a unique opportunity to assess generality.

Here I propose to establish a global experimental network to examine the ubiquity and generality of the interaction between long-term changes in ocean temperature and short-term disturbances for kelp forests ecosystems.

2.2 Kelp Ecosystems

Roughly 25% of the world's coastlines are dominated by kelps (Steneck et al. 2002, Krumhansl et al. 2016). Kelps provide numerous ecosystem functions and services. They provide food for a wide variety of herbivores, detritivores, and filter feeders (Duggins et al. 1989, Krumhansl and Scheibling 2012), alter water flow around shorelines (Gaylord et al. 2007), give habitat to both adult and juveniles of a wide variety of species many of which are commercially harvested (Carr and Syms 2006), influence marine nutrient cycling (Kelly et al. 2012), and much more (Dayton 1985). Even modest shifts in their abundance and distribution would mean a major change to coastal ocean ecosystems and to the human communities that rely on them.

Kelps are particularly susceptible to changes in ocean temperature due to their physiological and ecological dependence on cold water. Kelps equatorward range limits are set by a combination of physiological tolerance of adults (Lüning 1984, Hatcher et al. 1987), limits to reproduction (Bartsch et al. 2012, 2013), tolerance of gametophytes (Bartsch 1993), failure of recruits (Ladah et al. 1999), and nutrient availability (Dayton 1985) which often correlates with temperature (Deysher and Dean 1986). Changes in temperature threaten to act on any and all of these. In particular, temperature induced decreases in growth and reproduction in kelps suggest that increases in temperature may inhibit kelps ability to recover from strong but local short-term disturbances (Wernberg et al. 2010). If kelps are not able to recover from a strong short-term disturbance, then the ecosystem may shift into one of several alternate states dominated by sea urchin barrens (Harrold and Reed 1985), algal turfs (Connell et al. 2008, Hughes et al. 2013, Connell et al. 2014), foliose understory algae (Harley et al. 2006, Arkema et al. 2009), sessile suspension feeders (Rassweiler et al. 2010, Roemmich et al. 2012, Gleckler et al. 2012) and more. Each of these alternate community states has radical implications for all species in the kelp forest food web. Indeed, changes in the food web may help to force and maintain these new alternate states (Estes et al. 1978, Wernberg et al. 2012, 2016).

We have already witnessed climate change related impacts on kelp forests in nearly every region of the globe. In Australia, climate change has hindered kelp recovery from heat waves (Byrnes et al. 2011, Wernberg et al. 2012, 2016), caused range shifts in giant kelp (Bender et al. 1984, Scheffer et al. 2001, Johnson et al. 2011), facilitated range shifts of urchin herbivores (McWilliams et al. 2005, Ling 2008, Ling et al. 2009), and has been implicated to interact with urbanization to alter the relative competitive superiority of kelps and algal turfs (Williams and Liebhold 2002, Connell et al. 2008, Bentz et al. 2010). In Norway, warming waters have facilitated epibiont growth, a dominance of ephemeral algae and large-scale kelp die-offs (sensu; Dayton 1972, Moy and Christie 2012). Similarly, in the eastern North America, warmer waters have been linked to declines (Dunne and Williams 2009, Novak et al. 2011, Filbee-Dexter et al. 2016) via stress (Simonson et al. 2015, Krumhansl et al. 2016), the success of epibionts (Steneck et al. 2002, Krumhansl et al. 2011, 2016) and increases in herbivore grazing rates (Duggins et al. 1989, Krumhansl and Scheibling 2011, 2012), which cause kelp canopy defoliation. Open space on the substratum may then be rapidly colonized by invasive algal species that prevent the recruitment of kelps (Levin et al. 2002, Gaylord et al. 2007). We are also beginning to see range shifts in southern Europe as climate drives shifts in kelp biomass (Carr and Syms 2006, Pehlke and Bartsch 2008, Fernandez 2011, Tuya et al. 2012) and reproduction (Kelly et al. 2012, Bartsch et al. 2013). Both in the UK and Japan, colder-water kelps are being driven towards the pole by more warm-water tolerant kelps and competitors, causing a latitudinal reorganization of the dominant subtidal foundation species (Dayton 1985, Haraguchi et al. 2009, Tanaka et al. 2012, Smale et al. 2014, Smale and Moore 2017). In Northern California, the warm-water "Blob" has precipitated an enormous decline in kelp-forests region-wide. Last, in the exception that proves the rule, climate change has led to shifts in oceanography that have caused waters around South Africa to become colder, and thus actually has led to kelps marching towards the equator (Lüning 1984, Hatcher et al. 1987, Bolton et al. 2012).

In systems where climate change has not yet been documented to impact kelp forests, we have witnessed climatic events, such as El Niños, that give us a window into how climate change may alter these systems. For example, while giant kelp (*Macrocystis sp.*) forests have not had any documented climate-change related shifts, we know that increased temperatures after strong storms from ENSO events can suppress their recovery due to shifts in nutrient availability (Ladah et al. 1999, Hernández-Carmona and Robledo 2001, Edwards 2004, Edwards and Estes 2006, Bartsch et al. 2012, 2013). Furthermore, even though no impacts have as yet been demonstrated in kelp systems of the NE pacific, there is a signal of climate change in temperature (Bartsch 1993, Hansen et al. 2006) and maximum wave heights in the region (Ladah et al. 1999, Bromirski et al. 2003, Ruggiero et al. 2010) that are expected to have strong impacts on food web structure(Dayton 1985, Byrnes et al. 2011). Curiously, though, despite Southern California experiencing elevated temperatures, it has not witnessed similar decreases in kelps like Northern California (Deysher and Dean 1986, Reed et al. 2016). This system also experiences markedly lower annual wave disturbance (Reed et al. 2011). Incorporating long-term thermal stress and disturbance may be a key to understanding why the giant kelp systems of North and South America have, as of yet, not witnessed any large-scale changes shifts.

Given this background, we seek to answer the overarching question: *How do temperature and disturbance interact to affect kelp bed persistence?* This general question will be addressed by investigating *a) How temperature affects the ability of kelp forests to recover from disturbance and 2) How temperature interacts with local scale wave disturbance to affect kelp forest community structure?* To address these questions, I will utilize a combination of manipulative and observational experimental approaches. I have built a nascent global network of researchers studying the effects of climate change on kelp forests – the Kelp Ecosystem Ecology Network (KEEN) – using best practices (Borer et al. 2013). With this grant, I will establish a global research program that examines the consequences of controlled and natural disturbance on kelp forests across thermal gradients within different biogeographic regions. This will enable my to build models to tease apart the role of temperature change *per se* versus local species-specific effects on the response of kelps and their communities to disturbance.

2.3 Current KEEN Results and Preliminary Data

How are kelp forests currently faring, and to what extent is temperature change interacting with local disturbances? Our 2016 analysis of kelp forest time series (Krumhansl et al. 2016) shows that roughly one third of ecoregions for which we have data are experiencing decline, one third are showing no change, and one third are actually increasing. This pattern is spatially variable, with even nearby ecoregions showing opposing trends. Preliminarily, regional variation in temperature change appears to match some of these trends. For example, South Africa (Blamey et al. 2015) and parts of the Gulf of Alaska are experiencing cooling while the Gulf of Maine is

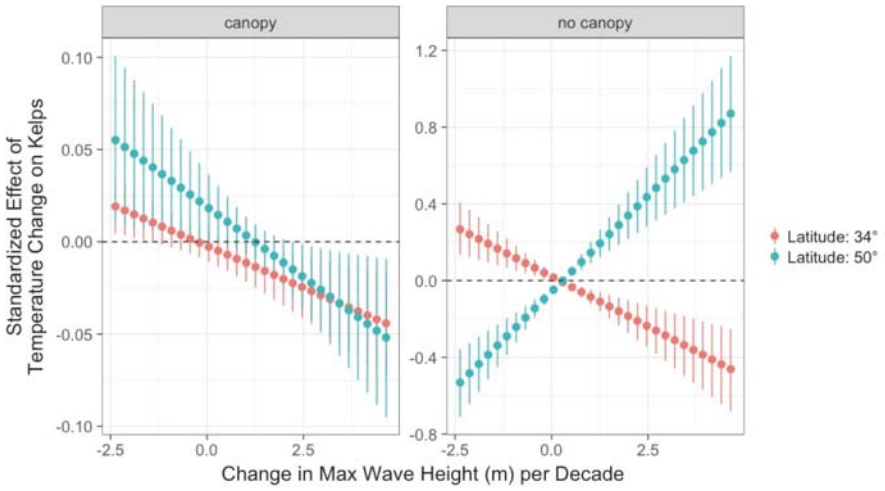

Figure 1 The effect of linear change in temperature over time on kelp abundance as influenced by linear change in maximum wave height over time for canopy and subcanopy kelps at different latittudes based on a meta-analysis of 700 different timeseries.

one of the fastest warming bodies of water on earth (Pershing et al. 2015), matching kelp trends. Further, the primary abiotic force removing kelp – winter storm disturbances – is both spatially and temporally variable. For an upcoming manuscript, I've been leading the KEEN synthesis team to model rates of kelp change as a function of rates of change in temperature (i.e., warming or cooling), as mined from the Hadley Met Centre's SST database (Rayner et al. 2003) and rates of change in maximum annual wave heights (i.e., storms) from the GOW model (Reguero et al. 2012, 2015) using a Bayesian mixed model meta-analysis. Linear rates of change in temperature and storms interact with each other, kelp morphology – whether kelps form a canopy like giant kelp or are subsurface like sugar kelp – and that high and low latitude subcanopy forests respond quite differently. This match of linear trends suggests that acclimation alone is not enough to protect forests. While this analysis is compelling, suggesting a press disturbances modify the outcome of pulse disturbances, a) the mechanism behind the latitude effect is unclear and might depend on our specific dataset – a problem common to meta-analyses – and b) due to data limitations, this analysis cannot accommodate the full range of potentially nonlinear responses in the system. Only a globally standardized set of observations and experiments manipulating kelps across temperatures regimes address these issues.

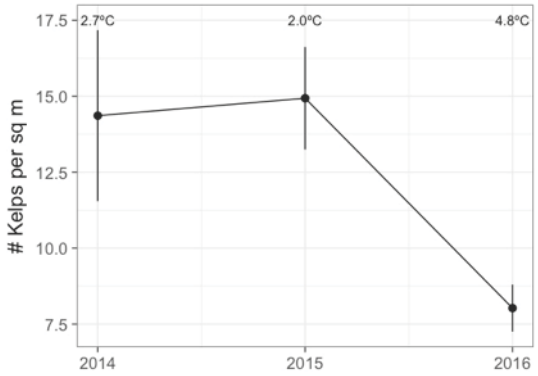

Figure 2: Kelp abundance over time sampled by KEEN ONE in New England from 36 transects sampled over three years. Temperatures are February bottom temperatures at 10m from Appledore Island as a reference.

Thus far, I have been using New England as a test regional network to determine how to scale our approach globally. Within New England we have observations from 2014-2016 and sites that range from Rhode Island to the Damriscotta River in Maine. This dataset shows two striking patterns. First, the winter of 2016 was unusually warm, relative to the other two (average winter temperatures from benthic loggers averaged 2ºC higher). Regionally, this year also showed a decline in kelp abundances at most sites, as seen when all sites sampled for all three years are pooled. Second, 2016 was also the year when we added our farthest north and south sites. In this year we finally see a statistical negative correlation between Latitude as a proxy for temperature and kelp % cover. This could be due to the local network hitting a critical range or it could be an effect of the warm water that year. These are issues we cannot answer without more time, nor can I assess their generality by looking at New England alone.

KEEN also set out to conduct a large-scale manipulation of kelp cover across the globe (see Objective 1). Whether manipulations needed to be uniformly large in size or scaled to the size of kelps was unclear, however. While 8 sites conducted large-scale manipulations, they were in different regions leading to low replication within region for modeling. Further, members in systems with subcanopy only species, such as the stout *Ecklonia radiata* of Australia, found this not practical, hauling >1 tonne of kelps off site. Fortunately, both the Byrnes (New England) and Shears (New Zealand, student masters thesis in prep) labs conducted manipulations at varying sizes and found that, for sessile and demersal species using algae as habitat, results were invariant to manipulation size until edge effects based on the size of local kelps became an issue (unpublished data). Thus, we determined we could decrease work and increase replication with a scalable experimental design where removal size matched regional kelp size. This opens up new data, as well as the potential integration of past data.

3. Specific Objectives & Hypotheses

To understand how the press perturbation of changes in ocean temperature will interact with pulsed disturbances that physically remove kelp, I will pursue the following objectives

Objective 1) Coordinate a global experiment to ask how will global increases in water temperature affect the ability of kelp forest communities to recover from disturbance.
To what extent does temperature alter the effects of kelps to pulsed kelp-removing events world-wide? To test this idea, I will coordinate and help conduct a global experiment with the following hypotheses:

H_0: Temperature and biogeography will have no effect on kelp recovery and resulting community structure. Any removal will lead to full regrowth of a bed.
H_1: Recovery of kelps and local community structure will depend on the species within biogeographic region alone. Recovery from disturbance will be idiosyncratic and species-specific.
H_2: Kelps recover less in warmer than cooler waters (i.e., a linear relationship between temperature relative to kelp thermal limit and kelp recovery) with concomitant shifts in communities. This relationship is general across the globe, but may vary in strength regionally.
H_3: Kelps recover fully from disturbance until a critical threshold temperature, region or species specific, is reached. At this threshold, we witness whole community shifts. This suggests acclimation at Southern Range limits may play a key role in resilience.

Of the above, available evidence appears to most support either H_2 or H_3, but which is unclear.

Objective 2) Foster an international observational experiment leveraging biogeographic variability to ask if temperature interacts with a common disturbance (storm waves) to affect kelps and their associated communities across the globe.
Focusing on a particular shared disturbance, does the regular annual pulsed disturbance of waves interact with changes in temperature to alter kelp forests? Can we observe a signal of these effects beyond sessile species and into mobile fauna? What are the relative contributions of direct versus indirect elements of environmental perturbations to these forests and their communities? To test this, I will coordinate a global observational experiment with the following hypotheses:

H_0: Temperature, wave disturbance, and biogeography will have no direct effect on kelp forest community structure, nor any indirect effect mediated by kelp abundance.
H_1: Temperature, wave disturbance, and biogeography will indirectly determine kelp forest community structure via changing kelp abundance.
H_2: Temperature, wave disturbance, their interaction, and biogeography will indirectly alter kelp forest community structure via changing kelp abundance.
H_3: Temperature, wave disturbance, their interaction, and biogeography will indirectly alter kelp forest community structure via changing kelp abundance. Temperature, disturbance, and biogeography will have additional direct effects on community structure.

