02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS

Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.C.a. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Jarrett Byrnes

Gender: ☐ Male ☐ Female

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

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

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

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

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

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

Ethnicity Definition:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

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

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 14-1

NSF 14-532 **07/23/14**

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

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
				808008122	

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

043167352

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

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

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

University of Massachusetts Boston

AWARDEE ORGANIZATION CODE (IF KNOWN)

0022228000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

University of Massachusetts Boston
100 Morrissey Boulevard
Dorchester, MA. 021253300

NAME OF PRIMARY PLACE OF PERF

University of Massachusetts Boston

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

University of Massachusetts Boston
100 Morrissey Blvd
Boston ,MA ,021253300 ,US.

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

☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **CAREER: Foundation Species and Biodiversity as Drivers of Ecosystem Multifunctionality in Temperate Rocky Reef Ecosystems**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **858,160**	**60** months	**02/01/15**	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

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

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

☒ COLLABORATIVE STATUS
Not a collaborative proposal

PI/PD DEPARTMENT
Biology Department

PI/PD POSTAL ADDRESS
100 Morrissey Blvd.

Boston, MA 02125
United States

PI/PD FAX NUMBER
805-892-2501

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **Jarrett Byrnes**	**PhD**	**2008**	**401-529-4104**	**jarrett.byrnes@umb.edu**
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,Part I: the Grant Proposal Guide (GPG). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

Certification Regarding Conflict of Interest

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

Drug Free Work Place Certification

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

Debarment and Suspension Certification

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

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

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

Certification Regarding Lobbying

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

Certification for Contracts, Grants, Loans and Cooperative Agreements

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

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

Certification Regarding Nondiscrimination

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

Certification Regarding Flood Hazard Insurance

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

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

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

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

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

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

Certification Regarding Federal Tax Obligations

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

Certification Regarding Unpaid Federal Tax Liability

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

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

Certification Regarding Criminal Convictions

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

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

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME		

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER

PROJECT SUMMARY

Overview:

As science grapples with the effects of global change in ocean ecosystems, we have only begun to understand its impacts for ecosystem function. Changes to the environment can lead to a cascade of indirect effects in biological communities that ultimately shift multiple ecosystem functions - so called ecosystem multifunctionality. This project seeks to use experimental removals and observational studies to examine the indirect nonlinear links between the environment and multifunctionality in the Gulf of Maine. It does so by looking at how multifunctionality is affected by changes in foundation species, such as kelps, and the biodiversity of communities shaped by those foundation species. It will also train undergraduates in the techniques of underwater research as part of the work and to give them a greater connection to life in the ocean.

Intellectual Merit :

This project seeks to broaden our understanding of the cascading consequences of changes in the environment for multiple ecosystem functions (multifunctionality) while opening new theoretical ground in the study of drivers of ecosystem multifunctionality. Our current understanding is centered on the consequences of changes in biodiversity. Biodiversity change can alter multiple functions simultaneously. But biodiversity is driven by many phenomena, which could themselves alter ecosystem multifunctionality. Our understanding of shifts in multifunctionality is limited by not considering the direct and synergistic effects of these drivers. For example, we know that environmental change alters the abundances of keystone species that facilitate biodiversity and food web structure. However, we do not know 1) the strength of indirect interactions leading from shifts in the environment through changes in biodiversity to ecosystem multifunctionality, 2) whether experimental links between biodiversity and ecosystem multifunctionality scale to natural systems, 3) whether shifts in key foundation species alter multifunctionality independently, and 4) whether changes in biodiversity and foundation species synergistically alter ecosystem multifunctionality. This project will test these ideas using a combined observational and manipulative approach.

Broader Impacts :

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

Last, as part of this project, PI Byrnes will offer a course in Structural Equation Modeling, a powerful method of teasing apart networks of indirect effects, at UMB for any interested researchers and graduate students around the world. To date, he has taught over 150 students in the technique. He will also continue development of analytic techniques for multifunctionality for the proposed research. With these tools, scientists will be able to tackle a new field of problems in global change biology and marine ecology.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG 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: Foundation Species and Biodiversity as Drivers of Ecosystem Multifunctionality in Temperate Rocky Reef Ecosystems

1. Career Context Statement

1.1. Career Goals: My research and teaching focus on the effects of global change in subtidal ecosystems. This proposal will allow me to build a strong foundation for the next decade of this work. *This proposal will enable me to ground my current and future work in a dynamic human-altered marine ecosystem while developing frameworks for analyses of complex ecosystem change.* In my lab, we explore how the effects of global change cascade from marine organisms, populations, communities, and ultimately to ecosystem functions and services (Fig. 1). I have spent the past several years developing new methodological approaches to analyze these changes in ecological systems. I have developed new methods for the analysis of simultaneous change in multiple ecosystem functions (Byrnes et al. 2014) implemented in the R *multifunc* package. I am a leader in promoting the use of Structural Equation Modeling, a method of analyzing causal hypotheses about complex systems, in Ecology. I am a co-developer on two SEM packages in R, *sem* and *lavaan*, and I have taught SEM to roughly 150 students around the globe. As a former LTER postdoc, I recognize the importance of applying these ideas at large scales with an eye towards local natural history.

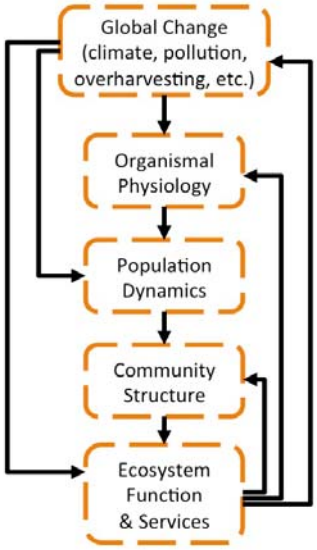

Figure 1 Conceptual framework of my research program.

