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

SUGGESTED REVIEWERS:

Kristy Kroeker kkroeker@ucsc.edu UC Santa Cruz
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Ken Dunton dunton@utmsi.utexas.edu University of Texas Austin
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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		
C:	Johnson, David	Virginia Institute of Marine Sciences		
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 07/20/18

☐ Special Exception to Deadline Date Policy

FOR NSF USE ONLY
NSF PROPOSAL NUMBER
1848112

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 ,021253393 ,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: Building New Paradigms in Foundation Species Research by Studying Non-Surface-Canopy Kelps' Influences on Biodiversity and Ecosystem Function**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 723,958	60 months	04/01/19	

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
_____
☒ COLLABORATIVE STATUS
Not a collaborative proposal

PI/PD DEPARTMENT
Biology Department

PI/PD POSTAL ADDRESS
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Boston, MA 02125
United States

PI/PD FAX NUMBER
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NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
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CO-PI/PD				
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 ☒

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

Certification Regarding Lobbying

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

Certification for Contracts, Grants, Loans and Cooperative Agreements

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

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

Certification Regarding Nondiscrimination

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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:

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

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 20 2018 1:54PM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
617-287-5370	**heather.carey@umb.edu**	

PROJECT SUMMARY

Overview:

Throughout shallow subtidal temperate ecosystems around the world, kelps form the dominant algal cover on the seafloor. In many systems they are thought to be key foundation species regulating biological diversity and ecosystem function. Given that roughly one-third of the world?s kelp forests are in decline, understanding how these species contribute to the ecosystems around them is of paramount importance. This will also aid in building a firmer theoretical framework around what defines a true foundation species. In this integrated research and education proposal, the project team will work to build a detailed understanding of the role of kelps in shallow subtidal ecosystems in New England through a suite of studies focusing on specific aspects of subtidal ecology. As a part of the project, the team will facilitate programs to train students in basic and scientific diving, giving them opportunities to participate in ongoing kelp forest observations. Students will then work within the Byrnes lab after completion of these courses to conduct original research as part of an ongoing kelp manipulation in order to assess the role of kelps as foundation species in the New England subtidal

Intellectual Merit:

Foundation species are species whose exceptionally high biomass and physical architecture regulates biological community structure and ecosystem function. Understanding the aspects of a species within a community that make it a foundation species is crucial for expanding our understanding of positive interactions for communities and ecosystems. Kelps have long been held up as exemplars of the foundation species concept, enhancing species diversity, enhancing recruitment of fish and invertebrates, mitigating disturbance, and regulating multiple aspects of energy flow within the temperate subtidal. Much of this research is based on systems where kelps grow 10-20 meters in height and forms dense surface canopies. New research calls into question the strength of the role of non-surface-canopy forming kelps. Understanding how kelps act as unique foundation species in the subtidal, as opposed to being a functionally redundant dominant will change our understanding of what constitutes a foundation species. This project is built around the hypotheses that 1) non-surface-canopy forming kelps provide unique benefits to select species, but community metrics merely depend on total algal biomass, 2) their high biomass and structure do influence ecosystem function in ways other species do not, and 3) ultimately, algal assemblage density and canopy height, regardless of species, is the determinant of community structure and ecosystem function. To evaluate these ideas, the project team will create and maintain a series of large-scale kelp clearings paired with controls in Salem Sound, Massachusetts over the course of the grant. In these areas, the team will investigate how local kelps influence biodiversity, community composition, recruitment, and ecosystem functions. This work will be paired with observations from a regional network of kelp forest scientists to evaluate generality of experiments

Broader Impacts:

As part of this research, undergraduates from UMass Boston will be 1) trained in the techniques of underwater research using SCUBA and 2) be given opportunities to use what they learn as part of senior honors theses. This is a unique opportunity for many UMB students. The university is a majority minority campus, drawing heavily from underrepresented groups in marine science. Many, even here in coastal Boston, have no experience with SCUBA or life underwater. This project will facilitate a program introducing them to the underwater world while making them a vital part of ongoing research. Coursework will be coupled with evaluation driven by best-practices in education research to assess how attitudes and knowledge of marine science change through engaging with SCUBA. High performing students will be given opportunities to participate in research as part of the project team and will use their work for senior honors theses. Additionally, this proposal will provide for the training of one graduate student. This project will also facilitate an annual meeting of regional kelp forest scientists focusing on knowledge exchange between labs and providing a training opportunity so that all labs conduct observational studies using the same protocols. Data from this effort is openly shared annually, and other scientists in the region will be invited to conduct measurements in manipulated plots for their own efforts

TABLE OF CONTENTS

For font size and page formatting specifications, see PAPPG section II.B.2.

*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: Building New Paradigms in Foundation Species Research by Studying Non-Surface-Canopy Kelps' Influences on Biodiversity and Ecosystem Function

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 member of the Plum Island LTER. My group has initiated a two-year space for time observational study to evaluate effects of seal-level rise starting in 2017. After this year, we will have sufficient data for our first paper. With this grant, I support one graduate student, one technician, two undergraduate students, and have mentored an REU student.

1. Career Context Statement

1.1. Career Goals: My research and teaching focus on the cascading effects of global change in kelp forest and salt marsh ecosystems. I spent the first decade of my career working in Giant Kelp forests of California, where we understand how kelp acts as a paradigmatic "foundation" species (sensu Dayton 1971), a unique competitive dominant providing habitat, food, and altering abiotic conditions through its sheer size and dominance of the ecosystem. Much of our understanding of kelps as a guild of foundation species is framed by insights from this system. Initial work from my lab in New England kelp forests suggests that our short non-surface-canopy forming kelps, though influential, might play a very different role than a traditional foundational species. My observations have caused me to call into question just what attributes comprise a foundation species versus a "redundant dominant" species. I want to build my career studying the intricate web of interactions that define how kelps influence community structure and ecosystem function in New England and across the planet. The work I propose here will fundamentally transform the lens with which we view kelp forest ecology. Further, the experiments, observations, and synthesis I propose will have significant implications for understanding global change impacts in other ecosystems dependent on foundation species such as seagrasses, corals, or terrestrial forests. This work will provide me with novel insights and directions to pursue for the rest of my career. ***Fundamentall***y, ***this proposal will enable me to transform our understanding of New England kelp forests and build new paradigms in our understanding of foundation species in all ecosystems.***

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. Fewer have seen life on the seafloor firsthand. I have spent the first few years of my career at UMB creating a recreational and research SCUBA diving program that did not previously exist. Still, many students at our majority minority university lack the resources to participate, as it requires them to go beyond standard university fees. 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 our coastal habitats and, in particular, the subtidal kelp forests of Gulf of Maine. Moreover, it will give our pool of often underserved students an opportunity to enter a research field otherwise closed to them given structural disadvantages. ***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. Project Overview & Connection to Career Development: The central objective of this project is to redefine our understanding of how kelps in New England shape the biodiversity and ecosystem function of temperate rocky reefs. It will do so through 1) a repeated large-scale manipulations of kelp to create a suite of experimental sites to test different paradigms of kelp forest ecology, 2) observational work to evaluate generality of experiments, and 3) a manipulation of artificial habitat to uncover mechanisms of differences between kelp systems. It will focus on getting undergraduates into the water and involved in subtidal research via training and individual projects connected to kelp manipulations. ***Getting this proposal funded will enable me to cement a career-long connection to this vital ecosystem in both my research and teaching and allow me to use it to transform our understanding of kelp forest ecology for decades to come.***

2. Introduction & Motivation for Work

2.1 Overview: What happens not just to a house, but to a whole neighborhood when the foundation of a home crumbles? In ecosystems around the world, natural systems rely on so-called foundation species - competitively dominant species or guilds of species of high biomass and structural complexity (sensu Dayton 1972). These species regulate community structure and ecosystem function by providing habitat, food, altering abiotic conditions, enhancing resilience to and recovery from disturbance, influencing major nutrient cycles via their high biomass, and direct or indirectly provision of other ecosystem functions (Bruno et al. 2003; Ellison et al. 2005; Yakovis et al. 2008; Angelini et al. 2011; Orwig et al. 2013; Altieri & van de Koppel 2014; Angelini & Silliman 2014; Hughes et al. 2014; Angelini et al. 2015). Roughly 25% of the world's coastlines are dominated by kelps (Steneck et al. 2002; Krumhansl et al. 2016). In these temperate subtidal systems, they provide food for a wide variety of herbivores, detritivores, and filter feeders (Duggins et al. 1989; Krumhansl & 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 & Syms 2006), influence marine nutrient cycling (Kelly et al. 2012), enhance biodiversity (Byrnes et al. 2011), increase animal biomass across groups (Miller et al. 2018), and much more(reviewed in Dayton 1985; Graham et al. 2007; Bartsch et al. 2008; Teagle et al. 2017). Given this, they are oft cited alongside corals, oysters, and seagrasses as paradigmatic foundation species (Altieri & van de Koppel 2014). Therefore, their loss due to climate shifts – natural and manmade - (Edwards & Estes 2006; Ling 2008; Merzouk & Johnson 2011; Vergés et al. 2014; Filbee-Dexter et al. 2016; Vergés et al. 2016; Wernberg et al. 2016; Assis et al. 2017; Teagle & Smale 2018), overharvesting of top predators(Estes & Palmisano 1974; Steneck et al. 2004), pollution (Connell et al. 2008), and more in roughly 1/3 of their distribution (Krumhansl et al. 2016) is of grave concern. Further, understanding the consequences of kelp-loss in the context of foundation species theory will help us build a broader vision of how ecosystems should change when they either lose or have the identity changed of their primary foundation species.