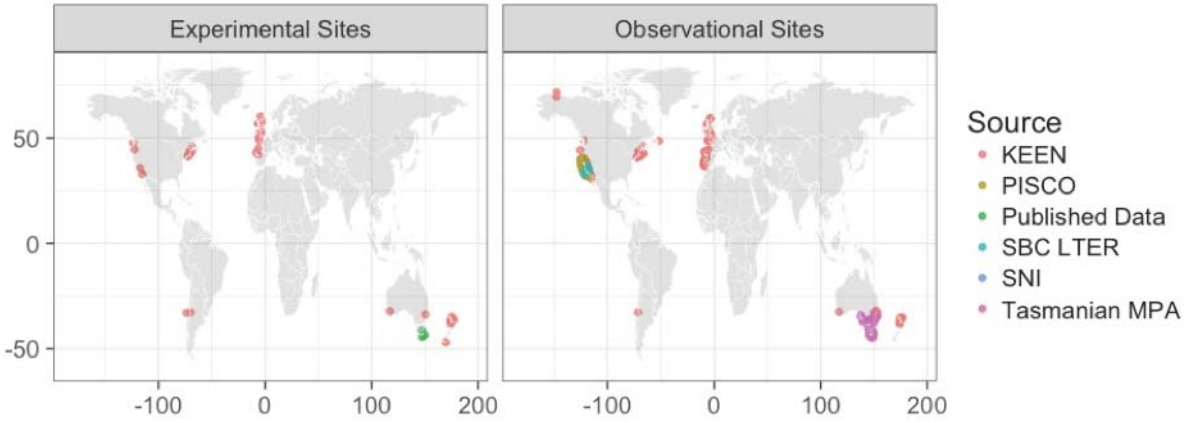

Figure 3 Map of sites for experimental removal and observational study. Colors denote source, if not from KEEN. Points are jittered to enable visualization of high density areas.

4. Objective 1) Coordinate a global experiment to ask how will global increases in water temperature affect the ability of kelp forest communities to recover from disturbance

To quantify the effect of temperature on the response of kelp communities to disturbance, we will conduct a standardized disturbance experiment. The experiment will be repeated in five kelp-dominated regions (Northeast Atlantic, Northwest Atlantic, Northeast Pacific, Southwest Pacific, Southeast Pacific). In each region, in collaboration with local members, I will assist in conducting a replicated kelp removal experiment at sites that span kelp's thermal gradients. I will then use nonlinear models to examine the effect of temperature on the response of kelps and the associated community to manipulation based on this replicated regression design.

Site selection: Each of our region's research groups have selected multiple sites within their region that span a gradient of temperature from the equatorward edge of local kelps' distributions to colder areas that support kelp communities in abundance. Sites have been selected in areas that are characterized by low wave activity to avoid the confounding effects of excessive wave disturbance. Within each site, groups will randomly select two points along the 7-12m isobath where kelps are abundant. One point will be designated the center of a control and the other of a removal plot. A total of n=36 (Fig 1.) sites will be used.

Sampling and Experimental Manipulation: Initial sampling and kelp removal will occur during the time of year when large-scale kelp losses are most likely to occur: early fall in the Northwest Atlantic when hurricanes can drive large swell (Bromirski and Kossin 2008, Filbee-Dexter and Scheibling 2012) January in the Northwest Pacific matching the timing of the largest winter swell disturbances (Bromirski et al. 2003), August in Alaska matching when the annual kelps naturally senesce and storms easily take the weakened individuals away (Hamilton and Konar 2007), September-November in the Northeast Atlantic matching the periods of maximum wave height in fall and early winter (Woolf et al. 2002), May-June in the Southwest Pacific matching the frequency of swells in late fall and early winter (Graham et al. 2007), and April in the Southeast Pacific matching kelp erosion (Hepburn et al. 2007) and after potential Austral summer induced die-backs (Wernberg et al. 2012).

At each site, we will sample six plots using 4 $1m^2$ quadrats in the center of each plot. In each plot, we will count the abundance of kelps and estimate the cover (point-contact-method) of other large algae, and sessile invertebrates. We will also measure densities of mobile invertebrates using algae as habitat. In experimental plots we will then remove the major structure-forming kelps in a circle whose radius is determined by the size of the dominant kelp species – e.g. 8m for giant kelp in California but only 4m for sugar kelp in the Gulf of Maine - by clipping them just above their holdfast, as kelps meristems are located just beneath their blades. We have found in preliminary work (see Introduction) that this scaling of size is appropriate for the target taxa sampled here to ensure generality across regions. This method will simulate kelp die back without leading to disturbance of other sessile species. A temperature logger will be placed in the middle two of the control plots.

Team Participation in Manipulation: Member labs vary in personnel and resources. To aid in accomplishing the manipulations, PI Byrnes and/or the project postdoc, the graduate student, and one student from the UMB training classes (see Broader Impacts) will travel to the region of interest per year. The team will travel for a month, being hosted by network member labs (see Facilities and Equipment, and Other Resources), and working together to conduct the manipulations. Network members will perform the resampling the following year.

Analysis to Address Hypotheses: For our analyses, I will examine the relationship between temperature relative to kelp thermal limit of the kelp species removed and three variables: 1) response of kelp abundance to manipulation relative to control, 2) response of non-kelp algal percent cover, and 3)

response of sessile invertebrate cover (see metric below). I will also examine change in mobile invertebrate abundance as they use kelps as habitat (Bologna and Steneck 1993, Teagle et al. 2017). To calculate temperature relative to kelp thermal limit, I will use published estimates for manipulated species. I repeat the analyses below for relative temperature calculated using a) average temperature from date of removal to date of sampling, b) average temperature during peak recruitment after sampling (e.g., February/March in New England).

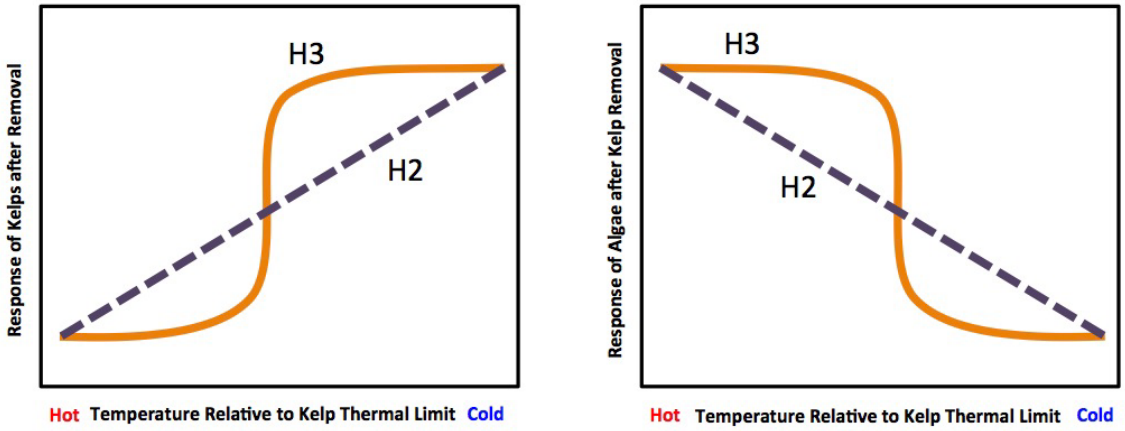

Figure 4: Conceptual models of the relationships between temperature and response of kelps and algae to removal. The linear and nonlinear responses of H2 (dashed) and H3 (solid) are highlighted.

To evaluate the effect of kelp removal and temperature on measured variables, I will fit and compare multiple mixed models with different functional forms using an information theoretic approach (Burnham and Anderson 2002), all with the same general form of their linear link:

$$M_{ijk} = \alpha_{0[ik]} + \alpha_1 T_i + \alpha_2 R_{ij} + \alpha_3 R_{ij} T_i \Sigma\alpha_{r..l} C_{r..l} + \varepsilon$$

where M_{ij} is the variable measured in plot j at site i in ecoregion k, α_{0i} is a random effect of site and ecoregion, T_i is the temperature relative to manipulated kelps' thermal limit at site i and α_1 is the temperature effect, coefficient, α_2 is the effect of the removal (R_{ij}) treatment, α_3 is the effect of how temperature modifies the effect of removal, and $\Sigma\alpha_{4..l}C_{4..l}$ is the sum of additional covariates – percent cover of rocky substrate, urchin abundance, and regional maximum significant wave height from Reguero et al. 2012 (see Q2). Covariates will be included in all analyses. Models tested include all permutations of the first three terms, including a null model, using linear, logistic, and broken stick functional forms with the appropriate error distribution for the response variable of interest. With the information theoretic analyses, I will evaluate the balance of evidence for each model, and how temperature influences kelp forest community response to disturbance.

Meta-analysis: As part of the graduate student research on this project, they will conduct a meta-analysis (REF) of all past kelp removal experiments published in the literature. Using techniques developed for global meta-analysis in the Byrnes Lab (Dunic et al. In Review), they will combine removal log response ratios of change in kelps and other species to temperature data recorded either during the experiment or derived from the HadSST data set (REF).

5. Foster an international observational experiment leveraging biogeographic variability to ask if temperature interacts with a common disturbance (storm waves) to affect kelps and their associated communities across the globe.

Manipulative experiments are, by their nature, limited in scope and scale. In order to evaluate whether temperature and disturbance interact to affect whole communities, we will conduct an observational experiment as well. This experiment will be used to build a model of how temperature modifies the

effects of a class of disturbance common to all kelp systems – wave disturbance (Dayton 1985, Graham et al. 2007, Reed et al. 2011). In some cases, higher temperatures have been shown to depress the recovery of kelps after wave disturbance (Edwards and Hernández-Carmona 2005). Curiously, while increased temperatures appear to be leading to the rapid decline of kelps in Northern California, where wave disturbance is intense, that is not the case in Southern California, where annual wave disturbance is comparatively mild (Reed et al. 2016). Whether this is the driver of the difference is speculation. Further, it is unclear a) to what extent decreased recovery could affect whole communities and b) whether temperature, wave disturbance, and their interaction all affect community structure independent of their effect on kelp. Indeed, the direct effects have the potential to outweigh the indirect effects.

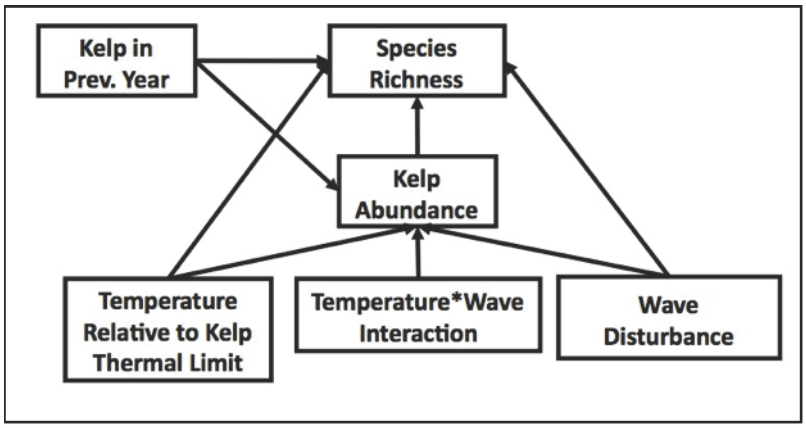

Figure 5: Model for how temperature and wave disturbance might interact to shape community richness. Other models would disaggregate richness into components by trophic group with additional interactions amongst them.

To answer the question of how temperature and wave disturbance interact to shape community structure both directly and indirectly via their impact on kelp and evaluate whether these effects are entirely system specific or general across the globe, we will use Structural Equation Modeling (Bollen 1989, Grace et al. 2012). SEM is a multivariate framework that will allow us to fit models with several interacting factors. It has proven to be an ideal method to model direct and indirect effects of disturbance on kelp forest ecology at single sites in the past (Arkema et al. 2008, Byrnes et al 2011, Miller et al. In Review). This approach has never been applied at a global scale, however, to evaluate the variability in how temperature could modify the effect of wave disturbance in kelp forests across different bioregions.

Site Selection: To collect data appropriate for SEM, research groups around the globe (Table 1) will sample temperate rocky reefs annually during the summer using a modified version of the Santa Barbara Coastal LTER's rocky reef sampling protocol (Arkema et al. 2009, Byrnes et al. 2011). Researchers will sample four 40m transects at 56 sites between 7-12m around the globe that vary in temperature, wave exposure, and community structure (Fig. 3). Sites are defined as areas within half a kilometer that share similar abiotic conditions. The regional distribution of sites has been selected to maximize variation in explanatory variables to increase the power of our analyses. Sites will be sampled in the middle of their hemisphere's summer.

Using Other Monitoring Data: Many KEEN partners have ongoing monitoring programs. These include the Partnership for Interdisciplinary Study of Coastal Oceans (PISCO), the Santa Barbara Coastal LTER, the Reef Life Survey, and the National Park Service Kelp Forest Monitoring Program. Further, there are other kelp forest community monitoring efforts that are at and end and whose data may be in the literature (e.g., Walter Addey's surveys of the Gulf of Maine, currently being replicated after 50 years). Each of these programs implements a slightly different protocol than KEEN, although measurements are broadly similar. Part of the KEEN postdoctoral associate's position on this grant will be collecting and cross-calibrating these different programs so that KEEN can utilize their data. Nearly all provide temperature data, but we will substitute wave height data from the Global Ocean Wave Model (Reguero et al. 2012). This work is already underway – KEEN and the SBC LTER's data are completely compatible, and recently the SBC, PISCO, the KFM, and Jim Estes's San Nicholas protocols were cross-calibrated. This

effort should open up many sites from programs already underway. This work should add as many as 300 additional monitoring sites.

Data Collection: To assess abiotic variables at the site scale, we will use both *in situ* and modeled measurements. For temperature, we will deploy two HOBO pendant loggers at each site sampling temperature every half hour. We will assess transect depth by averaging together the depth at the beginning, middle, and end of each transect. For waves, members will use our Open Wave Height Logger (see below), an inexpensive wave pressure sensor my lab has spent the past three years developing for this widespread deployment.

To evaluate community structure along each 40m transect, we will take the following measurements: Divers will count and visually estimate the length of all fish visible along a 40m transect. The width of the fish transect will vary by biogeographic region, as differences in dominant algal type (e.g., canopy forming giant kelp versus benthic *Ecklonia radiata*) and regional variation in fish behavior have historically led to different optimal transect widths (e.g., 2m wide versus 5m wide for the aforementioned habitats). In the first summer of the project, one research team per region will conduct one set of four fish transects. On each transect, they will sample at 2 -5m widths. We will plot the width by average fish count estimate in order to ensure that the selected width for fish transects is correct within a biogeographic region, and that results are directly comparable between regions. Along the same 40m transect, we will sample common solitary sessile invertebrates (e.g., anemones, solitary tunicates), mobile invertebrates (e.g., urchins), and large algae using six evenly spaced 1m quadrats positioned on alternating sides along the transect. For species that are rare and/or have excessively clumped distributions (e.g., sea stars, crabs and lobsters) we will sample four 20x1m band transects. For the multistiped giant kelp (*Macrocystis sp.*) we will also record the number of stipes per plant, which is a good predictor of biomass (Reed et al. 2009). We will sample small cryptic fish in those same band transects. For each of the above methods, researchers within a biogeographic region will create closed species lists for these methods. Last, we will sample 80 evenly-spaced points (40 per side, each 1m apart) and record the identity of all sessile species (i.e., open list) and substrate type (e.g., sand or rock) at each point.