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 is right on the water. However, most of our students have little experience with the sea around them. Even fewer have seen life on the seafloor firsthand. If funded, this proposal will expand students' horizons and give them first-hand experience of life in the sea. My work will connect UMB students to the biological richness of the subtidal Gulf of Maine. I have already begun to lay the necessary groundwork to involve students by developing a SCUBA-oriented subtidal research capability at UMB and creating a formal dive-safety board and AAUS compliant safety handbook. Currently, I am working with administrators to create a path for students from dive certification to participating in underwater research.

1.3. Project Overview & Connection to Career Development: The central objective of this project is to understand how foundation species abundance and biodiversity jointly affect ecosystem multifunctionality in the subtidal Gulf of Maine. It will do so via structured surveys of community structure and multifunctionality as well as manipulative experiments. It will blend a variety of tools to analyze complex ecological systems, providing a template for other researchers. Most importantly, the project will occur in the context of an understudied ecosystem from the perspective of community ecology – the nearshore subtidal of the Gulf of Maine – and do so by getting undergraduates into the water. It will enable me to establish a career-long connection to this vital ecosystem both in my research and teaching.

2. Introduction & Motivation for Work

At first glance, understanding the impacts of global change in the ocean requires thinking about a large system of many moving pieces. For many, this complexity is a non-starter. There's too much – too many different ecosystem processes influenced by too many different pathways. Thinking about complex often indirect processes within ecosystems can lead down rabbit holes of incorrect inferences when researchers ignore natural history (Foster et al. 2006, Steele et al. 2006). Clearly, we need theory and research frameworks that let us understand ecosystem change holistically while incorporating mechanistic insights from local natural history. Research in the fields of *Biodiversity Ecosystem Function* (Naeem et al. 1995, Loreau 1998, Loreau et al. 2001, Hooper et al. 2005, Spehn et al. 2005, Balvanera et al. 2006, Cardinale et al. 2006, Stachowicz et al. 2007, Naeem 2012, Hooper et al. 2012, Cardinale et al. 2012), a growing interest in characterizing *Ecosystem Multifunctionality* (Duffy et al. 2003, Hector and Bagchi 2007, Zavaleta et al. 2010, Byrnes et al. 2014), and the increasing modeling of complex ecological systems with *Structural Equation Modeling* show a way forward.

Bringing these frameworks together will help us move beyond the driver-response thinking that characterizes much of global change biology today. We can develop a richer holistic framework to understand large-scale simultaneous shifts in ecosystem structure and function. There is nowhere better for this research than in systems experiencing heavy human impacts and possessing substantial biological variation.

Here I propose to evaluate the joint influences of foundation species and biodiversity on ecosystem multifunctionality on subtidal rocky reefs in the Gulf of Maine.

Conceptually, I propose a general model where ecosystem multifunctionality is synergistically determined by foundation species abundance and biodiversity; however, foundation species also determines species diversity. Thus, I propose that high ecosystem multifunctionality only occurs at high levels of the foundation species and biodiversity (Fig. 2). Ultimately, the levels of both are then linked back to the state of the abiotic environment around them.

2.1. Theoretical Framework Underpinning Drivers of Ecosystem Multifunctionality: The emerging field of Ecosystem Multifunctionality explores the drivers of simultaneous change in multiple ecosystem functions. It allows us to examine systemic change rather than focusing on a single indicator. The concept of ecosystem multifunctionality arose as biodiversity ecosystem function researchers began measuring the effects of changing diversity on progressively more – sometimes correlated – functions (Duffy et al. 2003, Hector and Bagchi 2007, He:2009wa Zavaleta et al. 2010). Developing a generalized way to understand these system-wide shifts proved elusive until recently (Byrnes et al. 2014). Given how many different global change drivers can cause simultaneous shifts in multiple ecosystem functions (Deegan et al. 2012), this framework has the potential for a wide variety of applications. We have only begun to understand its potential in global change research.

Taking the concept of multifunctionality beyond BEF research opens up new areas of ecological theory. BEF has shown that, due to resource use complementarity (Loreau and Hector 2001, Petchey 2003, Burkepile and Hay 2008, Vanelslander et al. 2009, Poisot et al. 2013), synergistic facilitation (Stachowicz and Whitlatch 2005), or the probability of including a dominant species in a diverse assemblage (Loreau and Hector 2001, Fox 2005, Bruno et al. 2006, Jiang 2007, Boyer et al. 2009), diversity increases many different ecosystem functions (Loreau et al. 2001, Hooper et al. 2005, Balvanera et al. 2006, Cardinale et al. 2006, Worm et al. 2006,

Cardinale et al. 2011, 2012). However ,these effects can all be modified by food web structure, another aspect of ecosystem biodiversity (Snyder et al. 2006, Finke and Snyder 2008, O'Connor and Byrnes 2013). Thus, any modern investigation of the effects of biodiversity must consider food web structure as a component of biodiversity. Ecosystem multifunctionality appears due to single species each maximizing different functions in mixture (Duffy et al. 2003, Hector and Bagchi 2007, Isbell et al. 2011, Byrnes et al. 2014). But why? Theory suggests that the maximizing the use of one resource in niche-space should correspond to maximizing one function related to that resource (e.g., biomass production Tilman 1999). Thus, anything that increases provision of available niches or efficiency of niche-use should enhance multifunctionality.