While kelp removal experiments have taught us much of the role of kelps as foundation species (Moreno & Jara 1984; Reed & Foster 1984; Bodkin 1988; Carr 1989; Graham 1997; Graham et al. 1997; Graham 2004; Siddon et al. 2008; Byrnes et al. 2011; Miller et al. 2018), this understanding is built primarily largely using kelps that form canopies on the surface of the ocean – i.e. have a holdfast attached to the substrate and then extend up to tens of meters to the surface of the water creating canopies – such as the giant kelp Macrocystis, bull kelp Nereocystis, and others. *My own work from the start of my career at UMass Boston shows that these conclusions might not be true for other kelps that do not exhibit this surface canopy forming morphology, despite being the dominant biomass of rocky reefs and providing significant structural (Figs. 1-4).* Indeed, there have even been indications of this in previous work (Levin 1991; 1994; Levin et al. 2002; Schmidt & Scheibling 2007). Moreover, few of the aforementioned studies, or many of those discussed below, experimentally measured changes in ecosystem functions via removals, focusing instead on communities alone. This raises problems in attempting to couple community and ecosystem ecology in the subtidal. These issues raise fundamental questions. What truly defines a foundation species? How do differences in morphology translate to differences in properties of a foundation species? Are non-surface-canopy forming kelps (hereafter non-canopy or subcanopy kelps) a foundation species, or merely one of a large suite of species in an ecosystems that perform the same role? Does this mean that their loss may have fewer consequences than anticipated? The answers to these questions have deep implications for our understanding of temperate subtidal systems and global change.

Here I propose to systematically evaluate when, where, and why non-surface-canopy kelps enhance biodiversity and ecosystem function in temperate rocky reef systems. I will do this using a combination of experimental large-scale kelp removals with nested experiments in New England, comparisons to ongoing regional observational data collection, and extensions of extant data synthesis.

2.2 Subcanopy Kelp Ecosystems: Much of the world's kelp forests, are comprised of non-canopy forming species, such as *Ecklonia radiata*, members of the generas *Saccharina* and *Laminaria* (Bartsch et al. 2008; 2012), and others(Dayton 1985; Bartsch et al. 2008; Bennett et al. 2016; Krumhansl et al. 2016). While these kelps provide high structural complexity close to the benthos, they often coexist with other algae that, when dominant, can also form assemblages of high structural complexity and biomass (Johnson & Mann 1988; Levin et al. 2002). Are these subcanopy kelps truly foundation species *sensu stricto*, or are they merely redundant to the many other algae with which they coexist? What unique functions do they provide? The subcanopy kelp removal literature shows us that they are competitively dominant, regulating sessile community composition (Johnson & Mann 1988; Kennelly 1989; Flukes 2014). When kelps are present, decreases in light lead to more coralline algae (Melville & Connell 2008) or other low light tolerant species. When eliminated, however, the larger native and non-native structurally complex algae that flourish often provide similar functions for communities and ecosystems (Johnson & Mann 1988). It is only more recently with the rise of a global epidemic of replacement by turf algae (Gorgula & Connell 2004; Connell et al. 2014; Filbee-Dexter & Wernberg 2018), particularly the now cosmopolitan *Dasysiphonia japonica*, that we have seen real shifts in the dominant morphology of temperate algal beds from foliose beds to low turfs when kelps are eliminated (Newton et al. 2013; Dijkstra et al. 2017; Filbee-Dexter & Wernberg 2018). However, while composition clearly shifts in many clearing experiments, net species richness and total algal cover often stays the same (Flukes 2014) or merely changes slightly (Kennelly 1989). Other biodiversity metrics only change with only full kelp removals. Further, effects on community metrics often occur on reefs that are topographically simple (Toohey & Kendrick 2008) where kelp is necessary for structure. Last, while canopy forming kelps often regulate a sessile invertebrate to algal competitive hierarchy (Arkema et al. 2009), subcanopy kelp removal often enhances invertebrates due to their scouring activity (Kennelly 1989).

The larger consequences of subcanopy kelp elimination are mixed. For example, subcanopy kelps enhance lobster recruitment and abundance(Bologna & Steneck 1993; Palma et al. 1999) and urchin recruitment in the Gulf of Maine (Harris & Chester 1996). Across the world, non-canopy kelp holdfasts, stipes, and blades provide habitat for a wide array of epibionts and micrograzers (for an excellent review see Teagle et al. 2017). Their structure provides a significant amount of physical habitat that is similarly used by many larger species as well, although this appears to vary by physical conditions and species identity (2015, 2016). How loss of kelps would affect biodiversity when they are replaced is less clear given higher morphological complexity directly on the seafloor from replacement algae. In some systems, climate shifts have driven replacement of one kelp by another morphologically similar alga, leading to a decline in diversity (Teagle & Smale 2018), in other systems increases in structurally complex foliose algae have actually increased diversity (Dijkstra et al. 2017). In Australia, many removals lead to increases in sedimentation as kelps no longer scour the substrate (Kennelly 1989) or just the opposite as turfs accumulate sediment (Melville & Connell 2008). The net effects of kelp loss as ecosystems shift to alternate species are unclear, and were recently identified as an open area for future research (Teagle et al. 2017). Further, how other ecosystem functions, such as NPP, decomposition rates, recruitment, and others are affected by subcanopy removals are less well understood. We know that understory kelps do affect flow (Eckman et al. 1989). Effects on recruitment appear to vary by species (Duggins et al. 1990).

New England and Eastern Canada have provided an interesting if indirect testing ground to examine the consequences of kelp loss. Over the past few decades, as the system has recovered from extreme overgrazing due to urchins (Steneck et al. 2004), invasive algae such as *Codium fragile* or turfs of *Dasysiphonia japonica*, *Bonnemaisonia hamifera*, and others have taken their place in many areas (Trowbridge 1998; Harris & Tyrrell 2001; Levin et al. 2002; Mathieson et al. 2003; Newton et al. 2013; Steneck et al. 2013; Dijkstra et al. 2017). Curiously, this replacement has not always meant a loss of biodiversity or ecosystem function. Densities of lobster and crab are similar in kelp and *Codium* beds, although adult fish abundances differ (Levin et al. 2002). Curiously recruits of at least Cunner show no species specific preference but rather favor high algal cover and canopy height (Levin 1991; 1994). This

appears in contrast to urchins, that have higher recruitment in areas of kelp mimics (Harris & Chester 1996), although whether this result is driven by structure *per se* rather than kelps *sensu stricto* is unclear. Invasive *Dasysiphonia* appears to increase habitat structural complexity, and thus mesoinvertebrate abundance, many of which are consumed by fish (Dijkstra et al. 2017), nor was it clear how this affected the ability of fish to find refuge (O'Brien et al. 2018). With respect to other aspects of community structure, recent comparisons of offshore kelp beds with 150x the abundance of kelp than onshore sites suggests these communities host more fish and sessile invertebrates (Witman & Lamb 2018), although to what extent this is driven by other oceanographic differences is unclear. In these sites, however, enhanced fish abundances does drive higher predation rates, indicating more rapid energy transfer within food webs and changes in community structure as an element of community structure and function regulated by subcanopy kelps (Witman & Sebens 1992).

2.3 Preliminary Evidence of Variability in Kelp's Ability to Function as a Foundation Species: Work from my lab and the regional network of kelp forest ecologists I coordinate, the Kelp Ecosystem Ecology Network Of New England, shows that non-canopy kelps, and *Saccharina latissima* in particular, have a fundamentally different role in regulating species diversity that surface canopy forming kelps. Starting in 2013, we have surveyed kelp forests from Narragansett Bay, RI to Hurricane Island, Maine using a protocol adapted from the Santa Barbara Coastal LTER (Byrnes et al. 2014b) to understand the links between environmental change, kelp abundance, and community structure. Our data (Byrnes et al. 2014a, b; Dijkstra & Mello 2015; Humphries et al. 2016; Rasher & Price 2017) shows that while environmental drivers – in this case seawater temperature and rocky substrate – drive kelp abundance, changes in kelp abundance do not affect species richness (Fig. 1).

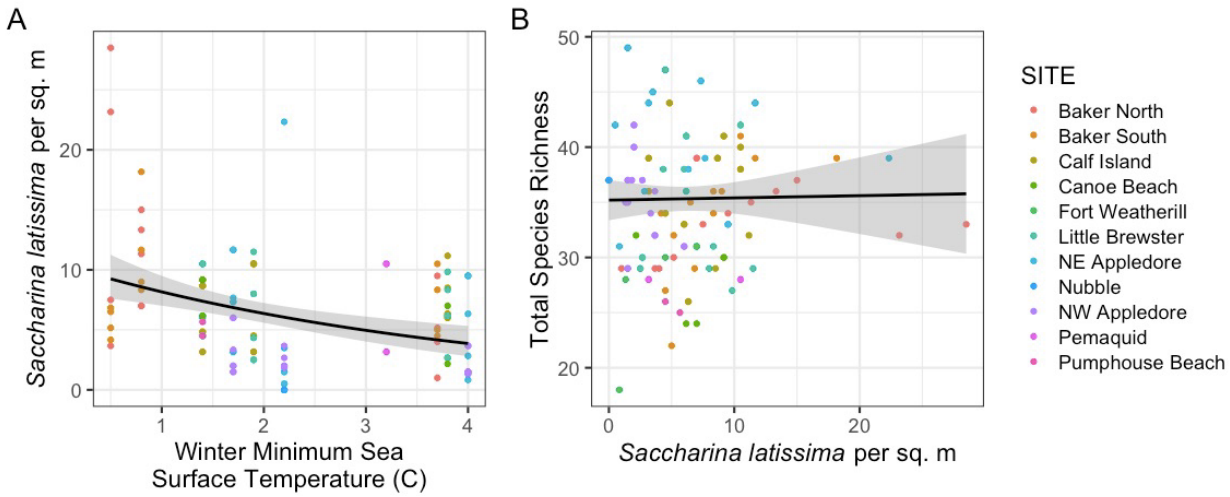

Figure 1. Relationship between winter minimum SST, sugar kelp abundance, and species richness in the New England. *Models were fit using generalized linear models with gamma or Poisson errors and log links. A) SST and kelp are negatively related to one another. B) Sugar kelp abundance and total species richness shows no relationship.*

This lack of relationship holds true for total species richness and species richness of all functional groups surveyed. Moreover, in contrast to my own previous work in canopy forming kelp systems, environmental drivers appear to directly impact community structure when effects are decomposed using Structural Equation Modeling (Grace & Bollen 2008; Lefcheck 2016). Therefore any correlation between changes in kelp and community structure are incidental rather than causal (Fig. 2).