The Open Wave-Height Logger: Developed as part of an MIT SeaGrant to my lab in 2014, the OWHL was designed by Luke Miller of San Jose State University and one of my masters students, Ted Lyman, who would be responsible for assembling them for the entirety of the KEEN network in year 1. We have recently finished the final shakedowns of the sensor and are writing up the specifications for publication, although its full designs can be found at https://github.com/millerlp/OWHL. Our current wave sensor design uses easy to find and durable 4" PVC pipe as a housing. It uses an Arduino AVR 328P microcontroller, a Measurement Specialties MS5803 pressure transducer on a custom-designed stack of circuit boards we can order in bulk from any circuit board printer. The pressure sensor is isolated from the ambient environment using a simple oil filled reservoir. We record data to an SD card and separate components by Plexiglass epoxied within the housing. Our current design was created with two goals. 1) A year long deployment burst sampling twice an hour at 4Hz. 2) The design had to be simple enough as to be built by high school students, as we use this as a source of outreach to local schools. This means that the sensor can also be easily built and repaired by members. While we will build the first batch as well as a replacement batch two years in for those lost or missing, Ted Lyman will also host a workshop at UMB which will be livestreamed online for members where participants all build their own sensor.

Network Participation: Members will work either with their own lab groups or with nearby PI and collaborator groups to conduct the observational experiment. In years 1-3, I will hold 1-2 meetings in each region to discuss and simulate protocols, as well as make sure the full complement of materials – species list, data sheets, customized data entry forms, and Species ID book - are ready for immediate use. After this first meeting, members are asked to hold annual refresher meetings for new students and

technicians. We have been doing this for four years for KEEN ONE at the start of every field season. It has been an enormous success, fostering cross-lab communication and ensuring that we are all doing the same work. In the past year, we put the entire proceedings online for members who are unable to attend their own local network meeting.

Analysis to Address Hypotheses: To analyze these data, I will build SEMs to test the effects of waves, temperature, and their interaction on community structure, evaluating model structure using information theoretic approaches as before. Community structure will be characterized by several metrics: 1) species richness, 2) Shannon diversity (splitting point count versus non-point count species as the abundances for this metric come from two different sampling methods), 3) effective species richness (Jost 2006), and 4) functional group effective richness. For temperature, I will calculate the difference between the both the mean and maximum annual temperature versus the thermal maximum of the dominant kelps. I will also look at the anomaly from mean temperature during peak recruitment by region. For wave disturbance, I will use average of the ten largest swell heights between sampling events.

I will test each hypothesis for each of the above four metrics using SEM. In this model, percent rocky substrate is incorporated as a covariate for all endogenous variables. While biogeographic region is not shown in the path model, all paths are allowed to vary randomly by region. The model will be fit using a Generalized Linear Mixed Model approach (Shipley 2009, Grace et al. 2012, Lefcheck 2016). Fit of the whole model will be evaluated using an omnibus test of the implied conditional independence relationships (Fisher's C test *sensu* Shipley 2009). If the model does not fit the data, we will reject it. Models that adequately fit the data will be compared using AIC (Shipley 2012) to evaluate the weight of evidence for competing models.

6. KEEN Network Organization and Management

Leadership & Coordination: PI Byrnes and UMass Boston will act as the main coordinating entity for the program. I will serve as the central contact point for data co-ordination and management, and I will travel to all regions to hold initial workshops in years 1-3. PI Byrnes's lab will coordinate procurement and mailing of temperature sensors, housing, and wave sensors to all member nodes. Additionally, UMB will house a coordinating post-doc. The postdoc will plan and lead all travel related to the removal experiment, cross-calibrate other data sets with the KEEN protocol, and aid in data management as a part of their research duties. The project graduate student will aid in managing local implementation of the observational data set for the Byrnes lab and perform a meta-analysis of removal experiments.

Collaborating Partners & Coordination: This project relies on the expertise and experience of multiple U.S. and international collaborators. All are highly experienced marine ecologists many of whom bring years of experience in kelp forest ecosystems. To provide local coordination, each region has a within-region coordinator, responsible for managing efforts by regional scientists, creating materials (data sheets, species IDs, species lists) for regional fieldwork, and holding an annual meeting. We have so far relied on annual virtual coordinator meetings; once the network is funded, we will have quarterly virtual meetings to check in on network progress and discuss any questions or concerns. We will also meet at the International Temperate Reefs Symposoium in 2018.

Data Management: I have spent the last year using the KEEN ONE data as a test case for data management and quality control. With that pipeline in place, we will now begin hosting our data on TemperateReefBase, a repository by the University of Tasmania designed to serve data from temperate reef programs. Our KelpTime dataset (Krumhansl et al. 2016) is already hosted there and KEEN ONE data will be hosted once it passes final quality control. For more details, see data management plan. Given that TRB generates adheres to ISO compliant metadata standards, it should be straightforward to sync the

data with the Biological and Chemical Oceanography Data Management Office, National Centers for Environmental Information, and the Ocean Biogeographic Information Service.

7. Broader Impacts: Education Plan

How can we expect the next generation of citizens to make decisions about oceans management without any experience? Students may have some first-hand experience with tidal habitats (beaches and class field trips), the open ocean (fishing), and charismatic coral reefs (aquaria and the media). Many students, particularly those living in urban New England, have little to no experience of the nearshore subtidal. Despite this habitat being in their very backyard, they have minimal interaction with the riot of life on the seafloor. They likely have no context when asked to make decisions as citizens that could affect local oceans. Experiential education provides unique learning opportunities, particularly in connecting students to the environment (Russell 1997, Andrews and Stocker 2010) Participating in field-based coursework and research centered on the structure and function of local subtidal communities will change how students think about the ocean in their back yard. **Here I propose to expand an educational program I have spent my faculty career developing that will get urban students in the water to develop a new understanding of the ocean around them.**

My program has three distinct goals:
1) Increase knowledge of local subtidal natural history.
2) Enhance understanding of the difference between life underwater and life on land.
3) Increase knowledge of the response of local marine life to global change.

7.1. Context of Students at UMB: UMB serves a student population that is traditionally excluded from the benefits of higher education and with little access – due to financial or time constraints - to courses in remote field stations. We provide an education for "modest income and first generation students from urban areas". For example, the student enrollment in 2016, representative of enrollment over the last several years, had ~12,847 full-time undergraduate students. 53% were women, 57% were minorities (following the federal definition), and over 600 are veterans. This is by far the largest minority population of any public university in New England. It substantially exceeds the minority population of the Boston area (~22% based on the 2010 census). Furthermore, ~50% of UMB's undergraduates in 2016 were first generation college students. Our commitment to access extends to serving students from lower income brackets as well. Nearly 40% of undergraduates at UMB receive Pell Grants, federal student aid designed to help students in the greatest financial need (typically this number is ~20% at other University of Massachusetts campuses). The Biology department maintains even more impressive statistics. With approximately 1000 majors, 60% are female and 54% are minorities. UMB students have a long history with SCUBA diving. Our SCUBA and snorkeling club was founded in the late 1970s by Ted Maney, who went on to help found the American Academy of Underwater Scientists (AAUS). In 2013, I began trying to revitalize the club. Over the past five years, it has had 120 members, and is now going strong, with new leadership, and a direct connection to training classes. Many members, however, are merely SCUBA curious, and lack the resources to fully engage given their means and background. I would like to change that.

7.2. Current Efforts: I have spent the past few years working with UMB DSO Ted Lyman developing these courses at UMass Boston. We have run them here in Boston and out at our field station at Nantucket, but not mandated such close involvement between the UWR class and my lab's research. Nor have we conducted evaluations or helped students take the courses who could not have otherwise. Working with the University, I have created a college level Dive Safety Board and we hare applying this fall for admission to the American Academy of Underwater Scientists (AAUS). I have come far, but currently do not have coursework and research interwoven as they would be in this grant. Further, we have had enrollment issues with the course, as students at the last minute have been unable to procure gear or other resources needed to participate (we lost three for this reason this year). This is not

unanticipated given our population, and I hope that with this grant, I can help increase equity in access to subtidal research opportunities.

7.3. Approach & Courses Offered: Working with my student and UMB Dive Safety Officer, Ted Lyman, we have created three new courses as part of the new University Sea-Based Skills (USEA) program, an ongoing effort to increase offerings practical course offerings by the UMB waterfront. First is a basic SCUBA certification course. This course is taught primarily by Lyman, a PADI certified Dive Instructor, in the fall of each year. In the winter term, Lyman offers advanced certification coupled with a series of safety courses, including oxygen administration via D.A.N., diving CPR and first aid, and diver rescue. These are offered in conjunction with UMB Environmental Health and Safety, who have helped us develop the UMB dive safety program. As part of this grant, I will add lectures on natural history of New England and the identification of fish, mobile invertebrates, and the major dominant algae to both courses.

7.4 Underwater Research and Involving Students in KEEN Research: These courses prepare students for a full Underwater Research course Lyman and I have organized for the past three years. *The specific course goals are as follows*: 1) To acquire an understanding of commonly applied marine research methodologies. 2) To acquire an understanding of various scientific techniques, including hypothesis formulation and testing, sampling design, statistical analysis, library research, writing and presentation. 3) To acquire an understanding of the basic biology and ecology and physiology of subtidal organisms. 4) To acquire a deeper understanding of dive physics, physiology, decompression theory and dive planning. 5) To fulfill the training requirements for scientific diving according to American Association of Underwater Scientists (AAUS) standards using the NOAA diving handbook as our reference. The course currently takes place at our university's Nantucket Field Station. As part of this grant we will review the course and at the minimum require 1) students to participate in the KEEN ONE meetings, 2) students to use at least two KEEN sampling dives to fulfill their diving requirements, giving them needed scheduling flexibility, and 3) enable students to use the KEEN data for their course projects.

7.5 Addressing Student Need and Limitations to Participation in SCUBA: To bring new students into SCUBA diving, subtidal research, and enhance their knowledge of the natural world, we will aid in alleviating the major financial difficulty of these courses – gear. Gear rental is often outside of the budget of many of our students, and activities fees do not cover enough. We have negotiated a 20% discount rate from nearby United Divers to supply rental gear and additional instruction. This grant will provide additional funds for rental fees for three underprivileged students. We use our campus pool for in-water training, and weekend trips to popular local shore dives for certification.

7.6. Further Direct Involvement of Students in Research: Beyond participating in KEEN activities as part of UWR, each year, I will identify a pool of previous students who performed well and hire them as summer technicians for New England work. Last, I will identify the top-performing student and help them develop an honors thesis using KEEN data. For this thesis, I will have them participate in the trips to conduct removal experiments. This will serve the basis of an honors independent study with me the following semester. They or others exceptional students might be eligible for REU support (see below).

7.7. Assessment: I will administer a questionnaire before and after each course – basic, advanced, and research – asking 1) what species students think are important underwater and why, 2) what challenges species in the sea face as opposed to species in a protected forest or urban park, 3) how might climate change affect life in the sea, and 4) what benefits and costs do they see to a large seawall protecting Boston Harbor from Seal Level Rise. These are open-ended questions. I will assess students based on specificity of their answers, depth of thought, and application of biological principles, and ability to connect ecosystems to human goods and services using a graded rubric and compare change over the course for each student. I will also administer a SENCER Student Assessment of Learning Gains (Cook and Mulvihill 2008) survey at the end of each course to assess how well each course addresses my

programmatic goals according to the students. I use this instrument in all of my courses to assess my students' connections to my educational goals and to learn how to improve my courses. Working with Brian White, an expert in undergraduate biology education here at UMB, I will evaluate outcomes of both assessments from each of the three courses and compare the outcomes from each level of SCUBA training.

7.8. RET Opportunities: Beyond our students, I would like to identify high school and middle school teachers in the Boston area with dive experience who would be interested in auditing the UWR course and then participating as RETs. These teachers would be able to bring their experiences back to their classroom, and I would work with them to develop units on the biology of New England reefs. I have already identified one interested teacher, Jodie Cohen at Newton North High School, with whom I am developing a course about the influence of temperature and waves on the life of the seashore.

8. Broader Impacts: The Academic Community

Training: In addition to undergraduates, at least three, and possibly more, graduate students will be involved in this grant. In addition, as suggested by many colleagues who run research networks, I request funds for a postdoc to aid in network management, conducting the experiment, the focus of their position, and calibration with other observational data sets.

Building a Network of Kelp Forest Researchers: One of the primary reasons for launching this project is the collaborations already building from the network. Already with our NCEAS working group (http://www.nceas.ucsb.edu/projects/12660) and the initial organizational work of KEEN, I have begun building conversations and small collaborations between programs. In that spirit, the activities funded here will form the backbone of collaboration between the researchers involved. It will serve as a starting point for the next decade of kelp forest ecology. Moreover involved students will interact with other students and PIs they might never have connected to, opening up future professional opportunities

Providing Data to the Community: The data collected by KEEN will have a variety of uses beyond the network. The data we are already collecting is public, and will be in the future (see Data Management Plan). Our data sharing policy states that experimental data is available after publication and observational data is made available immediately under CC-BY licensing, so members get data citation. Already, New England agencies have queried us to use our data. We hope that these data will be useful to the Smithsonian Marine Biodiversity Observation Network, the UN Group on Earth Observations/Biodiversity Observation Network, of which network member Isabel Sousa-Pinto is an organizer, and any scientist or NGO involved in the study of temperate rocky reefs.

Stimulating New Research: The work conducted within this proposal is a starting point. Already members are adding their own twist onto local experiments, such as Doug Rasher meshing removals with evaluations of local seaweed harvest. Coordinator Wernberg wants to explore the dataset for evidence of and responses to heat waves around the globe. We will encourage others to push forward with their questions using this core dataset as a backbone. There are a

9. Personnel and The Network

Briefly, KEEN works as a centralized network with common protocols, but one that has regional coordinators to best address regional variations in materials and methods. Alaska: Brenda Konar of the University of Alaska Fairbanks, Southern California and Baja: Matt Edwards of San Diego State University, Pacific Northwest: Alison Haupt of Cal State Monterey Bay, New Zealand: Nick Shears of the University of Auckland, Australia: Adriana Vergés of the University of New South Wales, South America: Alejandro Pérez-Matus of the Pontifica Universidad Católica de Chile, Scandinavia: Kjell Magnus Norderhaug of the University of Oslo, Europe and South Africa: Thomas Wernberg of the

University of Western Australia, and the UK and Ireland: Dan Smale of the Marine Biological Association of the UK. A table of additional members and the commitment they have made for this proposal in terms of facilities, support, and what they will be doing, along with letters of support, is provided below.