Ecological drivers that create or enhance the use of niche-space increase species diversity and food web complexity as well (Menge and Sutherland 1976, Bruno et al. 2003, Schöb et al. 2012, Angelini and Silliman 2014, Altieri and van de Koppel 2014). These drivers have been shown to alter not only species richness, but affect single ecosystem functions as well (Cardinale et al. 2009). . I propose that drivers of diversity and food web structure (hereafter just biodiversity) should interact synergistically with that same diversity to increase ecosystem multifunctionality. Here I target foundation species, a strong driver of diversity (Dayton 1971, Witman 1985, Stachowicz and Byrnes 2006, Bracken et al. 2007, Bishop et al. 2009, Byrnes et al. 2011, Orwig et al. 2013, Angelini and Silliman 2014) whose distribution and abundance are shapes by the environment. I propose a general model of how the environment, foundation species, and biodiversity should jointly influence ecosystem multifunctionality (Fig. 2).

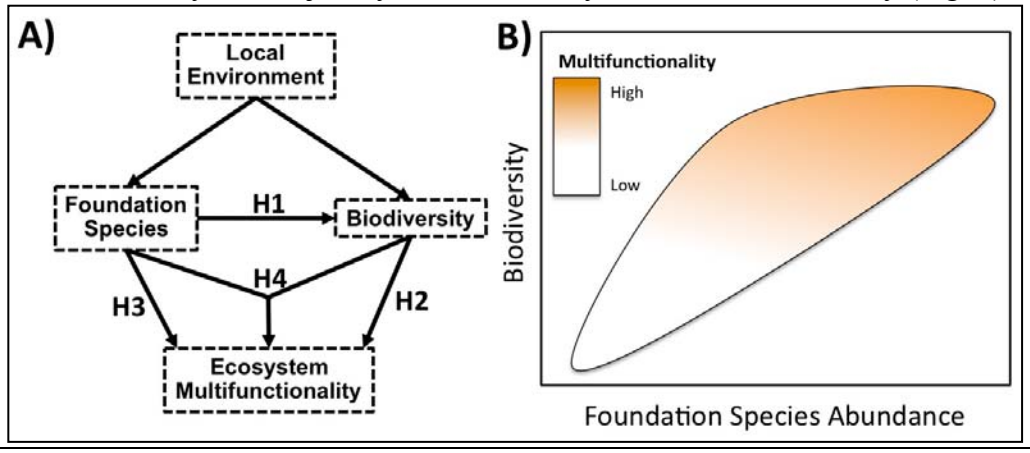

Figure 2: Conceptual model of drivers of multifunctionality. A) Causal diagram showing direct and indirect pathways from the environment, foundation species, and biodiversity to multifunctionality. The joined paths from foundation species and biodiversity indicate an interaction effect. Every link is a separate univariate hypothesis. Specific Hypotheses H1-4 are discussed in section 3. B) The predicted resulting pattern of foundation species abundance, diversity, and multifunctionality. The envelope surrounds the space where values of foundation species abundance and species diversity are predicted to occur. Intensity of color indicates level of multifunctionality (white=low, dark orange=high).

2.2. The Value of Studying Subtidal Communities in the Gulf of Maine: The nearshore subtidal of the Gulf of Maine has witnessed numerous system-wide shifts due to different human activities in the 20th and 21st centuries (reviewed in; Steneck et al. 2013). Yet we still have little idea of what they have meant for ecosystem function. Overfishing of cod and other predatory groundfish led to an increase in urchin abundance and impact in the subtidal (Steneck 1997) for a time. This trophic cascade transformed many areas in the Gulf and Nova Scotia into urchin barrens

dominated by coralline algae (Scheibling 1986, Scheibling et al. 1999, Steneck et al. 2004). Urchin grazing was then reduced by urchin fisheries (Andrew et al. 2002), disease in Nova Scotia (Scheibling and Stephenson 1984, Scheibling and Gagnon 2009, Scheibling and Lauzon-Guay 2010), and consumption of juvenile urchins by small crustaceans (McNaught 1999). At the same time, urchin consumption coupled with the impact of an invasive kelp-covering bryozoan facilitated the invasion of the green alga *Codium fragile;* many areas shifted to *Codium* meadows (Levin et al. 2002, Sumi and Scheibling 2005). Declines in *Codium* have been succeeded by invasive turf species such as *Bonnemaisonia hamifera*, *Neosiphonia harveyi, Heterosiphonia japonica* (Newton et al. 2013). During the same period of time, massive recruitment of mussels, often, but not exclusively, on turfs and bare patches, altered subtidal community dynamics (Witman et al. 2003). Currently, with climate change driven rising ocean temperatures (Balch et al. 2012) increases in average wave heights (Komar and Allan 2008, Young et al. 2011, Bertin et al. 2013), and shifts in species distributions (Pinsky et al. 2013, Hudson and Peros 2013), the Gulf is poised for further changes. The consequences of all of these shifts – past and present – for local scale biodiversity or ecosystem function, however, remain largely unexplored (but see Levin et al. 2002 for one example of little change in diversity due to Codium). *This lack of connection from ecosystem shift to biodiversity to ecosystem functions in the Gulf of Maine is something I will fill with this project.*

3. Specific Objectives & Hypotheses

To understand how foundation species, biodiversity, and the environment affect ecosystem multifunctionality (Fig. 2), I will conduct studies that satisfy two objectives:

3.1. Objective 1) Tease apart how the effect of foundation species are mediated and moderated by biodiversity on ecosystem multifunctionality. To satisfy this objective, I will evaluate ecosystem multifunctionality in sites that differ in environmental conditions, foundation species abundance and composition, and biodiversity. I will use this data to fit Structural Equation Models following the general form of Fig. 2. As I accumulate more data points over time, I will be able to test models that describe the system in increasing levels of detail (see below). Each will be evaluated to test four key hypotheses:

> *H1) Biodiversity is determined by foundation species.*
> *H2) Biodiversity influences ecosystem multifunctionality.*
> *H3) Foundation species influences ecosystem multifunctionality.*
> *H4) Biodiversity and foundation species abundance interact to affect ecosystem multifunctionality.*

3.2. Objective 2) Evaluate the relative importance of individual groups of foundation species for biodiversity and ecosystem multifunctionality. The series of models I will fit as part of Objective 1 incorporate increasing amounts of parameters about the foundation species present. But is this detail necessary, or do we only need to understand the ecology of dominant foundation species? To evaluate the relative impact of one versus many foundation species in understanding ecosystem biodiversity and multifunctionality, I will conduct a series of foundation species removal experiments. *Each experiment will test the hypothesis that removal of the individual foundation species in question affects both biodiversity and ecosystem multifunctionality.*

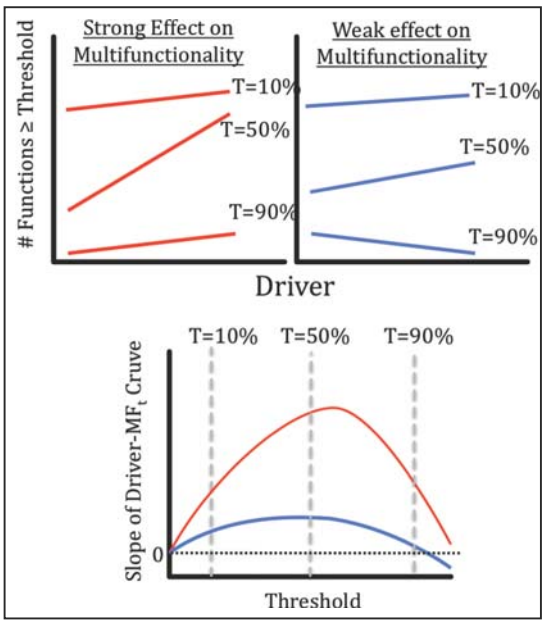

Figure 3 Conceptual representation of analyses of multifunctionality using the multiple threshold approach. See text for description.

4. Assessing Multifunctionality: Analytic Framework

In both of the specific investigations below, I will be using the *multiple threshold approach to multifunctionality* (Byrnes et al. 2014). Briefly, I will begin by assessing the number of functions performing above a threshold (MFt) in a replicate. Then I will model the effect of some driver on MFt. The choice of threshold influences the value of MFt, however (Fig. 3, top two panels). Therefore, I will assess the driver-MFt relationship at all thresholds from 0-100% (Fig. 3, lower panel). The resulting curve describing the slope of the diversity-MFt relationship versus the choice of threshold will show whether the driver has a weak or strong affect on multifunctionality (Fig. 3, red=strong, blue=weak in all panels).

5. Specific Investigations to Address Objectives and Hypotheses

5.1. Objective 1) Tease apart how the effect of foundation species are mediated and moderated by biodiversity on ecosystem multifunctionality

5.1.1. Rationale: Ecosystems with environmental conditions that facilitate foundation species likely have both higher biodiversity and higher ecosystem multifunctionality. My own work in California showed that wave disturbance and rocky substrate both shape the distribution of Giant Kelp, a critical foundation species, as well as species richness and food web structure (Byrnes et al. 2011). I did not look at how these variables affected any functions. In the Gulf of Maine, kelps serve a slightly different role. While many can reach up to 3m in length, they do not form surface canopies. My own data from around Appledore Island, Maine, shows that kelp percent cover appears correlated with species richness at least (n=12, log-log saturating relationship, p=0.049, Fig 4.), although I lack many intermediate kelp abundance values. Kelp is not the only species that plays a role as a foundation species facilitating biodiversity (Witman 1980, Levin et al. 2002), or, potentially, ecosystem multifunctionality.

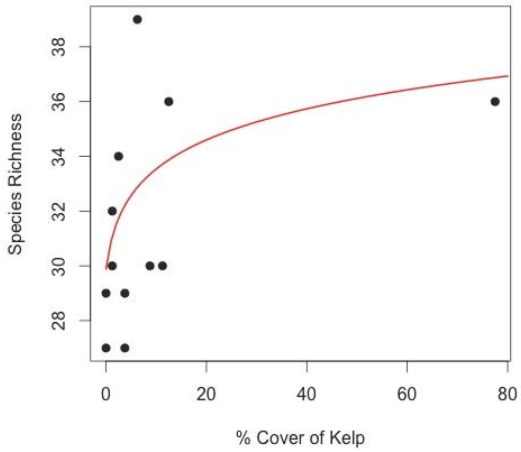

Figure 4 Relationship between percent cover of kelp and total species richness around Appledore Island, Maine, from surveys using the protocol described here in July 2012.