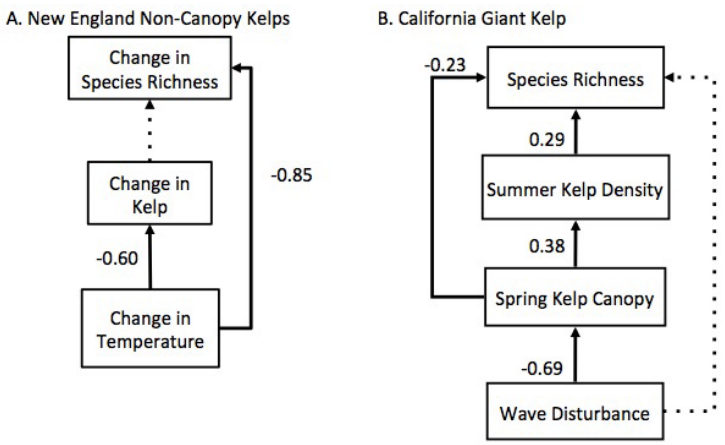

Figure 2. Structural Equation Modeling of the direct and indirect effects of environmental drivers on kelps. *Solid arrows represent links different from 0 at the $\alpha = 0.05$ level. Numbers are standardized effect sizes (i.e., Pearson partial correlations). A) Effects of change in temperature on the subcanopy sugar kelp and species richness in New England. Results using first difference models with the data from Figure 1 to cleanly evaluate whether change in one driver affected change in another. B) Effect of wave disturbance (kelp at t-1 * waves) on giant kelp canopies along the coast of Santa Barbara. Figure adapted from Byrnes et al. 2011.*

Looking to syntheses I have been working on with collaborators from the kelp and climate change working group I organized at the National Center for Ecological Analysis and Synthesis, we see again that non-canopy forming kelps function differently that canopy forming species in influencing fish communities. We have conducted a meta-analysis of studies looking at the influence of kelps of fish, splitting our data by kelp morphology. Our work shows that total fish abundance and species richness responds positively to canopy species but has no consistent response to non-canopy formers (Pérez-Matus et al. In Prep, Fig. 3). This results further supports the idea that differences in foundation species morphology translate to their impacts on the surrounding community.

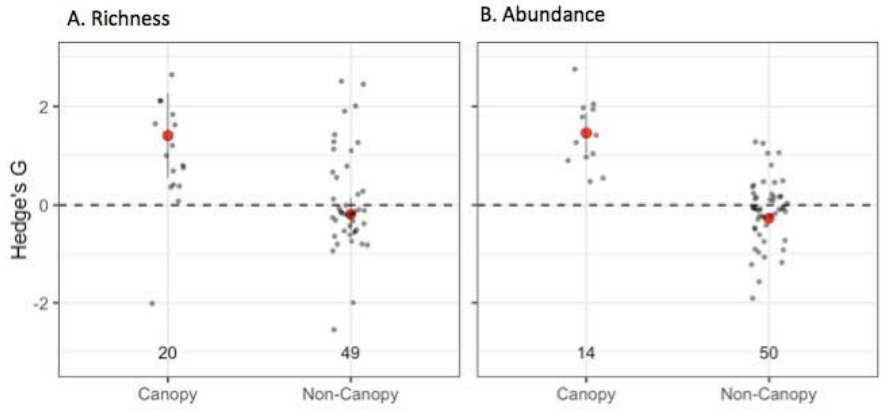

Figure 3. Effects of different kelp morphologies on fish species (A) richness and (B) abundance. *From a meta-analysis of all extant observational studies of the relationship between fish and kelp by Pérez-Matus, myself and other colleagues. Positive values of Hedge's G indicate kelp has a positive effect.*

In contrast, recent work by an REU student in my lab shows that *Saccharina* in New England does alter per capita foraging rates of fish. She showed that the probability of food items being consumed by fish, in this case Cunner, is higher in areas of higher kelp abundance. She observed this result despite fewer Cunner being found in areas of higher kelp abundance (Fig. 4). Thus, *per capita* predation rates appear

increased by kelp. This work complements additional recent studies showing that Cunner in particular use kelp as a refuge (O'Brien et al. 2018) rather than other algae.

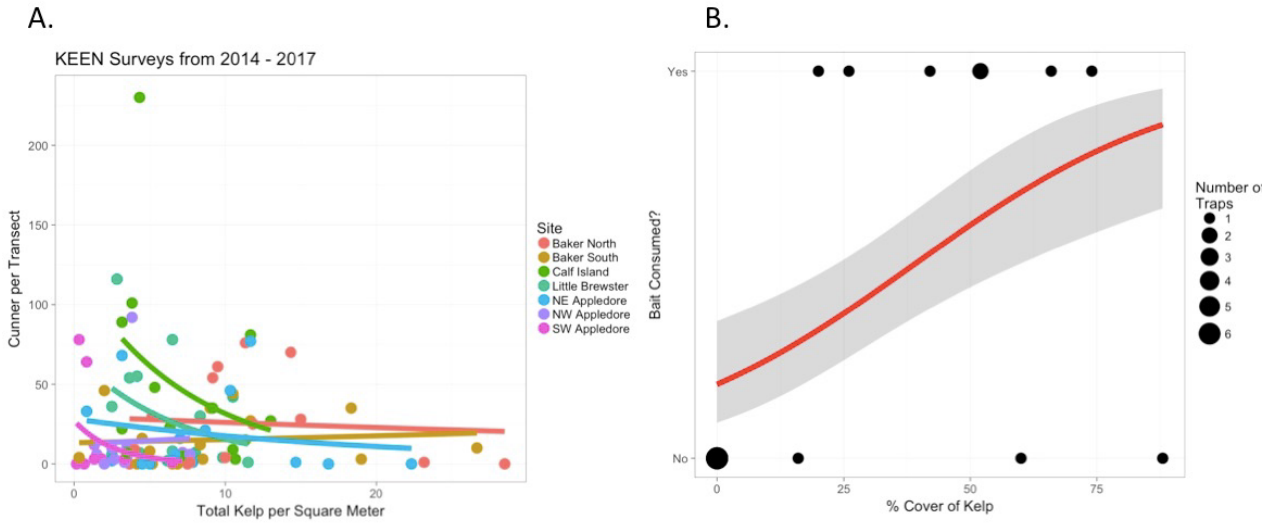

Figure 4 The relationship between kelp, Cunner, and predation by cunner on squid bait. *(A) shows no consistent relationship across all sites sampled by KENE ONE between kelp and cunner, although in some sites it was negative. Despite this, (B) shows that predation rates are higher in areas of higher kelp abundance, likely a behavioral effect of kelp on per capita predation rates.*

Coupling my work with evidence in the literature suggests that subcanopy kelps serve a fundamentally different role, even as competitive dominants, than surface-canopy forming kelps. This implies that not all structure forming competitive dominants are "foundation species" *sensu stricto*, and suggests a need to build a broader understanding of what it means to be a foundation species. However, 1) this preliminary data is correlative, requiring experimentation to establish causal links, and 2) there is conflicting evidence that kelps, still might influence ecosystem function, suggesting a need for a broader understanding of what foundation species as a concept.

3. Specific Objectives & Hypotheses

I propose to evaluate the following hypotheses to test whether kelps in New England, and non-canopy kelps in general, are foundation species, dominant yet redundant species, or whether there is a larger gradient of roles that we have yet to understand. I have broken this exploration into five hypotheses. Overall, I hypothesize that while aggregate community metrics will not change from loss of non-canopy kelps, community composition and ecosystem function will still be affected.

1. Non-canopy kelps do not alter species richness or total abundance of other functional groups, but will change community composition.
2. Non-canopy kelps alter rates of energy transfer in food webs via habitat provision for predators and prey.
3. Non-canopy kelps alter ecosystem functions in subtidal systems.
4. Non-canopy kelps alter recruitment and post-settlement survival.
5. Canopy height and individual abundance determine community structure and ecosystem function.

4. General Methodology for Evaluating The Effect of Non-Canopy Kelps

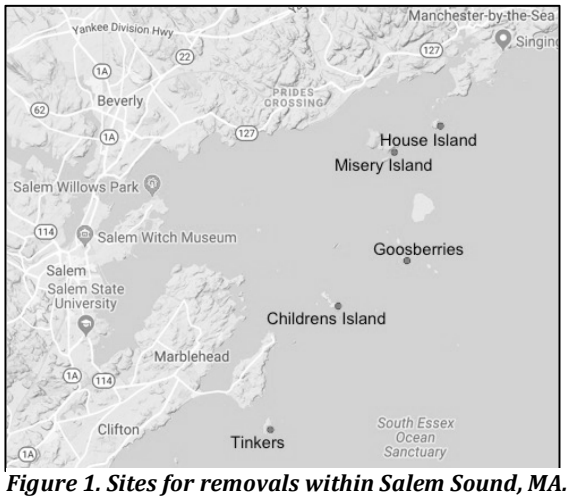

Figure 1. Sites for removals within Salem Sound, MA.