Name	Institution	Region	Removal	Observations	Has Ongoing Dataset	Will Use KEEN Data	Can Provide Meeting Venue	Will Host Removal Team	Can Provide Housing	Can Provide Tank Fills	Can Provide Boat	Can Be Coordinator
Ken Dunton	Uuniversity of Texas at Austin	Alaska/Arctic		x	x	x		x	x	x		x
Adriana Verges	UNSW	Australia	x	x		x	x	x		x	x	x
Graham Edgar	University of Tasmania	Australia	x	x	x	x	x	x	x	x	x	
Scott Ling	Institute for Marine and Antarctic Studies	Australia	x	x	x	x	x	x	x	x	x	x
Thomas Wernberg	The University of Western Australia	Australia, Scandinavia	x	x	x	x	x	x	x	x	x	x
Aaron Galloway	Oregon Institute of Marine Biology; University of Oregon	Central CA & Pacific Northwest	x	x		x	x	x	x	x	x	x
Amanda Bates	Memorial University	Eastern Canada		x		x	x	x	x	x	x	x
Austin Humphries	University of Rhode Island	New England	x	x		x	x	x	x	x	x	
Douglas Rasher	Bigelow Laboratory for Ocean Sciences	New England	x	x		x	x	x		x	x	x
Caitlin Cleaver	Hurricane Island Foundation	New England		x		x	x	x	x	x	x	
Jon Grabowski	Northeastern University		x	x	x	x	x	x				
Jen Dikstra	University of New Hampshire	New England	x	x	x	x	x	x				
Simona Augyte	University of Connecticut	New England		x		x	x	x	x	x	x	x
Chris Hepburn	University of Otago	New Zealand	x			x	x	x		x	x	
Nick Shears	University of Auckland	New Zealand	x	x	x	x	x	x	x	x	x	x
Isabel Sousa Pinto	CIIMAR - Interdisciplinary Centre of Marine	Northern European Coast	x	x	x	x	x	x	x	x	x	x
Jose M. Rico	Universidad de Oviedo	Northern European Coast	x	x	x	x	x	x	x	x	x	x
João N. Franco	CIIMAR - Interdisciplinary Centre of Marine	Northern European Coast		x	x	x	x	x	x	x	x	
Dan Reed	UCSB	Southern CA/Baja	x	x	x	x	x	x		x	x	
Jennifer Caselle	University of California Santa Barbara	Southern CA/Baja	x	x	x	x	x	x	x	x		
Rodrigo Beas	Universidad Autónoma de Baja California	Southern CA/Baja	x	x	x	x	x	x	x	x	x	x
Max Castorani	University of Virginia	Southern CA/Baja		x		x						
Mark Novak	Oregon State University	Southern CA/Baja, Central CA &		x		x	x		x			
Dan Smale	Marine Biological Association	UK/Ireland	x	x	x	x	x	x		x		x
Pippa Moore	Aberystwyth University	UK/Ireland	x	x	x	x	x	x		x	x	
Dr Nova Mieszkowska	The Marine Biological Association of the UK	UK/Ireland		x	x	x	x	x	x		x	x
Juliet Brodie	Natural History Museum, London, UK	UK/Ireland		x	x	x	x					
Alejandro Pérez-Matus	Pontificia Universidad Católica de Chile	Western S. America	x	x	x	x	x	x	x	x	x	x

10. Timeline

In years 1-3, PI Byrnes will hold workshops in New England, California, Chile, Australia, New Zealand, the UK, Northern Spain, and Alaska which network PIs and students will attend to familiarize themselves in the protocol. This is based off of the meetings PI Byrnes has held in New England the past four years. This will serve as a kickoff for the observational experiment in the area if it is not already running. Each year, a team from UMB will go to two regions (summer and Austral summer) to assist in executing the removal. We will troubleshoot any remaining issues in year one in New England. In year two, we will visit both California and Chile. In year three we will assist in removals in Europe and New Zealand. Last, in year four we will aid in removals in Alaska and Australia. Year five will solely be for data collection and manuscript preparation. Given that even after a single year of the observational or manipulative experiment, we should have notable results about the comparative biogeography of kelp forests, the project graduate student and, after arriving in year two, I, the project postdoc and graduate student will present results at meetings as possible. In addition we will present at the International Temperate Reef Symposium, where KEEN got its start, in year four. I hope to hold a larger session of KEEN members there, as they are frequent attendees and that meeting is where we designed the initial network.

References for CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales

Andrews, S. B., and L. Stocker. 2010. Underwater photoelicitation: a new experiential marine education technique. Pages 8–22 *in*. Canberra, Australian Capital Territory.

Arkema, K. K., D. C. Reed, and S. C. Schroeter. 2009. Direct and indirect effects of giant kelp determine benthic community structure and dynamics. Ecology 90:3126–3137.

Bartsch, I. 1993. Temperature tolerance and survival in darkness of kelp gametophytes (Laminariales, Phaeophyta): ecological and biogeographical implications. Marine ecology progress series. Oldendorf 100:253–253.

Bartsch, I., C. Wiencke, and T. Laepple. 2012. Global Seaweed Biogeography Under a Changing Climate: The Prospected Effects of Temperature. Pages 383–406 *in* Ecological Studies. Springer Berlin Heidelberg, Berlin, Heidelberg.

Bartsch, I., J. Vogt, C. Pehlke, and D. Hanelt. 2013. Prevailing sea surface temperatures inhibit summer reproduction of the kelp *Laminaria digitata* at Helgoland (North Sea). Journal of Phycology 49:1061–1073.

Bender, E. A., T. J. Case, and M. E. Gilpin. 1984. Perturbation Experiments in Community Ecology: Theory and Practice. Ecology 65:1–13.

Bentz, B. J., J. Régnière, C. J. Fettig, E. M. Hansen, J. L. Hayes, J. A. Hicke, R. G. Kelsey, J. F. Negrón, and S. J. Seybold. 2010. Climate Change and Bark Beetles of the Western United States and Canada: Direct and Indirect Effects. Bioscience 60:602–613.

Blamey, L. K., L. J. Shannon, J. J. Bolton, R. J. M. Crawford, F. Dufois, H. Evers-King, C. L. Griffiths, L. Hutchings, A. Jarre, M. Rouault, K. E. Watermeyer, and H. Winker. 2015. Ecosystem change in the southern Benguela and the underlying processes. Journal of Marine Systems 144 IS -:9–29.

Bollen, K. A. 1989. Structural Equations with Latent Variables. Wiley, New York.

Bologna, P. A. X., and R. Steneck. 1993. Kelp beds as habitat for American lobster Homarus americanus. Marine Ecology Progress Series 100:127.

Bolton, J. J., R. J. Anderson, A. J. Smit, and M. D. Rothman. 2012. South African Kelp Moving Eastwards: the Discovery of Ecklonia Maxima (Osbeck) Papenfuss at De Hoop Nature Reserve on the South Coast of South Africa. African Journal of Marine Science 34:147–151.

Borer, E. T., W. S. Harpole, P. B. Adler, E. M. Lind, J. L. Orrock, E. W. Seabloom, and M. D. Smith. 2013. Finding generality in ecology: a model for globally distributed experiments. Methods in Ecology and Evolution 5:65–73.

Bromirski, P. D., and J. P. Kossin. 2008. Increasing hurricane wave power along the US Atlantic and Gulf coasts. Journal of Geophysical Research: Atmospheres (1984–2012) 113.

Bromirski, P. D., R. E. Flick, and D. R. Cayan. 2003. Storminess variability along the California coast: 1858-2000. Journal of Climate 16:982–993.

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

Carr, M. H., and C. Syms. 2006. Recruitment. Pages 411–427 *in* L. G. Allen, D. J. Pondella, and M. H. Horn, editors. The Ecology of California Marine Fishes. University of California Press.

Connell, S. D., B. D. Russell, D. J. Turner, S. A. Shepherd, T. Kildea, D. Miller, L. Airoldi, and A. Cheshire. 2008. Recovering a lost baseline: missing kelp forests from a metropolitan coast. Marine ecology progress series. Oldendorf 360:63.

Connell, S. D., M. S. Foster, and L. Airoldi. 2014. What are algal turfs? Towards a better description of turfs. Marine Ecology Progress Series 495:299–307.

Cook, M., and T. M. Mulvihill. 2008. Examining US college students attitudes towards science: Learning from non-science majors. Educational Research and Reviews 3:038–047.

Dayton, P. K. 1972. Toward an understanding of community resilience and the potential effects of

enrichments to the benthos at McMurdo Sound, Antarctica. Pages 81–96 *in*.
Dayton, P. K. 1985. Ecology of kelp communities. Annual Review of Ecology and Systematics 16:215–245.
Deysher, L. E., and T. A. Dean. 1986. In situ recruitment of sporophytes of the giant kelp, Macrocystis pyrifera (L.) C.A. Agardh: Effects of physical factors. Journal of Experimental Marine Biology and Ecology 103:41–63.
Duggins, D. O., C. A. Simenstad, and J. A. Estes. 1989. Magnification of secondary production by kelp detritus in coastal marine ecosystems. Science 245:170–173.
Dunne, J. A., and R. J. Williams. 2009. Cascading extinctions and community collapse in model food webs. Philosophical Transactions of the Royal Society B: Biological Sciences 364:1711–1723.
Edwards, M. S. 2004. Estimating scale-dependency in disturbance impacts: El Niños and giant kelp forests in the northeast Pacific. Oecologia 138:436–447.
Edwards, M. S., and G. Hernández-Carmona. 2005. Delayed recovery of giant kelp near its southern range limit in the North Pacific following El Niño. Marine Biology 147:273–279.
Edwards, M. S., and J. A. Estes. 2006. Catastrophe, recovery and range limitation in NE Pacific kelp forests: a large-scale perspective. Marine ecology progress series. Oldendorf 320:79–87.
Estes, J. E., N. S. Smith, and J. F. Palmisano. 1978. Sea otter predation and community organization in the western Aleutian islands, Alaska. Ecology 59:822–833.
Fernandez, C. 2011. The retreat of large brown seaweeds on the north coast of Spain: the case of Saccorhiza polyschides. European Journal of Phycology 46:352–360.
Filbee-Dexter, K., and R. E. Scheibling. 2012. Hurricane-mediated defoliation of kelp beds and pulsed delivery of kelp detritus to offshore sedimentary habitats. Marine Ecology Progress Series 455:51–64.
Filbee-Dexter, K., C. J. Feehan, and R. E. Scheibling. 2016. Large-scale degradation of a kelp ecosystem in an ocean warming hotspot. Marine Ecology Progress Series 543:141–152.
Gaylord, B., J. H. Rosman, D. C. Reed, J. R. Koseff, J. Fram, S. MacIntyre, K. Arkema, C. McDonald, M. A. Brzezinski, and J. L. Largier. 2007. Spatial patterns of flow and their modification within and around a giant kelp forest. Limnology and Oceanography 52:1838–1852.
Gleckler, P. J., B. D. Santer, C. M. Domingues, D. W. Pierce, T. P. Barnett, J. A. Church, K. E. Taylor, K. M. AchutaRao, T. P. Boyer, M. Ishii, and P. M. Caldwell. 2012. Human-induced global ocean warming on multidecadal timescales. Nature Climate Change:–.
Grace, J. B., D. R. Schoolmaster Jr., G. R. Guntenspergen, A. M. Little, B. R. Mitchell, K. M. Miller, and E. W. Schweiger. 2012. Guidelines for a graph-theoretic implementation of structural equation modeling. Ecosphere 3:art73.
Graham, M. H., J. A. Vasquez, and A. H. Buschmann. 2007. Global ecology of the giant kelp Macrocystis: From ecotypes to ecosystems. Oceanography and Marine Biology Annual Review 45:39–88.
Hamilton, J., and B. Konar. 2007. Implications of substrate complexity and kelp variability for south-central Alaskan nearshore fish communities. Fishery Bulletin 105:189–196.
Hansen, J., M. Sato, R. Ruedy, K. Lo, D. W. Lea, and M. Medina-Elizade. 2006. Global temperature change. Proceedings of the National Academy of Sciences of the United States of America 103:14288–14293.
Haraguchi, H., K. Tanaka, Z. Imoto, and M. Hiraoka. 2009. The Decline of Ecklonia cava in Kochi, Japan and the challenge in marine afforestation.
Harley, C. D. G., A. R. Hughes, K. M. Hultgren, B. G. Miner, C. J. B. Sorte, C. S. Thornber, L. F. Rodriguez, L. Tomanek, and S. L. Williams. 2006. The impacts of climate change in coastal marine systems. Ecology letters 9:228–241.
Hatcher, B. G., H. Kirkman, and W. F. Wood. 1987. Growth of the kelp Ecklonia radiata near the northern limit of its range in Western Australia. Marine Biology 95:63–73.
Hepburn, C. D., J. D. Holborow, S. R. Wing, R. D. Frew, and C. L. Hurd. 2007. Exposure to waves enhances the growth rate and nitrogen status of the giant kelp *Macrocystis pyrifera*. Marine Ecology Progress Series 339:99–108.