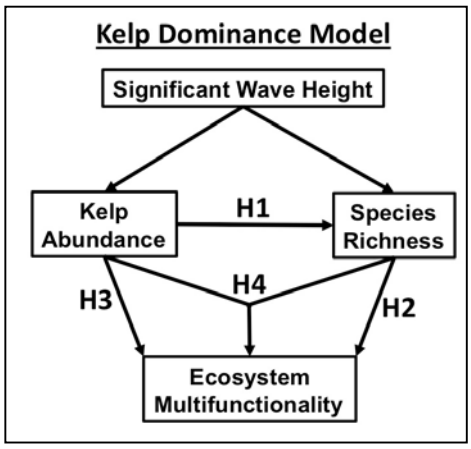

Figure 5 Simple kelp dominance model. Interaction effects are denoted by joined paths.

5.1.2. Models of Foundation Species, Biodiversity, and Multifunctionality: To evaluate the conceptual framework of Fig. 2, I will fit several models with increasing levels of detail. Structural Equation Modeling has a high sample size requirement (~5-10 data points per path). Thus, as this research progresses, I will be able to incorporate more nuance into fit models. The first model (fit after year 1 or 2) evaluates Fig. 2 assuming that kelp is the key foundation species in the system (Fig 5). This kelp dominance model incorporates average wave height as the environmental variable of interest and species richness as the measure of biodiversity. It is the closest linked model to current BEF thinking. Direct tests of H1-H4 are all possible.

The second model incorporates more biological realism (Fig. 6). It adds an additional descriptive variable for the environment – rugosity. It recognizes that turf and foliose algae create additional habitat heterogeneity and niche-space for additional species. Most notably, they increase micrograzer biomass, facilitating higher trophic levels (Davenport and Anderson 2007, O'Gorman et al. 2008). It also incorporates trophic height (i.e., number of trophic levels) as a second metric of biodiversity. Tall versus short food webs may function in fundamentally different ways. Note that while variables fall into categories matching the model in Fig. 2, paths from each variable represent different sub-hypothesis. For example, in this model, I can now test three subhypotheses: that species richness and/or trophic height affect multifunctionality (H2a&b), that different types of foundation species affect multifunctionality (H3a&b), and that multiple metrics of biodiversity interact with kelp abundance (H4a&b).

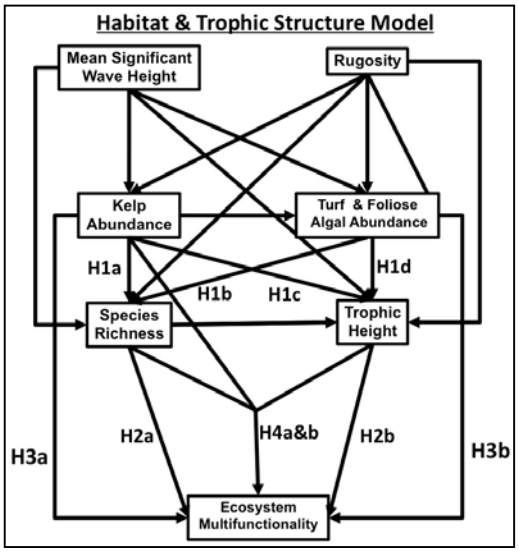

Figure 6. Adding complexity with the habitat and trophic structure model. Interaction effects are denoted by joined paths.

Last, I will test a more holistic model that matches the theoretical framework of this proposal, seeking to look at the abundance of different classes of foundation species and different aspects of biodiversity as indicators of underlying conceptual latent variables (Fig. 7). This model allows for a more general test of theory rather than a specific test of how one single ecosystem works (Grace and Bollen 2008). Given the indicators required, this model incorporates the most detail about the system, and thus the most data.

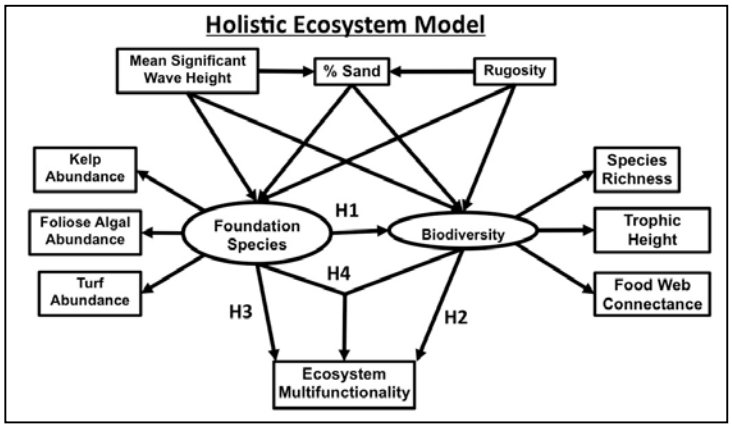

Figure 7: A model that matches theory explicitly - the holistic ecosystem model. Interaction effects are denoted by joined paths.

5.1.3 Methods to Evaluate Models: To acquire data to test these models, I will perform annual surveys and multifunctional assays of sites in the southern Gulf of Maine. As I collect increasing amounts of survey data, I will be able to fit models with increased levels of detail. I will survey temperate rocky reefs between 8-12m at the Isles of Shoals, Salem Sound, Boston Harbor, and with my class, offshore of Scituate (Fig. 8). At each location, I will set up a number of transects split among sites, defined as areas of <1km sharing similar environmental conditions, with 4 transects per site. *I am already sampling biodiversity at all locations save Scituate and will have two years of biodiversity data by project initiation. Complete sampling for biodiversity alone takes ~3 weeks, with an anticipated extra week for adding the multifunctional assays.*