4.1 Removals in Salem Sound: The only way to causally test the hypotheses above is experimentation. Therefore, I propose over the course of this grant to create and maintain a set of large-scale kelp removal areas paired with controls in the kelp forests of Salem Sound, MA. Sites have been selected for similar physical conditions with respect to exposure and distance from influence of the estuary (Fig. 5). My lab has worked in Salem Sound for the past five years and conducted removals of similar scale. Removals will include all species – *S. latissima, A. clathratum, A. esculenta,* and *L. digitata.* In practice, however, 95% of the kelp in these sites is *S. latissima*, and hence it will be the main target of this investigation. Within paired control-removal areas (n=5 areas, Fig. 5), students and I (see Project Personnel and Broader Impacts) will conduct experiments testing different mechanisms by which kelp might affect community and ecosystem structure and function. Removals will be initiated in mid-May by the project team and maintained monthly through the end of August. Removal and control areas will be 8m in radius with the central 4x4m area being sampled using 12 $1m^2$ quadrats before the removal and monthly thereafter until the fall. Removals will be re-initiated each following May in the same sites. One Hobo temperature and light logger will be placed at the center and 3m out from the center of each plot. They will be cleaned during maintenance and used to compare both physical quantities between plots. Maintenance (i.e. re-removal) will be paired with sampling and deployment of in-plot experiments. Previous work shows that plot setup takes two days (i.e. 4 dives) with additional sampling requiring one day (2 dives). In subsequent years, kelp in our preliminary trials has been ~75% less abundant, making setup faster.

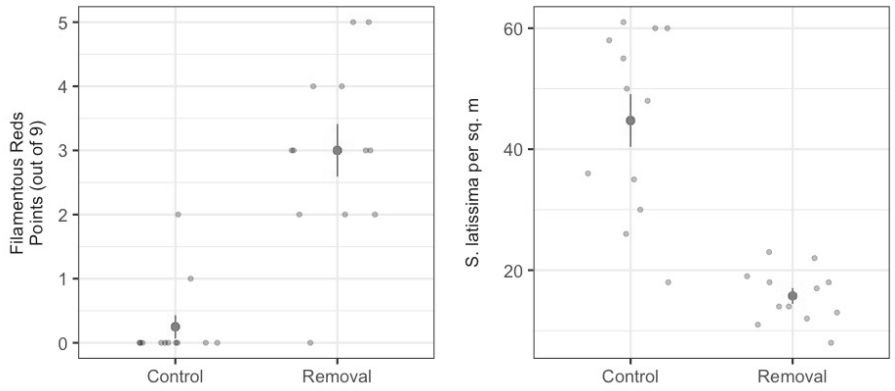

Figure 6. Results from past 8m radius removal (2014) showing an increase in filamentous red cover (# points in a quadrat out of 9) and decrease in sugar kelp abundance.

This design is ideal to create a template of kelp and no-kelp areas for a series of experiments. While it is a simple manipulation, it is powerful in creating a single clear differentiated factor. Many experiments done using this template require little more statistical complexity than a paired t-test or ANCOVA accounting for initial conditions. ***This simplicity is ideal for the undergraduate students who will be participating in this proposal as they conduct research for their own honors theses. Each investigation of an individual function or manipulation should be envisioned as a project that will be conducted by myself and the members of the project team.*** Moreover, from a philosophical standpoint, simplicity of design can often aid in providing clarity when addressing ecological problems (Murtaugh 2007).

4.3 Establishing Generality through Regional Kelp Forest Assessment: Experimental results can often generate an biased estimate of true effect size in nature, particularly in systems with multiple correlated drivers (Ruesink 2000; Boyd et al. 2018). In order to verify generality of results of the following experiments, particularly with respect to community structure, I will continue coordinating the Kelp Ecosystem Ecology Network Of New England (KEEN ONE) as I have for the last five years. This regional New England network of kelp forest ecologists engages with the Humphries and Thornber labs of URI, the Grabowski lab of Northeastern University, the Dijkstra lab of UNH, and the Rasher lab of Bigelow Labs to conduct a annual kelp forest community structure surveys from the Narragansett to Hurricane Island, Maine (see Fig 1. above for sample results). We conduct an annual training symposium and student poster session at different member campuses where we review our protocols (Byrnes et al. 2014b). Sampling for community structure consists of a modified version of the Santa Barbara Coastal LTER protocols with 40m transects using six$1m^2$ quadrats for kelp and large sessile species counts, counts of mobile species on 1m of either side of the transect, 80 uniform point counts of all sessile species, and fish counts in a 2x2m box around the entire transect. Sites from all labs are in areas with wave exposure and a rocky bottom. We also place temperature loggers at each site. With this grant, we would like to expand this by giving all participating labs wave sensors to add an additional abiotic variable to observational data analyses discussed below.

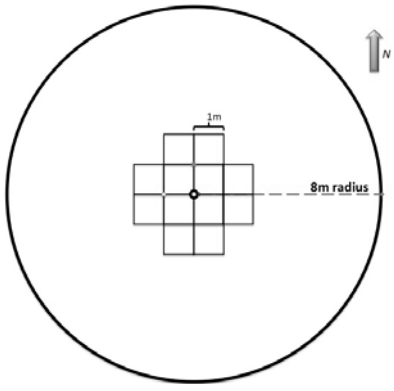

Figure 2. Layout of 8m radius control/removal area. Squares indicate sampled quadrats.

5. Year 1 through 5: Non-canopy kelps do not alter species richness or total abundance of other functional groups, although they will change their composition

While surveys of kelp forests in the region show little to no connection between kelp abundance and species richness of the total community or functional groups, there are many covariates in such a regional sample that could underlie these results. As a first step in understanding the effect of kelps in the New England subtidal, I will use the removals to evaluate the effect of kelp removal on community change over the course of a full summer. I will then examine how this response changes over the duration of this project. In removal and control areas, I will sample 12 $1m^2$ areas (Fig. 7) in the center of each plot using quadrats to count kelp and other large easily individuated algae, sessile invertebrates, mobile invertebrates (e.g., urchins, stars, crabs), and demersal fish (e.g. rock gunnels). I will also sample these $1m^2$ plots with uniform point counts (98 points over the whole 12 plots) quantifying all sessile species and substrates present, including layering. Last, I will measure length of the 10 kelps in the center of control plots to quantify size distribution.

5.1 Analysis of change in the first year of kelp removal: To assess kelp impact on community structure in year 1, if kelp abundances across control plots are roughly equivalent, I will use a simple parametric or non-parametric paired t-tests with August data to ask if kelp influenced total richness, algal richness, sessile invertebrate richness, or mobile species richness. Further, for both individual functional groups and for all species sampled in UPCs (algae and sessile invertebrates), I will be able to perform the same analyses for rarified richness, Shannon diversity, evenness, and abundance. Further, I can evaluate beta-diversity across the 12 sampled plots in each treatment and evaluate whether kelp has an effect on turnover between plots. I will also look at changes in abundance of individual mobile species and the most common species in each sessile functional group to assess differences in composition. I hypothesize that this is where I will actually see differences in communities. I will also look at temporal turnover from June to August to assess whether kelp control or removal plots had greater amounts of change over the summer. If control plots do not have similar kelp abundances, I will use control abundance as a covariate for analyses in an ANCOVA or appropriate generalized linear model framework. These results paired with observational studies will constitute the first paper from this project.

5.2 Analysis of change after multiple years of kelp removal treatments: Over the course of the project, as the removal is repeated annually, I will look at interannual variability in richness, Shannon diversity, and composition across years using a mixed modeling approach. Further, I will look at the temporal coefficient of variation in August communities over the duration to evaluate if kelp has a role in contributing to stability. Last, I will be evaluate the amount of pre-removal kelp in control and treatment plots each May if repeated removals shifted the system from a kelp to non-kelp dominated system. This result has implications for the impact of increased wave disturbance in New England as has been observed over the past 40 years (Komar and Allan 2008). This long-term analysis will likely be one of the final papers from the project.

5.3 Assessing Generality via Synthesis: During year four and five of the project working with a project postdoc, I will work with the project graduate student will assess generality of the community results via data synthesis. In Krumhansl. et al.'s analysis of global kelp trends (Krumhansl et al. 2016), many of the datasets I harvested to build the analysis were from larger-scale community sampling programs (e.g., PISCO, the SBC LTER, the Australian MPA monitoring network, etc.). Working together, we will 1) update the analysis of Krumhansl et al. with twelve more years of kelp time series data, enhancing it's robustness and 2) harvest all extant community data from a subset of those studies. Using Bayesian generalized linear mixed models (Ellison 2004; Bolker et al. 2009), we will analyze the data to assess the relationship between kelps and species abundance, richness, evenness of fish, mobile invertebrates, sessile invertebrates, and algae. Depending on the data available, we will work to properly incorporate other covariates or use data from global data layers (e.g., the Hadley Met Center SST database) to evaluate environmental drivers. We will allow kelp effects to vary by morphology – canopy versus non-canopy - to assess the impact of morphology on these different aspects of community structure.

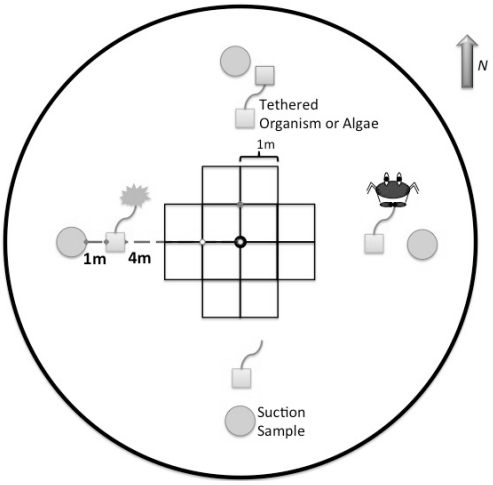

Figure 3 Layout of control/removal area with location of tether experiments and suction samples for reference.