Hernández-Carmona, G., and D. Robledo. 2001. Effect of nutrient availability on Macrocystis pyrifera recruitment and survival near its southern limit off Baja California. Botanica ….
Hughes, T. P., S. Carpenter, J. Rockström, M. Scheffer, and B. Walker. 2013. Multiscale regime shifts and planetary boundaries. Trends in Ecology & Evolution 28:389–395.
Johnson, C. R., S. C. Banks, N. S. Barrett, F. Cazassus, P. K. Dunstan, G. J. Edgar, S. D. Frusher, C. Gardner, M. Haddon, F. Helidoniotis, K. L. Hill, N. J. Holbrook, G. W. Hosie, P. R. Last, S. D. Ling, J. Melbourne-Thomas, K. Miller, G. T. Pecl, A. J. Richardson, K. R. Ridgway, S. R. Rintoul, D. A. Ritz, D. J. Ross, J. C. Sanderson, S. A. Shepherd, A. Slotwinski, K. M. Swadling, and N. Taw. 2011. Journal of Experimental Marine Biology and Ecology 400:17–32.
Jost, L. 2006. Entropy and diversity. Oikos 113:363–375.
Kelly, J., K. Krumhansl, and R. Scheibling. 2012. Drift algal subsidies to sea urchins in low-productivity habitats. Marine Ecology Progress Series 452:145–157.
Krumhansl, K. A., and R. E. Scheibling. 2011. Spatial and temporal variation in grazing damage by the gastropod Lacuna vincta in Nova Scotian kelp beds. Aquatic Biology 13:163–173.
Krumhansl, K. A., D. K. Okamoto, A. Rassweiler, M. Novak, J. J. Bolton, K. C. Cavanaugh, S. D. Connell, C. R. Johnson, B. Konar, S. D. Ling, F. Micheli, K. M. Norderhaug, A. PÈrez-Matus, I. Sousa-Pinto, D. C. Reed, A. K. Salomon, N. T. Shears, T. Wernberg, R. J. Anderson, N. S. Barrett, A. H. Buschmann, M. H. Carr, J. E. Caselle, S. Derrien-Courtel, G. J. Edgar, M. Edwards, J. A. Estes, C. Goodwin, M. C. Kenner, D. J. Kushner, F. E. Moy, J. Nunn, R. S. Steneck, J. Vásquez, J. Watson, J. D. Witman, and J. E. K. Byrnes. 2016. Global patterns of kelp forest change over the past half-century. Proceedings of the National Academy of Sciences 113:13785–13790.
Krumhansl, K. A., J. M. Lee, and R. E. Scheibling. 2011. Grazing damage and encrustation by an invasive bryozoan reduce the ability of kelps to withstand breakage by waves. Journal of Experimental Marine Biology and Ecology 407:12–18.
Krumhansl, K., and R. Scheibling. 2012. Detrital subsidy from subtidal kelp beds is altered by the invasive green alga Codium fragile ssp. fragile. Marine Ecology Progress Series 456:73–85.
Ladah, L. B., J. A. Zertuche-Gonzalez, and G. Hernandez-Carmona. 1999. Giant kelp (*Macrocystis pyrifera*) recruitment near its southern limit in Baja California after mass disappearance during ENSO 1997-1998. Journal of Phycology 35:1106–1112.
Lefcheck, J. S. 2016. *piecewiseSEM*: Piecewise structural equation modeling in R for ecology, evolution, and systematics. Methods in Ecology and Evolution 7:573–579.
Levin, P. S., J. A. Coyer, R. Petrik, and T. P. Good. 2002. Community-wide effects of nonindigenous species on temperate rocky reefs. Ecology 83:3182–3193.
Ling, S. 2008. Range expansion of a habitat-modifying species leads to loss of taxonomic diversity: a new and impoverished reef state. Oecologia 156:883–894.
Ling, S. D., C. R. Johnson, S. D. Frusher, and K. R. Ridgway. 2009. Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift. Proceedings of the National Academy of Sciences 106:22341–22345.
Lüning, K. 1984. Temperature tolerance and biogeography of seaweeds: the marine algal flora of Helgoland (North Sea) as an example. Helgolander Meeresuntersuchungen 38:305–317.
McWilliams, J. P., I. M. Côté, J. A. Gill, W. J. Sutherland, and A. R. Watkinson. 2005. Accelerating impacts of temperature induced coral bleaching in the Caribbean. Ecology 86:2055–2060.
Moy, F. E., and H. Christie. 2012. Large-scale shift from sugar kelp (*Saccharina latissima*) to ephemeral algae along the south and west coast of Norway. Marine Biology Research 8:309–321.
Novak, M., J. T. Wootton, D. F. Doak, M. Emmerson, J. A. Estes, and M. T. Tinker. 2011. Predicting community responses to perturbations in the face of imperfect knowledge and network complexity. Ecology 92:836–846.
Pehlke, C., and I. Bartsch. 2008. Changes in depth distribution and biomass of sublittoral seaweeds at Helgoland (North Sea) between 1970 and 2005. Climate Research 37:135–147.
Pershing, A. J., M. A. Alexander, C. M. Hernandez, L. A. Kerr, A. Le Bris, K. E. Mills, J. A. Nye, N. R. Record, H. A. Scannell, J. D. Scott, G. D. Sherwood, and A. C. Thomas. 2015. Slow adaptation in the

face of rapid warming leads to collapse of the Gulf of Maine cod fishery. Science 350:809–812.
Rassweiler, A., R. Schmitt, and S. Holbrook. 2010. Triggers and maintenance of multiple shifts in the state of a natural community. Oecologia 164:489–498–498.
Rayner, N. A., D. E. Parker, E. B. Horton, C. K. Folland, L. V. Alexander, D. P. Rowell, E. C. Kent, and A. Kaplan. 2003. Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. Journal of Geophysical Research: Atmospheres (1984–2012) 108:n/a–n/a.
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.
Reed, D., L. Washburn, A. Rassweiler, and R. Miller. 2016. Extreme warming challenges sentinel status of kelp forests as indicators of climate change. Nature Communications 7:13757.
Reguero, B. G., I. J. Losada, and F. J. Méndez. 2015. A global wave power resource and its seasonal, interannual and long-term variability. Applied Energy.
Reguero, B. G., M. Menéndez, F. J. Méndez, R. Mínguez, and I. J. Losada. 2012. A global ocean wave (GOW) calibrated reanalysis from 1948 onwards. Coastal Engineering 65:38–55.
Roemmich, D., W. John Gould, and J. Gilson. 2012. 135 years of global ocean warming between the Challenger expedition and the Argo Programme. Nature Climate Change 2:425–428.
Ruggiero, P., P. D. Komar, and J. C. Allan. 2010. Increasing wave heights and extreme value projections: The wave climate of the U.S. Pacific Northwest. Coastal Engineering In Press, Corrected Proof:539–552.
Russell, C. 1997. Approaches to environmental education. Holistic Education Review 10:34–39.
Scheffer, M., S. Carpenter, J. A. Foley, C. Folke, and B. Walker. 2001. Catastrophic shifts in ecosystems. Nature 413:591–596.
The SENCER-SALG. http://www.sencer.net/Assessment/sencersalg.cfm.
Shipley, B. 2009. Confirmatory path analysis in a generalized multilevel context. Ecology 90:363–368.
Shipley, B. 2012. The AIC model selection method applied to path analytic models compared using a d-separation test. Ecology 94:560–564.
Simonson, E. J., R. E. Scheibling, and A. Metaxas. 2015. Kelp in hot water: I. Warming seawater temperature induces weakening and loss of kelp tissue. Marine Ecology Progress Series.
Smale, D. A., and P. J. Moore. 2017. Variability in kelp forest structure along a latitudinal gradient in ocean temperature. Journal of Experimental Marine Biology and Ecology.
Smale, D. A., T. Wernberg, A. L. E. Yunnie, and T. Vance. 2014. The rise of *Laminaria ochroleuca* in the Western English Channel (UK) and comparisons with its competitor and assemblage dominant *Laminaria hyperborea*. Marine Ecology 4: 1439-0485.
Steneck, R. S., M. H. Graham, B. J. Bourque, D. Corbett, J. M. Erlandson, J. A. Estes, and M. J. Tegner. 2002. Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental Conservation 29:436–459.
Tanaka, K., S. Taino, H. Haraguchi, G. Prendergast, and M. Hiraoka. 2012. Warming off southwestern Japan linked to distributional shifts of subtidal canopy-forming seaweeds. Ecology and Evolution 2:2854–2865.
Teagle, H., S. J. Hawkins, P. J. Moore, and D. A. Smale. 2017. The role of kelp species as biogenic habitat formers in coastal marine ecosystems. Journal of Experimental ….
Tuya, F., E. Cacabelos, P. Duarte, D. Jacinto, J. J. Castro, T. Silva, I. Bertocci, J. N. Franco, F. Arenas, J. Coca, and T. Wernberg. 2012. Patterns of landscape and assemblage structure along a latitudinal gradient in ocean climate. Marine Ecology Progress Series 466:9–19.
Wernberg, T., D. A. Smale, F. Tuya, M. S. Thomsen, T. J. Langlois, T. de Bettignies, S. Bennett, and C. S. Rousseaux. 2012. An extreme climatic event alters marine ecosystem structure in a global biodiversity hotspot. Nature Climate Change 3: 78-82.
Wernberg, T., S. Bennett, R. C. Babcock, T. de Bettignies, K. Cure, M. Depczynski, F. Dufois, J. Fromont, C. J. Fulton, R. K. Hovey, E. S. Harvey, T. H. Holmes, G. A. Kendrick, B. Radford, J.

Santana-Garcon, B. J. Saunders, D. A. Smale, M. S. Thomsen, C. A. Tuckett, F. Tuya, M. A. Vanderklift, and S. Wilson. 2016. Climate-driven regime shift of a temperate marine ecosystem. Science 353:169–172.

Williams, D. W., and A. M. Liebhold. 2002. Climate change and the outbreak ranges of two North American bark beetles. Agricultural and Forest Entomology 4:87–99.

Woolf, D. K., P. G. Challenor, and P. D. Cotton. 2002. Variability and predictability of the North Atlantic wave climate. Journal of Geophysical Research: Atmospheres (1984–2012) 107:3145.

BIOGRAPHICAL SKETCH

Jarrett Byrnes
Assistant Professor, Department of Biology
University of Massachusetts Boston, Boston, MA 02125
jarrett.byrnes@umb.edu 401.529.4104

PROFESSIONAL PREPARATION

BA	2001	Brown University, Biology
MS	2003	University of California Davis, Population Biology
PhD	2008	University of California Davis, Population Biology

APPOINTMENTS

2012-present	Assistant Professor, Department of Biology, University of Massachusetts Boston
2010-2012	Postdoctoral Fellow, National Center for Ecological Analysis and Synthesis
2006-2010	Postdoctoral Fellow, Santa Barbara Coastal LTER, UC Santa Barbara

PRODUCTS

Five scholarly products related to project; † post doc; ‡graduate student; †† undergraduate student

Krumhansl, K.A.†, Okamoto, D.K., Rassweiler, A., Novak, M., Bolton, J.J., Cavanaugh, K.C., Connell, S.D., Johnson, C.R., Konar, B., Ling, S.D., Micheli, F., Norderhaug, K.M., PÈrez-Matus, A., Sousa-Pinto, I., Reed, D.C., Salomon, A.K., Shears, N.T., Wernberg, T., Anderson, R.J., Barrett, N.S., Buschmann, A.H., Carr, M.H., Caselle, J.E., Derrien-Courtel, S., Edgar, G.J., Edwards, M., Estes, J.A., Goodwin, C., Kenner, M.C., Kushner, D.J., Moy, F.E., Nunn, J., Steneck, R.S., Vásquez, J., Watson, J., Witman, J.D., **Byrnes, J.E.K.,** 2016. Global patterns of kelp forest change over the past half-century. Proc. Natl. Acad. Sci. U.S.A. 113, 13785–13790.

Byrnes, J.E.K., Grabowski, J.H., Dijkstra, J.A., and Humphries, A. 2017. Kelp Ecosystem Ecology Network Of New England Community Sampling, 2013-2016. Data Product available at http://temperatereefbase.imas.utas.edu.au. Methods at http://www.kelpecosystems.org/projects/protocols-materials/

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.

Byrnes, J. E. K., Cardinale, B.J., and D. C. Reed. 2013. Interactions between sea urchin grazing and prey diversity on temperate rocky reef communities. *Ecology* 94:1636-1646.

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.

Five additional scholarly products; † post doc; ‡graduate student; †† undergraduate student

Dunic, J.C.[‡], Elahi, R., Hensel, M.J.S.[‡], Kearns, P.J., O'Connor, M.I., Acuña, D.[‡], Honig, A.[‡], Wilson, A.R.[‡], **Byrnes, J.E.K.**, In Review. Human activities influence the direction and magnitude of local biodiversity change over time. Available at bioRxiv 162362. http://www.biorxiv.org/content/early/2017/07/12/162362

Witman, J.E., Lamb, R., **Byrnes, J.E.K.** 2015. Towards an integration of scale and complexity in marine ecology. *Ecological Monographs*. 85: 475-504.

Foster, M.C.[††], **Byrnes, J.E.K.**, Reed, D.C., 2015. Effects of five southern California macroalgal diets on consumption, growth, and gonad weight, in the purple sea urchin *Strongylocentrotus purpuratus*. PeerJ 3, e719. doi:10.7717/peerj.719

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.

Byrnes, J.E., Stachowicz, J.J., Hultgren, K.M., Hughes, A.R., Olyarnik, S.V., Thornber, C. 2006. Predator Diversity Enhances Trophic Cascades in Kelp Forests by Modifying Herbivore Behavior. *Ecology Letters*. 9: 61-71.

SYNERGISTIC ACTIVITIES

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

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

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.

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

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.

SUMMARY PROPOSAL BUDGET

YEAR 1

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 - PI**	0.00	0.00	0.50	**4,702**	
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	**4,702**	
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				**21,000**	
4. (**2**) UNDERGRADUATE STUDENTS				**14,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**39,702**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**223**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**39,925**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,200**	
2. INTERNATIONAL				**3,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **6,000**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**10**) TOTAL PARTICIPANT COSTS				**6,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**34,396**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**13,756**	
TOTAL OTHER DIRECT COSTS				**48,152**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**98,277**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 89701)**					
TOTAL INDIRECT COSTS (F&A)				**47,093**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**145,370**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**145,370**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*
Heather Carey

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

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

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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 - PI**	0.00	0.00	0.50	**4,843**	
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	**4,843**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**51,000**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**21,000**	
4. (**2**) UNDERGRADUATE STUDENTS				**14,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**2,500**	
TOTAL SALARIES AND WAGES (A + B)				**93,343**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**18,820**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**112,163**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**10,150**	
2. INTERNATIONAL				**8,400**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **4,000**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**8**) TOTAL PARTICIPANT COSTS				**4,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**9,780**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**10,476**	
TOTAL OTHER DIRECT COSTS				**20,256**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**154,969**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 150969)**					
TOTAL INDIRECT COSTS (F&A)				**79,259**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**234,228**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**234,228**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*
Heather Carey

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

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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 - PI**	0.00	0.00	0.50	**4,989**	
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	**4,989**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**52,530**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**21,000**	
4. (**2**) UNDERGRADUATE STUDENTS				**14,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**2,500**	
TOTAL SALARIES AND WAGES (A + B)				**95,019**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**20,238**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**115,257**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**4,950**	
2. INTERNATIONAL				**27,400**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **5,000**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**4**) TOTAL PARTICIPANT COSTS				**5,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**17,750**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**10,476**	
TOTAL OTHER DIRECT COSTS				**28,226**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**180,833**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 175834)**					
TOTAL INDIRECT COSTS (F&A)				**92,313**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**273,146**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**273,146**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*
Heather Carey

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

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 - PI**	0.00	0.00	0.50	**5,138**	
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	**5,138**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**54,106**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**21,000**	
4. (**2**) UNDERGRADUATE STUDENTS				**14,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**2,500**	
TOTAL SALARIES AND WAGES (A + B)				**96,744**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**20,815**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**117,559**	
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. INTERNATIONAL				**20,950**	
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				**9,780**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**10,876**	
TOTAL OTHER DIRECT COSTS				**20,656**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**159,165**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 159165)**					
TOTAL INDIRECT COSTS (F&A)				**83,562**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**242,727**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**242,727**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*
Heather Carey

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

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 5

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 - PI**	0.00	0.00	0.50	**5,292**	
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	**5,292**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**55,730**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**21,000**	
4. (**2**) UNDERGRADUATE STUDENTS				**14,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**96,022**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**21,410**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**117,432**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**2,950**	
2. INTERNATIONAL				**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				**9,780**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**10,476**	
TOTAL OTHER DIRECT COSTS				**20,256**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**140,638**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 140638)**					
TOTAL INDIRECT COSTS (F&A)				**73,835**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**214,473**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**214,473**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*
Heather Carey

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 - PI**	0.00	0.00	2.50	**24,964**	
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	2.50	**24,964**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**4**) POST DOCTORAL SCHOLARS	48.00	0.00	0.00	**213,366**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**5**) GRADUATE STUDENTS				**105,000**	
4. (**10**) UNDERGRADUATE STUDENTS				**70,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**7,500**	
TOTAL SALARIES AND WAGES (A + B)				**420,830**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**81,506**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**502,336**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**19,250**	
2. INTERNATIONAL				**59,750**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **15,000**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**22**) TOTAL PARTICIPANT COSTS				**15,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**81,486**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**56,060**	
TOTAL OTHER DIRECT COSTS				**137,546**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**733,882**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**376,062**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**1,109,944**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**1,109,944**	

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

PI/PD NAME: **Jarrett Byrnes**

ORG. REP. NAME*: **Heather Carey**

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

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget and Justification

A. Senior Personnel: We request half a month of summer support for PI Byrnes. We request support for a postdoctoral research associate, for years two through five of the grant. This postdoc will coordinate the network participants, conduct data management, lead all removal experiments in the field, and conduct additional.