To measure foundation species abundance and ecosystem biodiversity, I will use methods I have developed for the International Kelp Ecosystem Ecology Network (http://kelpecosystems.org) adapted from the SBC-LTER, the Partnership for Interdisciplinary Study for Coastal Oceans, and the Tasmanian Marine Protected Area program. Transects within sites consist of 40m x 2m areas sampled by divers on SCUBA. Along each transect, abundances of all large fish and large mobile invertebrates are sampled in four 20m x 1m swaths. Individual sessile algae, sessile invertebrates, and small mobile fish and invertebrates are sampled in 6 evenly spaced 1m^2 quadrats. Ten individuals of all kelps spaced evenly along transects are sampled for blade length and width and stipe length so that their abundance can be translated to biomass using standard equations. Last, colonial invertebrates and space-filling algae are sampled using 40 uniform point contacts along the transect (n=80 over both sides). All species under a point are counted, such that total transect cover may be >100% due to layering of species. This protocol typically takes 3-4 divers one dive per transect, depending on kelp density. Food web metrics, such as connectance or trophic height, will be derived for each transect (by determining the transect-level food web) based on a master food web my lab is currently building for the nearshore Gulf of Maine using methods described in Byrnes et al. 2011.

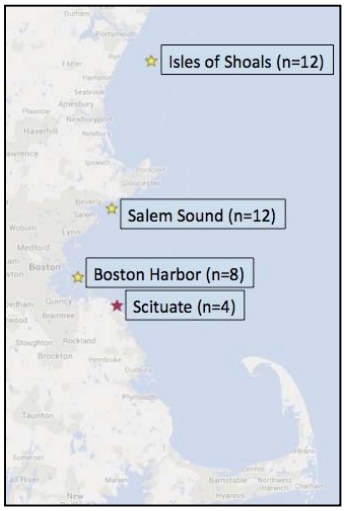

Figure 8. Sites sampled. Yellow stars will be sampled by my lab. The red star will be sampled by students in the underwater research course.

I will measure several environmental variables. At the site level, I will assess mean significant wave height over the course of a year. My lab has spent the past year developing inexpensive Arduino-based wave height sensors that we are currently testing in a controlled wave tank and then deploying alongside a Seabird wave pressure sensor. Our sensors allow for rapid deployment of redundant sensors and easy repairs. We will deploy two sensors at each site for one year, burst sampling for half an hour four times a day to assess daily mean significant

wave height. In case of sensor failure, I will model the relationship between sensor wave heights and wave heights as measured at the nearest buoy to extrapolate missing data. Substrate types (e.g., % sand cover) will be assessed in point counts. For rugosity, at each transect I will place a 1m chain along the reef every 10m perpendicular to the transect, making sure it is snug in all cracks and crevices. I will then assess the horizontal distance of the chain (e.g., a highly rugose habitat might have a horizontal distance of only 0.5m) and take the average of all four chains.

To assess multifunctionality, I will measure a suite of eleven functions that fall into four categories. All assays can be setup during a single dive, and then recovered and measured during one to two subsequent dives. The assays are as follows:

Type	Function	Measurement
Production	Algal Biomass	Biomass derived from calibrated model of % cover and grams carbon as in Harrer et al. 2013
	Micrograzer Mass	Mass of dried and weighed micrograzers from five 100cm^2 scrapped plots
Decomposition	Detrital Kelp Decomposition	Mass of five dried and pre-weighed pieces of kelp in a fine decomposition bag after one week
	Detrital Animal Decomposition	Mass of five dried and pre-weighed dead crabs in a fine decomposition bag after one week
	Beach Decomposition	Mass of dried and pre-weighed algae from 100cm^2 plots left on a beach in a decomposition bag after two weeks
Energy Flow	Herbivory	% change of 10cm x 1cm kelp pieces after 24 hours
	Predation on Macroherbivores	Mortality of ten <10cm urchins in closed v. open pens over 24 hours
	Predation on Crustaceans	Mortality of five tethered v. caged crabs over 24 hours
	Predation of Undefended Prey	Number of missing pieces of twenty tethered 5 x 5cm dried squid pieces after 24 hours
Environmental Modification	Change in flow	Difference in mass change in six gypsum blocks in 1m radius cleared v. uncleared areas over one week
	Sedimentation	Difference in dried mass of sediment accumulated in dishes after one week in cleared v. uncleared areas

5.1.4. Analyses to Evaluate Models & Hypothesis: To evaluate the models in 5.1.2, I will use the data to fit corresponding Structural Equation Models (Bollen 1989, Grace 2006). Given the sample size requirements for SEM, I will be able to fit the kelp-richness model after year 1 of the project (6 free coefficients, 34 data points). I will have a sufficient sample size for the multiple foundation species – food web structure model after year 3. I will have sufficient data for the holistic ecosystem model by after the last data is taken in year five. All models can be developed in year 1, but will only have sufficient power after the relevant data has been collected. Previous model fits can also be updated. All analyses discussed here will apply to each modeling framework.

I will use equation-level SEM (Grace et al. 2012), as this will give me the flexibility to fit generalized linear mixed model (i.e., models with nonlinear functional forms and non-normal error terms) where necessary for particular responses (Shipley 2009). Latent variables will be incorporated into the model via factor scores for each individual latent variable. For each modeling framework, I begin by fitting the full model with multifunctionality calculated using the number of functions ≥ a threshold of 50%. This will enable me to test whether a given full

model is sufficient or missing any paths (e.g., direct effects of the environment on multifunctionality) using Shipley's D-Separation test (Shipley 2000, 2009). I will evaluate H1 (or H1a&b) by fitting an alternate model(s) without paths connecting foundation species and metrics of diversity and food web structure. If model fit remains unchanged (again, using the D-Sep test for comparison), I will reject H1.