6. Year 2: Non-canopy kelps alter rates of energy transfer in food webs via habitat provision for predators and prey

Complex habitats can either enhance energy flow in food webs via providing habitat for both predators and prey (Dyer & Letourneau 2003) thus increasing chances for interactions, or, more commonly, they can reduce it by making foraging more difficult for predators (Almany 2004; Grabowski 2004; Grabowski & Powers 2004; Aquilino et al. 2005; Ferner et al. 2008). My REU's results show that kelp increases Cunner per capita predation rates even as their densities decrease. Again, this was a correlational approach, and the squid-pop assay, while an emerging tool for assessment of predation pressure (Duffy et al. 2015), does not capture the natural history of predation in the system. Further, questions of herbivory are still open, as is an experimental assessment of microherbivores.

To assess the impact of kelp on energy transfer within food webs, I will use the paired kelp removals as a background to conduct additional assessments of food web function. I will conduct multiple predation assays (Fig. 8) with a) standardized squid bait, b) tethered urchins, c) tethered crabs, and d) tethered amphipods. For each assay within each plot, I will deploy 10 replicates over the course of the summer with individuals placed ~ 4m from the center of plots with one of each assay type per deployment to minimize predator attraction to any one item type. Based on the rig we designed for squid assays, GoPro underwater cameras will be trained on tethered organisms to record the identity of predators and predation

rates when possible with filming either continuous or time-lapse. Assays will last ~1 hour for small organisms to 1 week for larger organisms. Similarly, I will conduct assays of herbivory by looking at mass change of 10 pieces of pre-weighed kelp and *Ulva* sp. as well as change in percent cover of agar on window screens (Cronin et al. 1997) in each plot. Each herbivory assay will last for ~1 week, or until noticeable herbivory occurs in the field. Results from all assays will be analyzed either using paired t-tests or, if assumptions are violated, comparable non-parametric tests. Further, herbivory assays will be bagged on collection, and I will count microherbivores (e.g., the snail *Lacuna vincta* and amphipods) found present. While urchin herbivory is possible, over the five years of my surveying Salem Sound, I have only observed significant densities at Halfway Rock, far from any of these sites.

Last, to assess how kelp versus non-kelp habitats affect abundance of micrograzer prey, I will take 4 100cm^2 samples from each plot 5m from the center using a suction sampler and quantify micrograzer abundance. I will analyze both number and dried weight at the species or family level, depending on taxonomic group, and use paired t-tests to quantify differences between kelp and no-kelp areas. I will also look a community composition of algae and sessile invertebrates within these samples to assess any relationship between abundances and biomass of grazers with either abundance of kelps or other taxonomic groups, richness and evenness of habitat-forming species, or total algal biomass. For each analysis, I will use the appropriate generalized linear mixed models as well as a model with all predictors. I will use AIC to quantify the weight of evidence for each model.

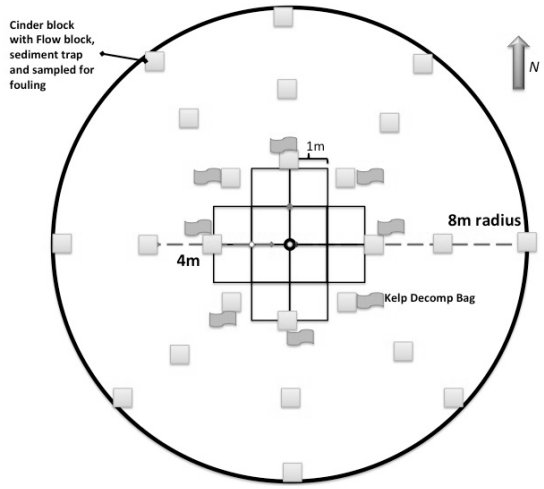

Figure 4 Layout of control/removal area with blocks and decomposition bag locations shown for reference.

7. Year 3: Non-canopy kelps alter ecosystem functions in subtidal systems

Kelps not only affect biotic community structure, but they can also alter the flux of matter and nutrients in the ecosystems around them. This change in ecosystem function can come directly from kelps altering the physical environment around them (e.g. flow rates Gaylord et al. 2007) or indirectly by changing biotic community structure (e.g. via determining algal community composition Miller et al. 2011a). I propose to use the template of kelp removals and controls to evaluate how ecosystem function changes in and as a result of said manipulations. I propose to evaluate kelps' effects on the following ecosystem functions: flow, sedimentation, decomposition, terrestrial wrack decomposition, standing biomass as a proxy for net primary production, and invasibility (Fig. 9 for layout).

To evaluate flow, I will use modified clod-cards (Doty 1971) made of gypsum dental cement deployed on cinder blocks for two weeks (or shorter, if significant erosion is observed). Blocks will be placed in concentric rings of eight at 8m, 4m, and 2m from the center of the plot and loss will be summed so that differences in flow direction do not affect results. I will evaluate difference in mass change between the edge and the two inner rings and compare results between treatments and controls to look at differences in flow within plots. To evaluate kelps' effects on sedimentation, I will deploy sediment traps (10cm x 50cm diameter PVC tubes as in Irving & Connell 2002) for two weeks using the same platform as flow blocks. Sediments will be sieved into coarse and fine fractions (250μm as a cutoff), dried, and weighed. Analysis will be the same as flow.

To evaluate how kelp shapes communities that affect kelp decomposition, I will assess kelp decomposition rates as well as what small micrograzers and epibionts colonize kelp detritus subtidally. I will use a modified protocol from the Norwegian Blue Forests Network Sugar Kelp decomposition

experiment in which I am currently participating. Briefly, eight 20g pieces of kelp will be put into decomposition bags and attached to the 2m ring of flow blocks at each site. This will be done for *Saccharina latissima, Agarum clathratum,* and *Laminaria digitata.* Kelp will be allowed to decompose for 4-6 weeks (or until complete loss appears imminent), harvested, and weighed after all epiobionts are cleaned. Epibionts will also be identified, dried, and weighed. As algal wrack on beaches from storms can be an important pathway for energy and nutrients, I will remove five 100cm^2 of algae (underneath flow cinder blocks) from each plot. Samples will be sorted to lowest taxonomic level possible, damp-dried, weighed, and then deployed in litter-bags at the high tide line of the beach by Salem State's Cat Cove marine lab. After 2-4 weeks (or until complete loss is imminent in one sample), samples will be again re-dried and weighed to quantify mass loss.

To evaluate how New England kelp beds affects net primary production and compare it to results from giant kelp systems (Miller et al. 2011b; Harrer et al. 2013), I will adopt the calibration method of Harrer et al. 2013. Outside of plot areas, I will survey 30 100cm^2 strung with 20 uniform points. After assessing number of points of algal species, I will scrape plots, sort to species, and record damp, dried weights after 3 days at 60°C, and ash free dry weight of a portion of the algae to calculate grams dried carbon. I will also collect and do the same for each species assessed as individuals in quadrat counts, and create a blade length to dried and AFDW relationship for each species of kelp. With these relationships, I will then use community sampling to calculate grams of dried carbon in quadrat counts and compare standing biomass between kelp removal and control areas.

Finally, I will monitor how canopy removal treatment alters invasibility. Cinder blocks for flow treatments, etc., will be secured to substrates with marine epoxy and eyebolts epoxied into the substrate with zip-ties. After flow blocks are removed and into the following year, I will assess species composition growing on the tops and sides of the blocks. I will assess species composition to see if these are native of non-native species, and evaluate which treatment has a higher cover on cinder blocks of non-native species each year thereafter.

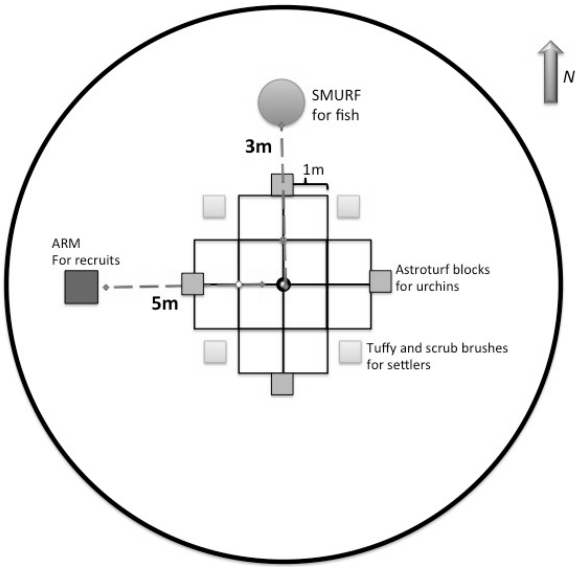

Figure 5. Layout of control/removal area with location of settlement substrates, SMURF, and ARM shown for reference.

8. Year 4: Non-canopy kelps alter recruitment and post-settlement survival

The effect of non-canopy kelps on recruitment and survival of animals is mixed. Cunner recruits, for example, respond to total algal cover, diversity, and canopy height rather than New England kelps *per se* (Levin 1991; 1994). Small lobster, however, are enhanced by kelps (Bologna & Steneck 1993). Further, *Saccharina* holdfasts can serve as an important habitat for juvenile urchins (Feehan et al. 2014). To evaluate the role in non-canopy kelps in altering recruitment and post-settlement survival, I will conduct a series of assessments looking at recruits into each habitat and the match or mismatch between recruits and juveniles using these habitat patches. To assess recruitment over the course of a summer in each area, I will deploy 1) one Standardized Monitoring Unit For the Recruitment of Fishes (Ammann 2004)3m to the north of the center of each plot, 2) four cinder blocks topped with 20 x 20 cm pieces of astroturf to monitor urchin settlement 2m from the center (Harris & Chester 1996), 3) four tuffy pads and scrub brushes 2m from the center to assess settlement of other invertebrate species, and 4) an Artificial Recruitment Module (ARM) placed

5m from the center of the plot to look at mobile species recruiting into plots by the end of the summer (Fig. 10 for layout).