We request summer and one additional semester of support for a graduate student for the first three years of the grant. Graduate students will coordinate the local observational experiment travel and participate in manipulative experiment. In year one this will be split between Byrnes lab PhD student Breckie McCollum who has been working on the KEEN observational data for three years and Byrnes lab graduate student Ted Lyman designed the Open Wave Height Logger. McCollum will take year two. Years three through five will be taken by incoming Byrnes lab student Brianna Shaughnessy, who worked as a technician on KEEN last summer and is currently funded off of an IGERT for the next two years. Her research focuses on natural versus farmed kelp forests. In off semesters, the students will be supported by TA-ships and additional funding opportunities at UMB.

Item	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Grad Student Stipend, summer and fall	21,000.00	21,000.00	21,000.00	21,000.00	21,000.00
1/2 month for PI Byrnes	4,702.00	4,843.00	4,989.00	5,138.00	5,292.00
Postdoc		51000	52530	54106	55729

B. Other Personnel: We request annual support for two summer undergraduates, primarily drawing from past UMB UWR students at $7,000 per technician. We also request $2,500 annual support in years 2-4 for an undergraduate technician to send on the month-long removal trips.

C. Fringe: 1.90% rate applies to PI for summer compensation and 29.17% rate plus $28.00/bi-weekly per FTE applies to the base salary of benefited Post Doc appointment. 1.59% applies to the Graduate student stipend in the summer only. Fringe Rate is negotiated between DHHS and the Commonwealth of Massachusetts. Fringe rates includes: General Fringe, Health & Welfare, Medicare, Unemployment Insurance, Universal Health Insurance and Worker's Compensation Insurance.

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Benefits for Postdoc		18595	20011	20585	21177
Grad Student Summer Fringe	75	77	80	82	85

D. Equipment: N/A

E. Travel – 1) Domestic Travel:
PI Travel to Conduct KEEN Workshops: In years 1-3, PI Byrnes will travel to regions within KEEN and hold in person trainings on the KEEN protocols as requested by network members. In year 1, this will be a trip to the San Diego and Monterey. Based on current US ticket prices, this should be $1200. Lodging is not necessary. In year three, PI Byrnes will travel to Sitka, Alaska, to hold a workshop for Alaskan members. Airfare and lodging are budgeted at $2,000.

Travel for Experimental Manipulation: In the winter of year 2, the PI, graduate student, and postdoc will travel on the US West Coast during January or February, conditions permitting, with an estimated airfare cost of $1800, car rental for a month of $1800, and room and board of $3600.

Travel to Meetings: In years two, three, and five, I request $1,200 for travel for the graduate student and

postdoc to national meetings (either the Benthic Ecology Meetings or Western Society of Naturalists). I request $1250 for lodging and $500 for per diem at standard UMass Boston rates.

2) International Travel:
PI Travel to Conduct KEEN Workshops: In years 1-3, PI Byrnes will travel to regions within KEEN and hold in person trainings on the KEEN protocols as requested by network members. In year 1, PI Byrnes will travel to both Sydney, Australia and Auckland, New Zealand with an estimated airfare of $3,000. Lodging is not needed. In year two, PI Byrnes will travel to Plymouth, UK and to northern Spain with an estimated airfare of $1,200 from Boston. Lodging is not required. In the winter of that year, he will travel to Santiago Chile with an airfare of $1,100. Lodging is provided by the Las Cruces marine station.

Travel for Experimental Manipulation: International travel for the manipulation will occur in years 2-4. The postdoc, graduate student, and either PI or technician will travel and be hosted by participating network members. Budgets reflect host estimated costs for within-region travel and additional costs of boat time (air fills discussed above) for 4-6 sites, depending on members recommendations.

	Year 1	Year 2	Year 3	Year 4
Travel to Australia for three				6000
Car Rental in Australia for 1 month				1800
Room, board through Australia				4800
Boat Time in Australia for five sites				3000
Travel to New Zealand for three			6000	
Car Rental in NZ for 1 month			1800	
Room, board, and interisland travel through New Zealand			5200	
Boat time in New Zealand for five sites			3200	
Travel to Europe			3400	
Travel, Room, and Board in Europe			4800	
Boat time for four sites in Europe			3000	
Travel to Chile		3400		
Car Rental in Chile for 1 month		1200		
Boat time in Chile for six sites		1500		

Travel to Meetings: In year four, I request $3,600 for travel for myself, the graduate student and postdoc to attend the International Temperate Reefs Symposium meeting in Hong Kong. I request $1250 for lodging and $500 for per diem at standard UMass Boston rates.

F. Participant Support Cost: In order to facilitate network participation, I have budgeted for participant support cost to provide within-region travel for network members for workshops. Estimates of costs are based on consultation with regional coordinators for meetings at the locations mentioned in PI travel. In year 1 I request $3,000 to aid travel and lodging for members from Baja for the workshop in San Diego. I request an additional $3000 for member travel and lodging for them meeting in Sydney. With fewer members in Chile, I only request $1,000 in participant support costs for that meeting in year two and $3,000 for travel and lodging support for participants at the UK and European meetings. Gathering Alaskan members is difficult given logistical constraints of travel. Coordinator Konar has recommended $5,000 in support for member travel and lodging for that meeting.

G. Other direct costs (Equipment Lease and Repair):

Supplies for Members: For each site (observational experiment or manipulation), we will supply members with two Onset temperature pendant loggers ($59). For each observational experiment site, we will supply members with two Open Wave Height Loggers that we will construct at UMB at $150 each. With 56 observational sites and 36 experimental locations, this comes to $10,856 for temperature loggers and $10,800 for wave loggers in year one. We will ship these from UMB to save on shipping costs which we have costs out to $2,600. We anticipate by year three that some replacements will be needed, so we have budgeted $2,950 for 50 replacement temperature loggers, $3,000 for 20 replacement wave sensors, and $1500 for shipping.

UMB Materials: To conduct activities at the three locations in New England covered by UMB, we request $500 for gas and $100 for oil for our boat. We request $1000 for gas for our truck. We request $100 in years one and four for rebar for site markers and $420 those years for Z-Spar marine epoxy. We request $600 for annual field gear replacements.

Given dives both local and abroad for the duration of this grant an average tank fill rate of $6.50/tank, and an estimated 200 dives for each of the five divers involved per year over all activities, we request $6,500/year.

Computer Services: We request $1080 per year for Dropbox Business cloud file sharing services to manage data within the Byrnes lab and with KEEN network members.

Equipment Leasing/Rental for Research: We request $4376/year for truck and trailer insurance. We request $1400/year for winter boat storage and shrink-wrapping.

Equipment Leasing/Rental in Support of Students: We request $1350/year to allow three disadvantaged undergraduates to rent gear for basic and advanced SCUBA classes. We request an additional $750/year for them to rent gear for the Underwater Research course.

Equipment Repair: We request $1000 ($200/set for five sets) for SCUBA gear servicing (e.g., regulators and BCDs). We request $400/year for tank inspections, and an extra $400 in year 4 for Hydro inspections of the Byrnes lab's 16 tanks. We request $1000/year for boat repairs and equipment replacement and $200/year for trailer repairs.

H. Total Direct cost: Year 1 $98,277; Year 2 $154,969; Year 3 $180,834; Year 4 $159,165; Year 5 $140,638.

H. Indirect Rate is 52.5%: F&A Rate of 52.5% is negotiated between DHHS and the university. *Indirect funds requested in each year:* Year 1 $48,445.43; Year 2 $79,258.73; Year 3 $92,312; Year 4 $83,561.63; Year 5 $73,834.95.

I. Total costs requested in each year: Year 1 $146,722.43; Year 2 $234,227.73; Year 3 $273,146.85; Year 4 $242,726.63; Year 5 $214,472.95.

Current and Pending Support

(See PAPPG 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: CAREER:Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales

Source of Support: National Science Foundation

Total Award Amount: $ 9,000,000 Total Award Period Covered: 06/01/18 - 05/31/23

Location of Project: University of Massachusetts Boston

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: Feedbacks between Coastal New England Kelp Beds and Wave Disturbance

Source of Support: MIT SeaGRANT

Total Award Amount: $ 150,001 Total Award Period Covered: 02/01/15 - 01/31/18

Location of Project: University of Massachusetts Boston

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

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

Project/Proposal Title: Using Citizen Science to Understand Thirty Years of Change in Global Kelp Cover by Expanding the Zooniverse to NASA Satellite Imagery

Source of Support: National Aeronautics and Space Administration (NASA)

Total Award Amount: $ 910,620 Total Award Period Covered: 01/15/17 - 02/28/22

Location of Project: University of Massachusetts Boston

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: Woods Hole Oceanographic Institution (WHOI)

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

Location of Project: University of Massachusetts Boston

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: LTER Plum Island Ecosystems: Dynamics of Coastal Systems

Source of Support: Marine Biological Labs (MBL)

Total Award Amount: $ 60,000 Total Award Period Covered: 10/01/16 - 09/30/22

Location of Project: University of Massachusetts Boston

Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.10 Summ: 0.00

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

Facilities, Equipment and Other Resources

UMB Laboratory: On the UMB campus, students will be placed in the PI's fully equipped research laboratory in UMB's Integrated Sciences Complex. His 600 sq. ft. lab is fully supplied with computers, a fume hood for sample processing, and sample freezer, a full range of shop tools, dissecting scopes, drying ovens, balances, 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. Students and technicians in PI Byrnes's lab are equipped with iMacs that regularly backup to external drives. In addition, the lab supplies an unlimited Dropbox account to all students for off-site data backup and easy sharing.

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 and our shipping needs.

UMB Field Equipment: PI Byrnes's lab is currently equipped with the necessary equipment for a subtidal research program: wet and dry suits for lab personnel, 16 tanks, five full sets of dive gear - including BCDs, regulators, mask, fins, and weights – and a full suite of field sampling gear (PVC quadrats, transect tapes, etc). The lab also has several underwater digital still and video cameras for sampling sites and recording identifying photographs of organisms. The lab has a 20' Maritime Dauntless Skiff with a 135HP engine and accompanying trailer for use close to the coast. The boat is towed by the lab's Ford F150 truck.

Cat Cove Marine Lab: For sampling in Salem Sound, PI Byrnes work out of Salem State's Cat Cove Marine Lab. UMB has recently signed an MOU with CCML. CCML provides storage for dive gear, and the lab boat and truck. They also can provide flowing seawater and meeting facilities where necessary. CCML has served as the Byrnes lab's primary base of field operation for the past two years.

Shoals Marine Lab: For sampling at Appledore Island, PI Byrnes will work from UNH and Cornell's Shoals Marine Lab. SML provides multiple inflatable boats with access to the entire archipelago. It also provides mooring and docking facilities. Additionally, the larger R/V Heiser and Kingsbury can be used to access difficult sites or carry large numbers of divers, if necessary. SML provides housing accommodations and board for all scientists. It also provides tank fills and facilities for equipment storage and maintenance. PI Byrnes has worked out of SML for five years, and uses his teaching time to support research by his lab at the island.

KEEN Network Member Support: KEEN Networm members have agreed to participate in different KEEN activities and are able to do one or more of the following for the project: 1) Host a regional meeting, 2) Host a removal team, 3) Provide housing for the removal team, 4) Provide tank fills for the removal team, 5) Provide tank fills and gear support for the removal team. Some members have also suggested they would be willing to take over regional coordination activities, should the need arise. The list of current members who are willing to participate in activities directly is as follows, and each has provided a letter of support:

Name	Institution	Region	Removal	Observations	Has Ongoing Dataset	Will Use KEEN Data	Can Provide Meeting Venue	Will Host Removal Team	Can Provide Housing	Can Provide Tank Fills	Can Provide Boat	Can Be Coordinator
Ken Dunton	Uuniversity of Texas at Austin	Alaska/Arctic		x	x	x		x	x	x		x
Adriana Verges	UNSW	Australia	x	x		x	x	x		x	x	x
Graham Edgar	University of Tasmania	Australia	x	x	x	x	x	x	x	x	x	
Scott Ling	Institute for Marine and Antarctic Studies	Australia	x	x	x	x	x	x	x	x	x	x
Thomas Wernberg	The University of Western Australia	Australia, Scandinavia	x	x	x	x	x	x	x	x	x	x
Aaron Galloway	Oregon Institute of Marine Biology; University of Oregon	Central CA & Pacific Northwest	x	x		x	x	x	x	x	x	x
Amanda Bates	Memorial University	Eastern Canada		x		x	x	x	x	x	x	x
Austin Humphries	University of Rhode Island	New England	x	x		x	x	x	x	x	x	
Douglas Rasher	Bigelow Laboratory for Ocean Sciences	New England	x	x		x	x	x		x	x	x
Caitlin Cleaver	Hurricane Island Foundation	New England		x		x	x	x	x	x	x	
Jon Grabowski	Northeastern University		x	x	x	x	x	x				
Jen Dikstra	University of New Hampshire	New England	x	x	x	x	x	x				
Simona Augyte	University of Connecticut	New England		x		x	x	x	x	x	x	x
Chris Hepburn	University of Otago	New Zealand	x			x	x	x		x	x	
Nick Shears	University of Auckland	New Zealand	x	x	x	x	x	x	x	x	x	x
Isabel Sousa Pinto	CIIMAR - Interdisciplinary Centre of Marine	Northern European Coast	x	x	x	x	x	x	x	x	x	x
Jose M. Rico	Universidad de Oviedo	Northern European Coast	x	x	x	x	x	x	x	x	x	x
João N. Franco	CIIMAR - Interdisciplinary Centre of Marine	Northern European Coast		x	x	x	x	x	x	x	x	
Dan Reed	UCSB	Southern CA/Baja	x	x	x	x	x	x		x	x	
Jennifer Caselle	University of California Santa Barbara	Southern CA/Baja	x	x	x	x	x	x	x	x		
Rodrigo Beas	Universidad Autónoma de Baja California	Southern CA/Baja	x	x	x	x	x	x	x	x	x	x
Max Castorani	University of Virginia	Southern CA/Baja		x		x						
Mark Novak	Oregon State University	Southern CA/Baja, Central CA &		x		x	x		x			
Dan Smale	Marine Biological Association	UK/Ireland	x	x	x	x	x	x		x		x
Pippa Moore	Aberystwyth University	UK/Ireland	x	x	x	x	x	x		x	x	
Dr Nova Mieszkowska	The Marine Biological Association of the UK	UK/Ireland		x	x	x	x	x	x		x	x
Juliet Brodie	Natural History Museum, London, UK	UK/Ireland		x	x	x	x					
Alejandro Pérez-Matus	Pontificia Universidad Católica de Chile	Western S. America	x	x	x	x	x	x	x	x	x	x

Data Management Plan for CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales

Data Policy Compliance

The project investigators will comply with the data management and dissemination policies described in the *NSF Award and Administration Guide* (AAG, Chapter VI.D.4) and the *NSF Division of Ocean Sciences Sample and Data Policy*. This data management plan is written in accord with policies of the Biological and Chemical Oceanography Data Management Office. All data and code products of this research will be provided to the Biological and Chemical Oceanography Data Management Office, National Centers for Environmental Information, and the Ocean Biogeographic Information Service with accompanying metadata for full release either during the lifetime of the project or within two years of completion, project objective depending. Further, this data management plan follows the practices laid out by the Kelp Ecosystem Ecology Network as part of their network methods (http://kelpecosystems.org).