To test H2-4, the direct drivers of multifunctionality, I will use a multiple threshold approach (Byrnes et al. 2014) applied SEM. First, I will refit each model at all thresholds. I will test them using D-Separation and evaluate if there are certain thresholds where additional paths are missing. Next, I will look at the shapes of the threshold-coefficient curves for the relationship between the summed effect of foundation species and diversity on multifunctionality at different choices of threshold (Fig 9). H2-4 make distinctly different predictions about the shape of the curves. A flat curve rejects all hypotheses. If the curve is the same regardless of foundation species abundance, H2 is supported and H3 and H4 are rejected (Fig. 9a). Similarly, if it is the same regardless of diversity, H3 is supported and H2 and H4 are rejected (Fig. 9b). If the maximum coefficient depends jointly on diversity and foundation species abundance (Fig. 9c), but overall shape and where it crosses the x-axis are the same, H4 is rejected and H2 and H3 are supported. Last, if the shape and intercepts of the curve depends on both diversity and foundation species abundance, H4 is supported (Fig. 9d). In the habitat and trophic structure model, I will evaluate each of hypothesis for separate combinations of different foundation species and biodiversity metrics.

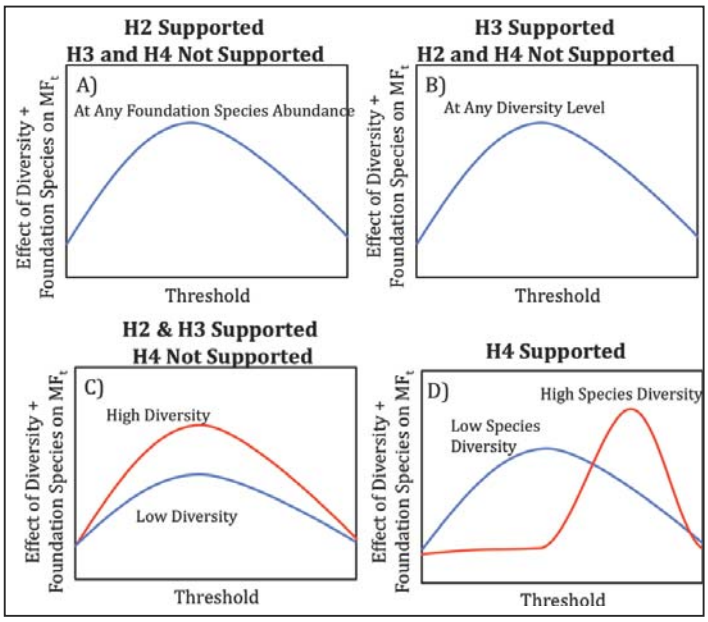

Figure 9: Potential curves showing the relationship between choice of threshold for MFt and the combined effect of diversity and foundation species abundance given different combinations of H2-4.

If answers remain consistent across all three modeling frameworks, then the weight of evidence suggests that the theoretical model in Fig. 2 is general for this system. I will evaluate differences in goodness of fit (R^2) for multifunctionality at all thresholds as a means of inter-model comparison. However, even with this comparison, the modeling frameworks may not be able to be compared directly in terms of utility. For that, I need an experiment to ask what level of detail may be necessary to understand shifts in multifunctionality.

5.2. Objective 2) Evaluate the relative importance of individual groups of foundation species for biodiversity and ecosystem multifunctionality

5.2.1. Rationale: The above investigations provides a detailed exploration of the pathways leading from the environment to ecosystem multifunctionality. But what are the core biological parameters scientists need in order to understand the link between environmental change and

multifunctionality? Does it require a nuanced approach, such as in the holistic ecosystem model? Do we need a detailed understanding of shifts in multiple foundation species? Preliminary large-scale kelp removals (8m radius) conducted by my lab have been able to kick the system into a new state, suggesting a test of the effects of different groups of foundation species.

5.2.2. Hypotheses: I hypothesize that the removal of any group of foundation species will alter ecosystem multifunctionality. However, the removal of kelps will far exceed that of others due to its role in facilitating biodiversity at multiple trophic levels.

5.2.3. Methods to Address Hypothesis: To evaluate this hypothesis, I will perform a manipulative experiment in Salem Sound. In this experiment, I will perform a removal experiment in areas dominated by kelps, other foliose large algae, (primarily *Desmerestia*), or turfs (primarily filamentous red algae). I will compare biodiversity and multifunctionality in removal versus control plots after one year of recovery (Fig. 10). For the experiment, I will select paired 6m x 6m areas that have a dominant cover of the target algal assemblage in question. I will clear removal plots of target species in a 3m radius from the center. This is due to potential 2m edge effects from large kelps or large foliose algae (Bologna and Steneck 1993). The removal will be conducted in June. The removals will be re-treated two months after initial removal. Given the scale and labor required for the removal (particularly of turfs – 1 full dive for 1m radius area in preliminary experiment), I will use temporal blocking so that I have an n=8 after four years. I have identified four sites around Salem Sound that have high degrees of variation in foundation species composition. I plan to conduct one block of the experiment at one site in any given year in order to avoid temporal auto-correlation.