Briefly, SMURFs are large mesh 1 x 0.35 mesh cylinders stuffed with additional mesh secured to float vertically for larval fish settlement (Ammann 2004). ARMs are wire cages containing ~20 halved cinder blocks providing habitat for organisms to recruit to after settlement and not be subjected to predation pressure. Recruitment substrates will be harvested and either rinsed or replaced biweekly after deployment. Recruits will be enumerated down to lowest taxonomic level possible. ARMs will be assessed in August by taking them apart, bringing individuals back to the surface, and counting and measuring all individuals. I will assess if there are any difference between removal and control plots in settlement or recruitment, as previous work suggests there might be – although this will vary by taxa (Levin 1991; Harris & Chester 1996). Second, in addition to standard quadrat sampling that includes juvenile mobile organisms, I will conduct three 5x2m swath transects and five 1 hour video observations within each plot. With these three pieces of data, I will evaluate whether treatments differ in settlers, recruits, or observed individual of multiple species. Discrepancies in patterns – e.g., no difference in settlers or ARM recruits, but differences in surveys, would indicate whether kelps play a role in enhancing settlement or mitigating post-settlement mortality.

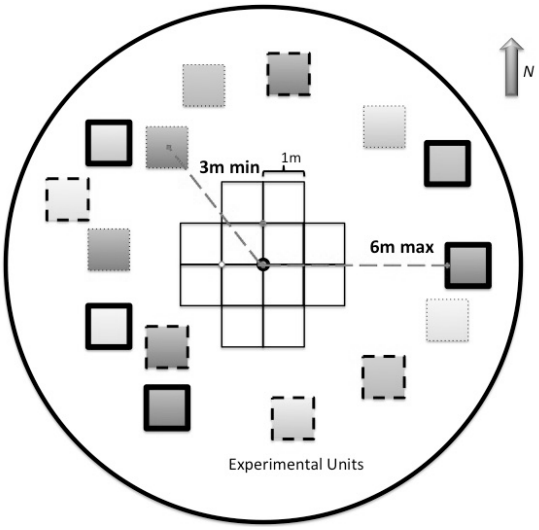

Figure 6 Layout of removal area with experimental blocks shown for reference. color indicates a different density treatment and line type indicates a different height treatment. Actual layout will vary with random number generation.

9. Year 5: Canopy height and individual abundance determine community structure and ecosystem function

If physical structure of the algal canopy, and not species identity, drives the effect of foundation species, then mimics that vary in architecture should affect those same processes. Indeed, kelp mimics have been shown in the past to alter recruitment in a similar manner to live individuals (Harris & Chester 1996). Therefore, in the final year of the project, I will conduct a field manipulation where I create artificial structure varying in density and height as has been suggested to affect community processes in past studies(Levin 1991). Each three removal sites, between 3-6m out from the plot center, I will clear 15 randomly placed $1m^2$ areas of all species taller than 10 cm (e.g., *Cystoclonium purpureum, Palmaria palmata*, etc.). In each area, I will use eyebolts, marine epoxy, and zip ties to secure weighted $1m^2$ quadrats strung in a 4x4 grid with polypro rope attached at variable density and canopy height. Grids will be strung with either 0, 20, 40, 60, or 80 ropes (n=3 per density per plot) ± 0-10 ropes chosen at randomly to create a continuous surface. Within the three densities, plots will be trimmed to either 25cm, 1.5m, or 3m ± 50cm randomly. One area per removal plot will be have 0 ropes (and 0 height) as a control (Fig 11 for layout). This design will create a factorial response surface (45 data points) so that all analyses will have height, cover, and a height-cover interaction. Additionally, plot identity can be included as a random effect. The experiment will be maintained for the summer. I will take monthly video observations and diver inspections to assess invertebrate use. At the center of each area, I will attach a dental cement flow block and astroturf recruitment tile to be switched out every two weeks and analyzed using methods as done previously. I will also take light measurements over the course of the summer using Hobo loggers. On each trip, divers will assess effective canopy height for each plot in order to provide a proper covariate for analysis. At the end of the summer, divers will place bags plots and remove them to the surface. Ropes will be soaked in

magnesium chloride to remove mobile fauna, and we will record the identity and cover of fouling epibionts. We will sample the substrate with counts of individual algae and invertebrates as well as percent cover using methods from the main community sampling at the center of plots. To evaluate the effect of canopy height and cover, I will look at all response variables using the appropriate general or generalized linear mixed models and assess how height and density affected each response.

10. Research Timeline and Personnel

As laid out above, each year will focus on a different theme. During year one, we will work to build the basic manipulation template. While I have conducted these manipulations before, albeit no more than two per year, year one will also involve troubleshooting initial setup given the higher sample size and maintenance as well logistics of undergraduate mentorship. The team and I will also conduct preliminary trials of methods for the following years in order to enhance efficiency (e.g., night-time videography, securing cinder blocks in appropriate locations, etc.). The project graduate student and I will refine new methods over the course of the year so that we are ready to start anew when the school year ends. Each summer, I will staff the project with three undergraduates and one graduate student. Undergraduates will continue in the year following as part of an honors seminar, an independent study, or as a paid intern. The graduate student will also focus on synthesis during the academic year, as well as additional projects that they create independently that fit the resources and themes of this project.

11. 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 & 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 created at UMB where urban students get in the water to develop a new understanding of the ocean around them and conduct research.**

My program has four 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.
4) Increase diversity in underwater research by providing students meaningful research opportunities.

11.1. 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 helped found the American Academy of Underwater Scientists (AAUS). In 2013, I revitalized 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 want to change that.

11.2. Current Efforts: I have spent the past five years working with UMB Dive Safety Officer Ted Lyman developing a diving program here at UMB. We have run courses here in Boston and out at our field station at Nantucket, but have not mandated close involvement between the classes and my lab's research. Working with the University, I have created a college level Dive Safety Board. We are 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've had students drop at the last minute because they were unable to procure gear or other resources required to participate. (We have lost seven students over the past three years for this reason). This is not surprising given our population. With this grant, I will increase equity in access to subtidal research opportunities.

11.3. Approach & Courses Offered: Working with our DSO, 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.

11.4 Underwater Research and Involving Students in Research: These courses prepare students for a full Underwater Research course Lyman and I have organized for the past four 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 our 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 observational survey dives to fulfill their diving requirements, giving them needed scheduling flexibility, and 3) enable students to use our network's data for their course projects.

11.5 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.

11.6. Direct Involvement of Students in Project Experimental Research: Beyond participating in observational sampling as part of UWR, each year, I will identify three students who performed well and

hire them as summer researcher assistants. They will help conduct removals, and I will work with these students to help them develop an honors thesis based on one of the sampling protocols conducted that year (e.g., one student works on change in flow, one on change in decomposition, and one on sedimentation). If additional exceptional students are identified, I will recommend them for REU support either through a pre-existing UMB program or through additional CAREER NSF support.

11.7. 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, and 3) how might climate change affect life in the sea. 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 designed with Dr. Brian White, an expert in undergraduate biology education here at UMB, and compare change over the course for each student. I will also administer a SENCER Student Assessment of Learning Gains (Cook & Mulvihill 2008; National Center for Science & Civic Engagement, 2014) 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 Dr. White, I will evaluate outcomes of both assessments from each of the three courses and compare the outcomes from each level of SCUBA training.

11.8. RET Opportunities: Beyond our students, I will identify high school and middle school teachers in the Boston area with dive experience interested in auditing the UWR course and then participating as RETs. These teachers would be able to bring their experiences back to their classroom. 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 have developed a module on the influence of temperature and waves on the life of the seashore in collaboration with my lab.

12. Broader Impacts: The Academic Community

Training: In addition to undergraduates, this grant will train one or more graduate students. I identify my student Brianna Shaughnessy as the initial student, as her research focuses on kelp ecosystem service provision with an eye towards comparing natural reefs and kelp farms.

12.1 A Regional Network of Kelp Forest Researchers: Over the past five years I have built a network of kelp forest researchers in New England. Under my leadership, we conduct annual monitoring using the same protocols (Byrnes et al. 2014b). We meet every June to conduct a two-day meeting where we train new students in the protocols, work on species identification, present posters of our work, and shape new collaborations. Data from this network is the preliminary data shown here in this proposal, and will be used for the observational grounding of experimental results. Further, methods used within our experiments could be deployed by other investigators as groundwork for future collaborative grants. As part of this proposal, I seek funding to continue our annual meetings over the next five years.

12.2 Providing Data to the Community: The data collected by both within the experiment and as a part of regional monitoring will be made public to the community. Experimental work will be made public after publication. Observational data will be made public immediately on completion of quality control at Temperate ReefBase, as we have done for all data collected thus far (http://temperatereefbase.imas.utas.edu.au/portal/search?uuid=a869dfaa-59a7-4d2f-aaa6-47c2dae5741a). Our data sharing policy states that observational data is available 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, and any scientist or NGO involved in the study of temperate rocky reefs.

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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., Humphries, A., Rasher, D., Price, N., and Thornber, C. S. 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 *piecewiseSEM*, *lavaan*, *sem*, and *semTools*- Libraries for the analysis of Structural Equation Models in R http://jslefche.github.io/piecewiseSEM, http://lavaan.org, https://github.com/simsem/semTools/wiki

Deep Sea news http://deepseanews.com - A blog about ocean science for the general public

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.