Description of Data Types

The project will produce several observational and experimental datasets, described in the list below. In addition to the datasets described below, the project will produce data on temperature and wave heights. All data and the code from the data processing pipeline will initially be made available via Github for version control. The data include: 1) Site description, logger deployment records, and diver sampled abundance and point count data from surveys from before and after experimental kelp manipulations and the same data from observational sampling. 2) Temperature logger CSV data from the removal and observational experiments and the same from wave height loggers.

Data and Metadata Formats and Standards

Pre-event planning will be done via a planning workshop and the data management plan for all activities will be detailed in a standardized handbook of methods. Sampling events will be recorded on paper logs which are photographed post-dive in the field to ensure no lost data (e.g., high winds or gear malfunctions on following dives) and when returned to shore are scanned into JPG documents before being sent to PI Byrnes for archiving. Data from benthic temperature loggers will be downloaded immediately following the cruise and archived using cloud data sharing services. Data will be entered using Excel with standardized templates using imposed data validation to minimize data entry error. Data will be quality control-checked using read-back methodology.

Upon completion of the quality control process, data is sent to the Byrnes lab for centralized data management. Data sets are run through scripted quality control checks ensuring completeness, scans for data entry outliers, and taxonomic standardization of species lists against the World Registrity of Marine Species (http://www.marinespecies.org/). Failures are turned back to the network member for correction. Data is then merged into a common set of long-format CSV files suitable for futher use and analysis. The data cleaning pipeline, including code, raw data, and cleaned merged data, is hosted on the version control archive GitHub (e.g., https://github.com/kelpecosystems/observational_data). Upon archiving (see below), the PI will generate metadata using the ISO19115 compliant Marine Community Profile 2.0 metadata schema (https://marinemetadata.org/references/marineprofile19115) via a user interface.

Data Storage and Access During the Project

The investigators (PI and network members) will store original project data (including spreadsheets, CSV and ASCII files, images, and scans of data sheets) on laboratory computers. In the Byrnes lab, all computers backup both to independent hard drives regulated by Apple Time Machine and to the cloud via a lab Dropbox (http://dropbox.com). Scans of data sheets will be sent to the Byrnes lab upon completion of each site for immediate redundancy and backed up in Dropbox. Once each member completes data entry and quality control, Excel or CSV data files will be sent to the Byrnes lab and immediately 1) be

placed into a cloud dropbox and 2) be added to the version controlled raw data portion of the project's public (for observational data) and private (for experimental data) Github account.

Mechanisms and Policies for Access, Sharing, Re-Use, and Re-Distribution
Pre-publication Data Management: Observational data sets are immediately available within and outside of the network upon deposition via the public Github archive (or other version control repository, should something happen with Github). Once quality controlled the Each member's dataset is available under CC-BY attribution for immediate use. Experimental data is available within the network immediately via a private Github Archive with the understanding that members are to be included as co-authors on the first publication using this data. After publication, or two years from the termination of this grant, this archive shall be made entirely public.

Data Sharing Policies: Broadly, KEEN is interested in open and transparent data sharing while ensuring that members get proper credit. Our data sharing policies are as follows:
1) Experimental manipulation data is private until publication or two years after the completion of this grant. Members are assured co-authorship on the first publication using their data, at which point it becomes public. Data is available after, but creators are offered collaboration as a term of use.
2) Observational data is public as soon as quality controlled data is merged into the network data set. Inividual member data sets will be made citable (see below) and are offered via a Creative Commons-By license. This ensures members get credit for their work. It also ensures that observational data is immediately available and relevant to the scientific and management communities.

Long-Term Data Sharing and Archiving with TemperateReefBase and the BCO-DMO: The Kelp Ecosystem Ecology Network is one of the partner organizations aiding in the creation of TemperateReefBase (http://temperatereefbase.imas.utas.edu.au/), a data warehouse funded by the Australian Integrated Marine Observing System (IMOS). Already, TRB hosts the KelpTime kelp timeseries dataset from the Krumhansl et al. 2016 paper, in addition to a wide variety of data sets from other organizations. TRB also enables generation of metadata for all data products. After deposition with TRB and metadata generation, I will work with the BCO-DMO to archive data with the National Centers for Environmental Information and the Ocean Biogeographic Information Service. Data, code, and other information from this project will publically available without restriction once submitted to the public repositories.

Plans for Archiving
The PI will ensure that the original underway measurements are archived permanently at TemperateReefBase, the National Centers for Environmental Information, and/or the Ocean Biogeographic Information Service as appropriate. BCO-DMO will also ensure that project data are submitted to the appropriate national data archive. The PI will work with TRB and BCO-DMO to ensure data are archived appropriately and that proper documentation are archived along with the data.

Roles and Responsibilities
The lead PI is ultimately responsible for the compliance with the DMP. PI Byrnes has provided members with data management plans, data entry templates, chain of custody logs, and data archival compliant with the DMP. Members are responsible for management of their initial raw data sets and send quality controlled data to PI Byrnes as soon as it is complete. PI Byrnes will work with the Postdoc to create a management pipeline for the experimental data set. After year one, the project postdoc will handle data management duties in consultation with PI Byrnes. The postdoc will also be responsible for creating software to translate other data sets to the KEEN format and to manage the dissemination of those data sets where possible to help them gain pracitcal experience in data managament as career development. For long term archiving, the PI with work with the BCO-DMO, TRB, and OBIS to ensure proper data deposition and access.

Postdoctoral Researcher Mentoring Plan for CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales

I request funds to support a postdoctoral researcher for years 2-5 of the grant. Members of networks such as the *Zostera* Experimental Network (ZEN), the Nutrient Network (NutNet), and others at the 2012 ESA symposium on collaborative research networks all agreed that a central co-ordinating postdoc was essential for the success of such networks and provides a unique opportunity. PI Byrnes is committed to actively supporting and mentoring the postdoc in research, teaching, mentoring, networking, and analytic and data management skills.

1. Orientation will include in-depth conversations between PI Byrnes and the Postdoctoral Researcher. Mutual expectations will be discussed and agreed upon in advance. The postdoctoral researcher will be involved in the KEEN ONE meeting and subsequent field sampling to learn the system and project, and they will be given an overview of all efforts to date.

2. **Gaining advanced skills** via research will be a focus of the postdoc. The proposed research requires the integration of intensive fieldwork, data management, networking, and analytic skills. The postdoc will receive training where necessary to supplement any deficits, and will attend (or lead) upcoming Data Carpentry workshops in Boston. For their research, the postdoctoral research will lead the removal experiment field campaign and efforts to harmonize other data sets with the KEEN protocol. They will also work with the PI to evaluate one additional measurement, manipulation, or analysis to carve out an independent research project.

3. Career Counseling will be directed at providing the Postdoctoral Researcher with the skills, knowledge, and experience needed to excel in his/her chosen career path, including job-talk workshops in lab meetings. Already, PI Byrnes initial KEEN postdoc, Alison Haupt, has achieved an assistant professor position at CSUMB.

4. Publications and Presentations are expected to result form the work supported by the grant. These will be prepared under the direction of PI Byrnes and in collaboration with network members. The Postdoctoral Researcher will receive guidance and training in the preparation of manuscripts for scientific journals and presentations at conferences. The postdoctoral researcher will be funded to present annually at one meeting per year.

5. Teaching and Mentoring Skills will be developed in the context mentoring summer students. The postdoc will participate as a mentor to undergraduate subtidal research interns at UMB, and if possible, work with a UMB Biology program REU. They will work with PI Byrnes to learn best practices in working with students and, if the right students are identified, in helping shape their honors theses. The postdoctoral researcher will also be invited to lecture in PI Byrnes's marine ecology course to gain classroom experience.

6. Instruction in Professional Practices will be provided on a regular basis in the context of the research work. They will also be mentored in the coordination of a large number of researchers in the Network. PI Byrnes has spent the past few years establishing best practices within this network, and using lessons learned from Borer et al. (2014) to facilitate communication within the network.

7. Success will be assessed by monitoring the publication count and personal progress of the Postdoctoral Researcher through a tracking of the Postdoctoral Researcher's progress toward his/her career goals after finishing the postdoctoral program.

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Rick Kesseli
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rick.kesseli@umb.edu

July 18, 2017

Dear Madam or Sir,

As Chair of the Biology Department at the University of Massachusetts, Boston (UMB), an accredited academic institution, I give my strong support for the CAREER proposal that Dr. Jarrett Byrnes is submitting. Dr. Byrnes has a tenure-track position and is submitting this one CAREER proposal, so he is eligible for this NSF program. His proposed research and educational activities parallel, and are extremely well integrated into, the educational and research missions of the Department and UMB. We are committed to supporting Dr. Byrnes' professional development. His proposal links his University mandated research, teaching and service responsibilities to each other and we are taking an active role to ensure that he is balancing his efforts appropriately to remain on track for his tenure evaluation in the future. Below, I outline our strong commitment to Dr. Byrnes and the wonderful success he is having with his program.

As background, UMB is a major and expanding (≈ 17,000 students) public research university in New England. We have the most diverse student body of any major 4-year university in our region. This diversity includes a wide ethnic and racial distribution but also many other factors such as age and economic and educational backgrounds; 31% of our undergraduates are underrepresented minorities, and 55% are students of color. UMB is a US Dept. of Education Title III-eligible institution—57% of UMB undergraduates are first-generation college students, 53% report speaking a language other than English at home, 86% receive financial aid, and 45% of in-state students receive Pell grants, which is an indication of low-income status. UMB has received significant recognition for its efforts serving diverse populations, including its designation as an Asian American and Native American Pacific Islander-Serving Institution (AANAPISI). In 2016, in recognition of its "outstanding commitment to diversity and inclusion," UMB received the Higher Education Excellence in Diversity Award from INSIGHT Into Diversity magazine, the largest diversity-focused publication in higher education.

Many of this highly diverse population of students are attracted to the biological sciences and our majors have increased by 50% in the last 6 years. At this time approximately 1/10 of all undergraduate majors now reside in our Biology or Biochemistry programs. Our mission and our "brand" in Biology Department is to give all students, regardless of their entering skill set and future goals, deep knowledge and a broad array of hands-on lab experiences that will make them marketable, but many have little understanding of the role of scientists in society or knowledge of possible careers in science other than medical programs. We are constantly interested in expanding the opportunities and success of our students and Dr. Byrnes' proposed integration of research, teaching and outreach fits wonderfully into this plan. He will have students engaged in active field research of interest to the public, and working in collaboration with a network of international scientists. He also will provide the students with rigorous training in biostatistics using data generated from these projects with original, publishable manuscripts being a potential outcome of these efforts. This is a unique combination of activities for our program.

Since his arrival at UMB, Dr. Byrnes has been developing these integrated teaching initiatives aimed at improving the success of all undergraduates and graduates. He created and taught upper level

Marine Ecology for majors which includes a field component. He is active in our recent efforts to upgrade and invigorate our second semester introductory biology course which focuses on the higher scales of biological organization and disciplines such as physiology, evolution, population biology and community ecology. He developed and taught a new Biological Data Analysis course which became one of the most popular and valuable courses in our graduate curriculum. Most recently, he developed the exciting Underwater Research techniques course that will get students in the water and conducting research.

One of the most impressive component of his teaching, in my opinion, is his willingness to direct students into active research projects while training them in useful and powerful analytical techniques; a theme which he will continue and extend with this proposal. This approach has already been very fruitful. For example, students in his biostatistics course analyzed the data on a project being conducted by a colleague; those students are now contributing authors on a publication of that work (Elahi et al 2015). Other students developed an independent group project and that too is currently being written for publication. Many students whom he has mentored in his classes have now continued into advanced degree programs at other universities while others are finding jobs as skilled research technicians. The best way to develop these useful and powerful skills in our students is to apply them to real problems and Dr. Byrnes has become a leader in this effort.

Dr. Byrnes' career goals and job responsibilities have developing a sustained and nationally recognized research program at its core and it is clear that his research program is already flourishing. He is a very strong computational community ecologist with interests in the effects of global climate change at many scales within ecosystems. He has developed field projects in several areas throughout New England and has collaborative interactions well beyond this region. His integration of academic and agency scientists at his Kelp Ecosystem Ecology Network (KEEN) meetings that he has held for the past two years here at UMB prove that he has become a leader in the local marine research community. Further, his work at NCEAS and beyond with the international scientists in this community prove his leadership and ability to build capacity in a remarkable way. He has also released well-received software packages that allow researchers to probe the functional changes in complex ecosystems. These new tools also positively affect the skill set of our own students. He has led several workshops at locations both within and outside of the U.S. as part of his extensive outreach efforts. Clearly he is quickly gaining a reputation among his colleagues in the field.

Our Department is absolutely committed to supporting the continued development of Dr. Byrnes and his research program. We have provided technical support, graduate student support and start-up funding to his program. We have assigned Dr. Rob Stevenson, a professor within our department with overlapping interests in community ecology, to be his direct mentor, and Dr. Byrnes very positive 4th year review indicates that he is doing extremely well. We will help Dr. Byrnes continue to maintain a proper balance of activities that will lead to a successful tenure decision. We shall institutionalize and support the innovative field experiences in his courses, including his new Underwater Research Methods. We will continue to support Dr. Byrnes's graduate students, supply research funds, prioritize his equipment needs and relieve him of excess teaching and service duties. Dr. Byrnes has demonstrated that this support has been worth the input. He has delivered on all fronts and I am certain will continue to be a leader in our program for years to come. Please consider supporting this dynamic young investigator and his proposal.

Best wishes,

Rick Kesseli

Rick Kesseli Professor and Chair

UCONN
UNIVERSITY OF CONNECTICUT

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Simona Augyte, MS
PhD Candidate
Ecology and Evolutionary Biology
University of Connecticut
1 University Place
Stamford, CT 06901-2315, USA
Office phone: 203-251-8530
Office: 3.71
Email: simona.augyte@uconn.edu

UNIVERSITY OF Southampton

Dear Grant Selection Committee, **20/07/2017**

I was delighted to be invited to contribute to the project project submitted by Dr. Jarrett Byrnes entitled “CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales”. The project is a premier example of the kind of innovative approach that is necessary to tackle the major challenges we face in understanding climate warming impacts on our global fauna, and offering key indicators for informing management decisions and identifying vulnerable systems and taxa.

I have been nominated as a Tier 2 Canada Research Chair in Marine Physiological Ecology, with an expected start date of November 1, 2017. My research will be based at the Ocean Sciences Centre (OSC) at Memorial University with an overarching aim of linking the physiological traits of species to community, diversity and food web patterns. Your proposal aligns tremendously well with my proposed research program. The broader research setting at Memorial will also allow me to take advantage of synergies and collaboration, with the potential to increase the scope and impact of the proposed research. I will also take advantage of my collaborator network and working group activities to increase the profile and impact of the work, including through my contributions to GEO BON (Group on Earth Observations Biodiversity Observation Network: http://geobon.org).

If your proposal is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Best wishes for the proposal and I look forward to working with you on an exciting and timely project.

Yours sincerely,

Dr. Amanda Bates

Ocean and Earth Science, National Oceanography Centre Southampton
University of Southampton Waterfront Campus, European Way, Southampton, SO14 3ZH United Kingdom
Tel: +44 (0)23 8059 2011 Fax: +44 (0)23 8059 3059 www.southampton.ac.uk/oes

Universidad Autónoma de Baja California
FACULTAD DE CIENCIAS MARINAS
http://fcm.ens.uabc.mx/

July 16th, 2017. Ensenada Baja California, Mexico.

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Dr. Rodrigo Beas
Profesor
Facultad de Ciencias Marinas
UABC

UNIVERSIDAD AUTONOMA DE BAJA CALIFORNIA
FACULTAD DE CIENCIAS MARINAS

Carretera Tijuana- Ensenada #3917 Col. Playitas, Ensenada BC, México c.p. 22860
Tel (646)174 5600 ext 117 - Fax (646) 174-4103 - rbeas@uabc.edu.mx

Hurricane Island
Center for Science and Leadership

July 18, 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Caitlin Cleaver
Direct of Science & Research

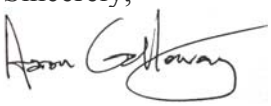
UNIVERSITY OF OREGON

18-July-2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,



Aaron Galloway, PhD
Assistant Professor
Oregon Institute of Marine Biology
Department of Biology
University of Oregon
541-888-2581 ext. 303
agallow3@uoregon.edu

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

18th July 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Associate Professor Christopher D. Hepburn

Director Aquaculture and Fisheries

Department of Marine Science – Te Tari Pūtaiao Taimoana

Campus Facilities:
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Portobello Marine Laboratory
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New Zealand Marine Studies Centre
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THE
UNIVERSITY
OF RHODE ISLAND

COLLEGE OF
THE ENVIRONMENT
AND LIFE SCIENCES

THINK BIG WE DO

DEPARTMENT OF FISHERIES, ANIMAL AND VETERINARY SCIENCE
20A Woodward Hall, 9 East Alumni Avenue, Kingston, RI 02881 USA p: 401.874.2477 f: 401.874.7575 uri.edu/cels/favs

July 15, 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Austin Humphries
Assistant Professor of Ecosystem-based Fisheries Science

COLLEGE OF FISHERIES AND OCEAN SCIENCES

University of Alaska Fairbanks

PO Box 757220 • Fairbanks, Alaska 99775-7220
Phone: 907 474-5870 • Fax: 907 474-5804
http://www.sfos.uaf.edu/

Dear Grant Selection Committee, July 17, 2017

If the proposal submitted by Dr. Jarrett Byrnes entitled “CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales” is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Dr. Brenda Konar

Professor
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220, Fairbanks, Alaska 99775-7220
Web: http://www.uaf.edu/sfos/people/faculty/detail/index.xml?id=8

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Dr Pippa Moore
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Tel: (01970) 622293
Fax: (01970) 628642
Email: pim2@aber.ac.uk
www.aber.ac.uk/ibers

18th July 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled “CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales” is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Regards

P J Moore

Dr Pippa Moore

Department of Integrative Biology, College of Science
Oregon State University, 3029 Cordley Hall, Corvallis, Oregon 97331-2914
T 541-737-3610 | **F** 541-737-3120 | http://people.oregonstate.edu/~novakm
mark.novak@oregonstate.edu

July 17, 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled “CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales” is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Mark Novak

Bigelow | Laboratory for Ocean Sciences

Douglas B. Rasher, Ph.D.
Senior Research Scientist
+1 207 315-2567 x318
drasher@bigelow.org

July 16, 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Douglas B. Rasher, Ph.D.
Senior Research Scientist
Bigelow Laboratory for Ocean Sciences

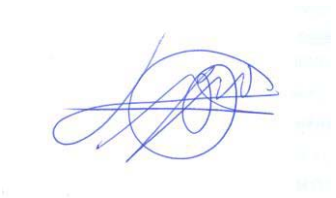
Facultad de Biología
Facultá de Bioloxía
Faculty of Biology

Universidad de Oviedo
Universidá d´Uviéu
University of Oviedo

Jose Manuel Rico Ordas
Decano

Dear Grant Selection Committee,
If the proposal submitted by Dr. Jarrett Byrnes entitled " CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales"
is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely



Jose M. Rico

Dean

Faculty of Biology

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The Marine Biological Association
Established 1884, incorporated by Royal Charter 2013

Patron: HRH The Prince Philip, Duke of Edinburgh
President: Sir John Beddington
Director: Professor Colin Brownlee

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email: **sec@mba.ac.uk**
www.mba.ac.uk

20th July 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Dr Dan Smale

Research Fellow

DR ADRIANA VERGES
Senior Lecturer in Marine Ecology

THE UNIVERSITY OF NEW SOUTH WALES
Centre for Marine Bio-Innovation
Evolution & Ecology Research Centre
School of Biological Sciences

17 July 2017

Dear Grant Selection Committee,

This letter is to express my full support for the proposal submitted by Dr. Jarrett Byrnes entitled “CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales”, and to confirm that if it is selected for funding by the NSF, it is my intent to collaborate and commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

_____

Dr Adriana Vergés

UNSW Australia
SYDNEY NSW 2052 AUSTRALIA

Telephone: +61 (2) 93852110
Facsimile: + 61 (2) 93851558
E-mail: a.verges@unsw.edu.au

THE UNIVERSITY OF WESTERN AUSTRALIA

Marine Ecology In a Changing World

Perth, 20 July 2017

DR THOMAS WERNBERG
Associate Professor
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Indian Ocean Marine Research Centre
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CRICOS Provider No.00126G

Editor-in-Chief Aquatic Botany:
http://ees.elsevier.com/aqbot/

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled “CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales” is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Dr Thomas Wernberg

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Brian T. White
Associate Professor
Department of Biology
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Fax: 617.287.6650
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http://intro.bio.umb.edu/BW/

July 18, 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Brian White, Ph.D.

University of New Hampshire

Center for Coastal and Ocean Mapping / Joint Hydrographic Center

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F: 603.862.0839
TTY: 7.1.1 (Relay NH)

www.ccom.unh.edu

20 July 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Jennifer Dijkstra

Jennifer A. Dijkstra, Ph.D.
Research Assistant Professor
Center for Coastal and Ocean Mapping
NOAA/UNH Joint Hydrographic Center,
School of Marine Science and Ocean Engineering
University of New Hampshire
163 Jere A. Chase Engineering Laboratory
24 Colovos Road
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Phone: 603-862-1775
Fax: 603-862-0839

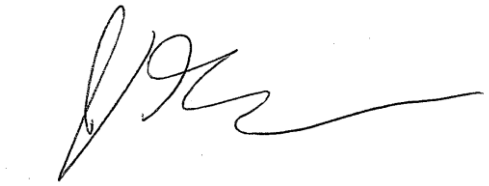
Northeastern

7 July 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,



Marine Science Center
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fx: 781.581.6076
j.grabowski@neu.edu

Jonathan H. Grabowski, Ph.D.
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Associate Director, Marine Science Center
Northeastern University
Marine Science Center
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STANFORD UNIVERSITY

OCEANVIEW BLVD.
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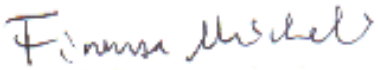
TEL: (831) 655-6200
FAX: (831) 375-0793

20 July 2017

To The Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,



Fiorenza Micheli,
David and Lucile Packard Professor of Marine Science
Co-Director of Center for Ocean Solutions
Tel. (831) 655-6250; E-mail: micheli@stanford.edu

IMAS
INSTITUTE FOR MARINE AND ANTARCTIC STUDIES

UNIVERSITY OF TASMANIA
UTAS

16 July 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Professor Graham Edgar
Senior Marine Ecologist
Institute for Marine and Antarctic Studies
University of Tasmania
GPO Box 252-49, Hobart, Tas 7001,
Australia

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO

SANTA BARBARA • SANTA CRUZ

DAN REED
TELEPHONE: (805) 893-8363
FAX: (805) 893-8062
E-MAIL: dan.reed@lifesci.ucsb.edu

UNIVERSITY OF CALIFORNIA
MARINE SCIENCE INSTITUTE
SANTA BARBARA, CALIFORNIA 93106-6150

20 July 2017

Dear Jarrett,

SBC LTER is excited to work with you on your proposed project entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales"

If your proposal is selected for funding by the NSF, then it is our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of your proposal.

Sincerely,

Dan Reed
Lead Principal Investigator, SBC LTER

MARINE SCIENCE INSTITUTE

THE UNIVERSITY OF TEXAS AT AUSTIN

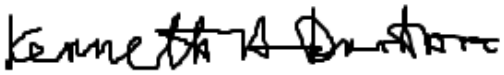
750 Channel View Drive • Port Aransas, TX 78373-5015 • (361) 749-6711 • FAX (361) 749-6777

19 July 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely



Kenneth H. Dunton
Professor

U.PORTO
FACULDADE DE CIÊNCIAS
UNIVERSIDADE DO PORTO
Departamento de Biologia

Porto, 20 of July 2017

To The Selection Committee,

I've been collaborating in Kelp research with Dr. Jarrett Byrnes and will be very happy to contribute to the project submitted by him "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales". This is a very timely project with an innovative approach that is necessary to help understand climate change impacts on key marine ecosystems as kelp forests, from local to global level offering not only advancements in our scientific knowledge but also key information and indicators for supporting management decisions.
If this proposal is selected for funding by the NSF, I'll be delighted to collaborate and commit resources facilities and equipment as necessary and to fulfill our team's role in Europe.
I will also take advantage of several European and global networks I participate and/or co –lead as e.g. MBON from GEO BON (Marine Biodiversity Observation Network, Group on Earth Observations Biodiversity Observation Network: http://geobon.org), or Euromarine , to increase the profile and impact of the work.

Best wishes for the proposal and I look forward to working with you on an exciting and timely project.

Yours sincerely,

Isabel Sousa Pinto

U.PORTO
FACULDADE DE CIÊNCIAS
DEPARTAMENTO DE BIOLOGIA

Isabel Sousa Pinto
Head of Coastal Biodiversity Laboratory
Co-Cahir of MBON
Steering Committee of EUROMARINE

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HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH

Grant selection committee

Dr. Kjell Magnus Norderhaug
Institute of Marine Research
Nye Flødevigenvei 20
4817 His

Deres ref: Ref

Vår ref: Saksnr

Arkivnr. Arkivnr
Løpenr: Løpenr

His, 21.7.17

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Kind regards,

Research professor

Havforskningsinstituttet
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Faks: 55 23 85 31
E-post: havforskningsinstituttet@imr.no

Avdeling: avdelingn
Saksbehandler: saksbehandelft
Tlf.:
E-post:
Besøk:

Reg.no. NO 971 349 077
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Swift-adr.: DNBANOKK

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THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

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Ph +64 9 923 3608
Email: n.shears@auckland.ac.nz
http://www.marine.auckland.ac.nz/uoa/nick-shears

20th July 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Yours sincerely,

Dr Nick Shears
University of Auckland, New Zealand

The Natural History Museum,
Cromwell Road,
London SW7 5BD,
United Kingdom
+44 (0)207 942 5910

21 July 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Juliet Brodie

Professor Juliet Brodie
Research Leader, Phycology,
Natural History Museum

THE UNIVERSITY of ADELAIDE

SOUTHERN SEAS ECOLOGY LABORATORIES
SCHOOL OF BIOLOGICAL SCIENCES
UNIVERSITY OF ADELAIDE, SA 5005, AUSTRALIA

PROFESSOR SEAN D. CONNELL
ph +61 8 8313 6125, fax +61 8 8313 4364
email sean.connell@adelaide.edu.au
http://www.marinebiology.adelaide.edu

20th July 2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales" is selected for funding by the NSF, it is my intent to collaborate and commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Yours sincerely,

Sean D. Connell

The Marine Biological Association

Established 1884, incorporated by Royal Charter 2013

Patron: HRH The Prince Philip, Duke of Edinburgh
President: Professor Sir John Beddington, CMG FRS
Director: Professor Colin Brownlee

The Laboratory
Citadel Hill
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PL1 2PB
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tel: **+44 (0)1752 633207**
fax: **+44 (0)1752 633102**
email: **sec@mba.ac.uk**
www.mba.ac.uk

18/07/2017

Dear Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled “CAREER: Examining Kelp Forest Ecosystems Response to Interactions Between Local Disturbances and Climate Change from Local to Global Scales” is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Dr Nova Mieszkowska

Research Fellow & Senior Lecturer