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				**31,500**	
4. (**4**) UNDERGRADUATE STUDENTS				**25,320**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**61,522**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**223**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**61,745**	
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 **1,750**					
4. OTHER **750**					
TOTAL NUMBER OF PARTICIPANTS (**20**) TOTAL PARTICIPANT COSTS				**2,500**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**14,776**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**12,776**	
TOTAL OTHER DIRECT COSTS				**27,552**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**94,747**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 92247)**					
TOTAL INDIRECT COSTS (F&A)				**48,430**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**143,177**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**143,177**	

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

YEAR 2

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

ORGANIZATION
University of Massachusetts Boston

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Jarrett Byrnes

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Jarrett Byrnes - 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. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**31,500**	
4. (**4**) UNDERGRADUATE STUDENTS				**25,320**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**61,663**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**226**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**61,889**	
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 **1,750**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**20**) TOTAL PARTICIPANT COSTS				**1,750**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**18,482**	
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				**28,958**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**95,547**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 93797)**					
TOTAL INDIRECT COSTS (F&A)				**49,243**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**144,790**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**144,790**	

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

YEAR 3

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	**4,989**	
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. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**31,500**	
4. (**4**) UNDERGRADUATE STUDENTS				**25,320**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**61,809**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**228**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**62,037**	
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 **1,750**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**20**) TOTAL PARTICIPANT COSTS				**1,750**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**16,421**	
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				**26,897**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**93,634**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 91884)**					
TOTAL INDIRECT COSTS (F&A)				**48,239**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**141,873**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**141,873**	

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 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. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**31,500**	
4. (**4**) UNDERGRADUATE STUDENTS				**25,320**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**61,958**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**230**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**62,188**	
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 **1,750**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**20**) TOTAL PARTICIPANT COSTS				**1,750**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**20,575**	
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				**31,051**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**97,939**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 96189)**					
TOTAL INDIRECT COSTS (F&A)				**50,499**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**148,438**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**148,438**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*
Heather Carey

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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. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**31,500**	
4. (**4**) UNDERGRADUATE STUDENTS				**25,320**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**62,112**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**233**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**62,345**	
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 **1,750**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**20**) TOTAL PARTICIPANT COSTS				**1,750**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**17,809**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**11,276**	
TOTAL OTHER DIRECT COSTS				**29,085**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**96,130**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 94380)**					
TOTAL INDIRECT COSTS (F&A)				**49,550**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**145,680**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**145,680**	

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

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. (**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. (**5**) GRADUATE STUDENTS				**157,500**	
4. (**20**) UNDERGRADUATE STUDENTS				**126,600**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**309,064**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**1,140**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**310,204**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**14,750**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **8,750**					
4. OTHER **750**					
TOTAL NUMBER OF PARTICIPANTS (**100**) TOTAL PARTICIPANT COSTS				**9,500**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**88,063**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**55,480**	
TOTAL OTHER DIRECT COSTS				**143,543**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**477,997**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**245,961**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**723,958**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**723,958**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*
Heather Carey

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Date Checked	Date Of Rate Sheet	Initials - ORG

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

Budget and Justification for CAREER: Building New Paradigms in Foundation Species Research by Studying Non-Surface-Canopy Kelps' Influences on Biodiversity and Ecosystem Function

A. Senior Personnel: We request half a month of summer support for PI Byrnes. We request summer and academic year support for a graduate student for the duration of the grant. Graduate students will coordinate the summer removal program in addition to using the removals and observational sampling as a piece of their own dissertation research. This grant will support Byrnes lab student Brianna Shaughnessy who is in her second year at UMB focusing on ecosystem functions provided by on natural versus farmed kelp forests.

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Grad Student Stipend	$31,500.00	$31,500.00	$31,500.00	$31,500.0	$31,500.00
1/2 month for PI Byrnes	$4,702.00	$4,843.00	$4,989.00	$5,138.00	$5,292.00

B. Other Personnel: We request annual support for three summer undergraduates drawing from past UMB UWR students at $7,000 per student. We also request $4,320 (4 hrs/week per student) during the academic year for these students to support data entry and assisting the graduate student in design and testing of method for the following year.

C. Fringe: The fringe rate 34.89% is a negotiated between DHHS and the Commonwealth of Massachusetts. However, 1.99% rate applies to PI for summer compensation. 1.73% applies to the Graduate student stipend in the summer only. Fringe rates includes: General Fringe, Health & Welfare, Medicare, Unemployment Insurance, Universal Health Insurance and Worker's Compensation Insurance.

D. Equipment: N/A

E. Travel – 1) Domestic Travel:

Travel to Academic Meetings: In each year, I request $1,200 for travel for the graduate student and I ($600 airfare each) to national meetings (either the Benthic Ecology Meetings, Western Society of Naturalists, or ESA). I request $1250 for lodging ($250/per night for 5 nights) and $500 for per diem ($100/day for 5 days) at standard UMass Boston rates.

2) International Travel: N/A

F. Participant Support Cost: In order to facilitate local collaborations for observational data collection, I have budgeted participant support cost for annual two day Kelp Ecosystem Ecology Network of New England meetings. I have budgeted for food and lodging costs for ~ 20 at $1,750 per year ($1000 for room reservations and food, and $750 for lodging at 1 night for a 4 person room at $150) with an additional $750 in year one in order to hold the meeting at the Bigelow Labs.

G. Other direct costs:

General Supplies for Dive Operations: To conduct activities in Salem Sound annually, we request $1800 for gas and $800 for oil for our boat based on previous year's use estimates. We request $1000 for gas for our truck. We request $600 for annual field gear replacements.

Given the intense diving activity 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 for tank fills.

Computer Services: We request $1296 per year for Dropbox Business cloud file sharing services to manage data within the Byrnes lab and with students.

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. We have gear for students working in the lab.

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 $800 in year one and for 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. We also request $1500 in year one to add a T-top to the Byrnes lab boat in order to extend its utility later into the fall field season for additional sampling and site cleanup.

Year 1 Removal Setup and Maintenance: We request $100 in years one and three for rebar for site markers and replacements. We request $840 per year for four gallons of marine epoxy for site marking and for attachment of devices for each of the proposed experiments. those years for Z-Spar marine epoxy. We request $320 for 40 marine stainless eyebolts and $40 for flagging and electrical tape. We request $50 in year one for polypro line for site marking and $100 for ten subsurface floats. We request $150 annually for 1000 8" cable ties. We request $330 per year for the duration of the grant for replacement eyebolts, flagging tape, floats, and other maintenance needs. We request $1,180 for 20 Hobo Temperature/Light loggers, and $295 per year for years 2-5 for replacements for any lost or damaged.

Year 2 Video Fish Counts and Consumption Assays: For the experiments for year two, we request the following, including funds for GoPro Hero cameras for video assays.

240' 1/2" Schedule 40 PVC for frames	$120.00
20 GoPro Hero Sessions	$2,960.00
10 LumeCube Mini-strobes for night photos	$1,480.00
100' of Polypro Line for tethers	$100.00
100' of 1/4" Chain for herbivory assays	$149.00
100g powdered agar for herbivory assay	$43.00
Window Screen for agar deployment	$20.00

Year 3 Ecosystem Function Assays: For the experiments for year three, we request the following for flow blocks and sediment traps. The lab already has a collection of decomposition bags.

150 lbs. Dental Plaster for flow blocks	$180.00
240 PVC end caps	$480.00
240' of 3" Schedule 40 PVC	$576.00
240 Cinder blocks	$455.00
480 marine stainless Eyebolts	$720.00
2000 14" Cable ties	$300.00

Year 4 Recruitment Assays: For recruitment assays within the removals in year four, we request the following materials to build SMURFS, ARMs, and deploy other recruitment.

2000 14" Cable ties	$300.00
100 Cinder blocks for SMURF anchors	$189.00
8' x 8' Astroturf	$68.00
240 SOS Tuffy Pads	$400.00
240 synthetic brushes	$1,200.00
100' Nylon Line for SMURF floats	$400.00
300 cinder blocks for ARMs	$567.00
400' 1x1" Green Garden Fencing	$400.00
40 marine stainless eyebolts	$60.00
30 5x11" buoys for SMURFs	$240.00
150' x 4' Black Safety Netting for SMURFs	$75.00
10 x Delta #1000 1/16" 8 ft. deep Stock Knotless Nylon Netting for Binke nets	$100.00
15' of 3/8" Tygon Tubing	$450.00
100' of Polypro Line	$100.00
15 2x100' Rolls of Lobster Mesh for ARMS	$2,415.00

Year 5 Habitat Manipulations: For the habitat manipulations, I request the following for supplies.

600' of 1" Schedule 40 PVC for frames	$2,673.00
1000' of Polypro Line as habitat	$1,000.00
700' of 5/16" Galvanized Chain @ 30/100' for weight	$525.00

H. Indirect Rate is 52.5%: F&A Rate of 52.5% is negotiated between DHHS and the university.

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: Building New Paradigms in Foundation Species Research by Studying Non-Surface-Canopy Kelps' Influences on Biodiversity and Ecosystem Function

Source of Support: NSF

Total Award Amount: $ 723,958 Total Award Period Covered: 04/01/19 - 03/31/24

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: Citizen Science to understand thirty years of change in Global Kelp by expanding the satellite zooinverse

Source of Support: National Areo and Space Aministration

Total Award Amount: $ 789,577 Total Award Period Covered: 09/01/18 - 08/31/20

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: Keeping up with Kelp

Source of Support: National Geographic Society

Total Award Amount: $ 50,000 Total Award Period Covered: 10/01/18 - 09/30/19

Location of Project: University of Massachusetts Boston

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

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

Project/Proposal Title: LTER-PLum Island Ecosystems: Dynamics of Coastal ecosystems in a region of rapid climate change, sea-level rise, and human impacts

Source of Support: Mass Biologica Labs (MBL) LTER NSF

Total Award Amount: $ 363,520 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 Sumr: 0.00

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

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

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

*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 for CAREER: Building New Paradigms in Foundation Species Research by Studying Non-Surface-Canopy Kelps' Influences on Biodiversity and Ecosystem Function

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 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.

Dive Gear Servicing and Maintenance: For the past five years, we have worked closely with two diver operations to fill tanks and service our gear. United Divers in Somerville, MA, has a long-standing relationship with the UMB dive program, supplies discounted rentals for students, and tank fills. Closer to Salem, we work with Undersea Divers primarily for tank fills and other service needs.

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.

Cat Cove Marine Lab: For sampling in Salem Sound, PI Byrnes work out of Salem State's Cat Cove Marine Lab. UMB has a signed 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 since 2013.

Shoals Marine Lab: For sampling at Appledore Island for observational surveys, 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, with his teaching time supporting research by his lab at the island, hence requiring no additional budget.

Collaborators: Collaborators listed in the project proposal all conduct kelp forest observational studies as part of their own work. Collaborators all work primarily in the subtidal, and labs at URI, Bigelow, Northeastern, and UNH all have dive facilities, gear for dive teams of four, capacity to fill tanks or nearby

dive shops. With the exception of Northeastern, labs also have access to one to three small boats used for sampling. All sampling at Northeastern is done via shore dives from their Marine Science Center.

Data Management Plan for CAREER: Building New Paradigms in Foundation Species Research by Studying Non-Surface-Canopy Kelps' Influences on Biodiversity and Ecosystem Function

Data Policy Compliance

The project investigators will comply with the data management and dissemination policies described in the NSF *Proposal & Award Policies & Procedures Guide* (PAPPG, Chapter II.C.2.j) 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 (BCO-DMO). 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.

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 multimedia video data and temperature and light measurements. 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 and light logger CSV data from the experiments. 3) Additional camera, sample device (e.g., flow blocks), and sub-experimental deployment records. 4) Digital video files from GoPro observations which will be archived with the BCO-DMO with relevant links provided as a CSV for future researchers. 5) Records of observations from post-processing each of the different sample connection methods, all recorded in CSV format.

Data and Metadata Formats and Standards

All field 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 archived. Data from benthic temperature loggers will be downloaded immediately following logger recovery and archived using cloud data sharing services. Data will be entered using Excel with standardized templates for each experiment using imposed data validation to minimize data entry error. Data will be quality control-checked using read-back methodology. Video data will be immediately downloaded to an external hard-drive and archived using a business account for cloud file sharing using Dropbox. Long-term archiving of video will be done in collaboration with the BCO-DMO at the appropriate repository. PI Byrnes will maintain CSV records for video access archived along with data files of processed results from video together in order to link recorded data to original observations.

As data entry templates are generated, PI Byrnes will generate metadata using the ISO19115 compliant Marine Community Profile 2.0 metadata schema (https://marinemetadata.org/references/marineprofile19115) via a user interface provided by TemperateReefBase (http://temperatereefbase.imas.utas.edu.au/) as well as the Ecological Meta-Language using the R OpenSci EML interface (https://github.com/ropensci/EML). All CSV and metadata records for all projects will be managed in a single project on GitHub with relevant file structure.

Data Storage and Access During the Project

The project team 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 from collaborators will be sent to the Byrnes lab upon

completion of each site for immediate redundancy and backed up in Dropbox. Once each collaborator 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 to the scientific community via a public Github archive (https://github.com/kelpecosystems/observational_data). This data is available under CC-BY attribution for immediate use. Experimental data and code for analysis will be made publically available upon publication of results or two years from the termination of this grant and will be stored until release on a private GitHub repository.

Data Sharing Policies: Broadly, PI Byrnes is interested in open and transparent data sharing while ensuring that proper credit. Data sharing policies are as follows for this project:
1) Experimental manipulation data is private until publication or two years after the completion of this grant.
2) Observational data is public as soon as quality controlled. Inividual data sets from collaborating labs will be made citable (and are offered via a Creative Commons-By license. This ensures contributors 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: PI Byrnes was one of the co-PIs on the grant aiding in the creation of TemperateReefBase (http://temperatereefbase.imas.utas.edu.au/), a data warehouse funded by the Australian Integrated Marine Observing System (IMOS). He did so as the coordinator of The Kelp Ecosystem Ecology Network. After deposition with TRB and automated metadata generation, PI Byrnes 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
PI Byrnes will ensure that the original 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. PI Byrnes 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
For data from the Byrnes lab, PI Byrnes is ultimately responsible for all data archiving, quality control, management, and archiving as laid out in the DMP. For observational data coming from KEEN ONE affiliated labs, PI Byrnes has provided lab heads with data management plans, data entry templates, chain of custody logs, and data archival compliant with the DMP. They are responsible for management of their initial raw data sets and send quality-controlled data to PI Byrnes as soon as they are complete. For long-term archiving, the PI with work with the BCO-DMO, TRB, and OBIS to ensure proper data deposition and access.

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July 16, 2018

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 is a tenure-track member in Biology in his final pre-tenure year. He is submitting this one CAREER proposal and is eligible for this NSF program. His proposed research and educational activities work in parallel and are extremely well integrated into the educational and research missions of UMB – indeed the Underwater Research Methods (URM) course that he developed is a wonderful example of this. The Department is taking an active role to ensure that he is balancing his efforts appropriately to remain on track for his tenure evaluation in the future. Indeed, he received high marks on his fourth year review, and we look forward to reviewing his tenure packet this fall. We have every confidence in his future here at UMB. Below, I will demonstrate the strong commitment that we have for Dr. Byrnes and the wonderful success he is having with his program.

As background, UMB is a major and expanding (currently at 17,000 students) urban, public university in New England. We are a majority minority campus and 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, economic and educational backgrounds, and military service. Many of our students come from working class backgrounds with no previous college education in their families. Many students are attracted to the biological sciences and our majors have increased by more than 50% in the last 5 years to now include 10% of all majors on the campus. Our mission and "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 experiences that will make them marketable to graduate programs or to private businesses with science based careers.

We are constantly interested in expanding the opportunities and success of our students and Dr. Byrnes' proposed integration of research and teaching fits wonderfully into this plan. He has been an active participant in our teaching initiatives aimed at improving the success of all undergraduates and graduates, particularly those from groups under-represented in the sciences with little knowledge or experience in this discipline. He exposes our diverse student body to unique, "life changing," educational opportunities and access to marine, coastal and subtidal research, fields traditionally lacking socio-economic diversity among its participants. He has created several new courses, taught both undergraduates and graduate students, and is actively supporting 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. One of his

new courses is upper level Marine Ecology course for majors that includes a field component. Another is his Biological Data Analysis graduate course. The word has spread on this course and based on registration it now stands as the most popular graduate course in the fall line-up. He has also developed the exciting URM field course that gets students in the water and conducting research. This course is still growing, as he and the Dive Safety Officer he recruited find the right approach for our students. In his proposal, his integration of active field research into the course will fundamentally change the experience of our students. Moreover, incorporating those students into active research after the course for honors theses is a unique opportunity, and will give these students an edge as they move forward in their careers in marine science. I have no doubt this will succeed given his current track record; his mentored students have already entered graduate programs at other universities or found jobs as research technicians.

Dr. Byrnes' career goals and job responsibilities are to develop a sustained and nationally recognized research program and it is clear that his program is beginning to flourish. 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 the Kelp Ecosystem Ecology Network (KEEN) meetings he organizes at UMB and other institutions, 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 will positively affect our own students as well as researchers across his discipline. 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 and graduate student support and start-up funding to his program; he has also been successful procuring additional funds from SeaGrant and NASA for his kelp forest research. We have assigned Dr. Rob Stevenson, a professor within our department with overlapping interests in community ecology to be his direct mentor. We will institutionalize and support the innovative field experiences that Dr. Byrnes has brought to his new courses and hope to attract a strong cohort of motivated young scientists to his URM course with the aim of stimulating their interests into research fields in environmental biology and ecology. We will continue to support Dr. Byrnes' 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 well 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. I urge you to consider supporting this dynamic young investigator and his proposal.

Best wishes, Rick Kesseli
Rick Kesseli, Professor and Chair

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July 18, 2018

To the Review Committee:

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Building New Paradigms in Foundation Species Research by Studying Non-Surface Canopy Kelps' Influences on Biodiversity and Ecosystem Function" 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.

Please let me know if you have any questions.

Sincerely,

Brian White, Ph.D.

Northeastern

July 18, 2018

RE: Letter of Support for Dr. Jarrett Byrnes' CAREER proposal

To Whom It May Concern:

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Building New Paradigms in Foundation Species Research by Studying Non-Surface Canopy Kelps' Influences on Biodiversity and Ecosystem Function" 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,

Jonathan H. Grabowski, Ph.D.
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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 18, 2018

Dear Sir/Madam:

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Building New Paradigms in Foundation Species Research by Studying Non-Surface Canopy Kelps' Influences on Biodiversity and Ecosystem Function" 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,

Austin Humphries
Assistant Professor

THE
UNIVERSITY
OF RHODE ISLAND

THINK BIG WE DO

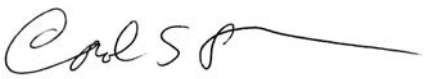
COLLEGE OF THE ENVIRONMENT AND LIFE SCIENCES

July 20, 2018

Dear NSF CAREER Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Building New Paradigms in Foundation Species Research by Studying Non-Surface Canopy Kelps' Influences on Biodiversity and Ecosystem Function" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description and the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,



Dr. Carol Thornber
Professor, Dept. of Natural Resources Science
Associate Dean for Research, CELS
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University of New Hampshire

Center for Coastal and
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F: 603.862.0839
TTY: 7.1.1 (Relay NH)

www.ccom.unh.edu

07.20.2018

Dear NSF Panel,

If the proposal submitted by Dr. Jarrett Byrnes entitled "CAREER: Building New Paradigms in Foundation Species Research by Studying Non-Surface Canopy Kelps' Influences on Biodiversity and Ecosystem Function" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description and the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

Jennifer Dijkstra

Jenn Dijkstra, PhD
Research Assistant Professor
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Bigelow | Laboratory for Ocean Sciences

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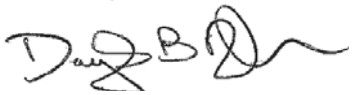
July 18, 2018

Dear NSF CAREER Grant Selection Committee,

If the proposal submitted by Dr. Jarrett Byrnes entitled "*CAREER: Building New Paradigms in Foundation Species Research by Studying Non-Surface Canopy Kelps' Influences on Biodiversity and Ecosystem Function*" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description and the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,



Douglas B. Rasher, Ph.D.
Senior Research Scientist
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