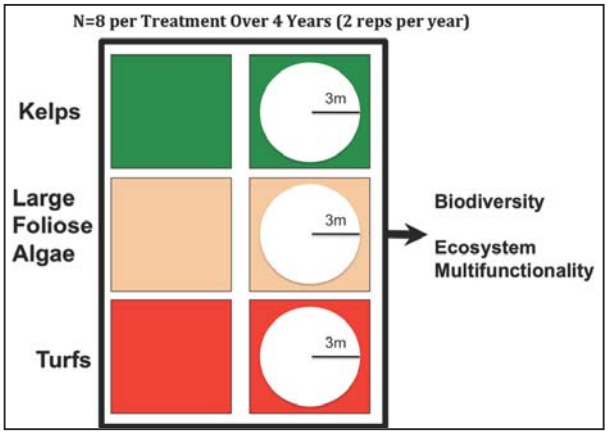

Figure 10. Schematic of experiment for Objective 2.

I will sample the plots for biodiversity and community composition before removal, two months after removal, and one year after removal. To sample plots, I will use four $1m^2$ quadrats centered on the middle of each plot. In each quadrat, I will sample the abundance of large individual algae, sessile, mobile invertebrates, and demersal fish. I will then conduct a uniform point count in each quadrat using a grid of 25 points. Results from quadrats will be summed. As mobile fish and large mobile invertebrates have a range much greater than these plots, I will place a GoPro camera at the center of each plot and record fish visitations for two hours (per plot?) to evaluate large fish visitation diversity and abundance.

I will evaluate ecosystem multifunctionality at the end of the experiment after biodiversity sampling. I will use all of the techniques from Objective 1, dividing the plot into four quadrants for any measurements replicated along Objective transects. Algae removed for secondary production estimates will be from areas created as clearings for flow and sedimentation measurements.

5.2.4. Analyses to Answer Hypothesis: To address the hypothesis that a given group of foundation species affects biodiversity, I will compare the control and removal treatments of each species type using mixed model Analysis of Variance with a fixed effect of treatment and a

random block effect. I will examine each group of foundation species separately, as the treatments and controls were selected to have high cover of the manipulated species. I will apply this analysis to species richness, food web connectance, and trophic height as response variables. I will also examine how loss of one group of foundation species affects the abundances of others, to examine trade-offs and redundancies using the same mixed model analysis.

To examine the importance of each species removal for multifunctionality I will take a two-pronged approach. First, I will perform a multiple threshold analysis using a mixed model with treatment and species richness as fixed effects, and block as a random effect. This will control for the effect of richness on multifunctionality, if there is one. If the curve of the threshold-treatment relationship is flat, then I will reject the hypothesis that the species in question has a direct effect on multifunctionality. If it is not flat, I will be able to compare the shape of the curve between different species to evaluate the differences in each species' net effect on multifunctionality. Given the results from the mixed model ANOVA above, I will also be able to look at the species richness-threshold relationship to evaluate whether there is an indirect path from removal via biodiversity to multifunctionality. The experiment lacks sufficient power, however, to detect an interaction effect. Nor would I be able to discern a clean signal given the nature of the manipulation. Additional environmental drivers of biodiversity are necessary to generate a wider range of variation – hence the added utility of the observational approach for objective 1. Second, after looking at the multiple threshold approach, I will perform separate univariate mixed model ANOVAs on the values for individual functions. This will enable me to evaluate whether removals of different types of foundation species affected particular ecosystem functions more strongly than others.

6. 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), But students, particularly those living in urban New England, have little to no experience of the nearshore subtidal. Despite this habitat being in their very backyard, they have minimal interaction with the riot of life on the seafloor. They likely have no context when asked to make decisions as citizens that could affect local oceans. Experiential education provides unique learning opportunities, particularly in connecting students to the environment (Russell 1997, Andrews and Stocker 2010) Participating in field-based coursework and research centered on the structure and function of local subtidal communities will change how students think about the ocean in their back yard. **Here I propose to develop of an educational program that will get students in the water to develop a new understanding of the ocean around them.**

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

6.1. 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 2010, representative of enrollment over the last several years, had ~11,500 full-time undergraduate

students. 57% were women and 44% were minorities (following the federal definition). 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 2010 were first generation college students. Our commitment to access extends to serving students from lower income brackets as well. Nearly 40% of undergraduates at UMB receive Pell Grants, federal student aid designed to help students in the greatest financial need (typically this number is ~20% at other University of Massachusetts campuses). The Biology department maintains even more impressive statistics. With approximately 1000 majors, 60% are female and 54% are minorities. UMB students have a long history with SCUBA diving. Our SCUBA and snorkeling club was founded in the late 1970s by Ted Maney, who went on to help found the American Academy of Underwater Scientists (AAUS). As of 2010, the UMB dive club had 120 members. This has dropped off in recent years, due to a poor organization. However, I have gotten many student requests to revive it and create an Underwater Research class during my Marine Biology class. Thus, the community is primed and ready for any efforts that get students out and onto the water.

6.2. Approach & Courses Offered: Working with my lab manager and former Northeastern University Dive Safety Officer, Ted Lyman, I plan to create two new courses at UMass Boston. The first will be a basic SCUBA certification course. This course will be part of an ongoing effort to increase offerings practical course offerings by the UMB waterfront. This course will be taught primarily by Lyman, a PADI certified Dive Instructor, in the fall of each year. We have negotiated a 20% discount rate from nearby United Divers to supply rental gear and additional instruction. United has worked with Harvard, Northeastern, MIT, and other universities in the past to create similar programs. This grant will provide additional funds for full rental fees for three underprivileged students. We will use our campus pool for in-water training, and weekend trips to popular local shore dives for certification, including our project site in Scituate (Fig. 8). Unlike standard PADI certification courses, we will include a unit on identification of fish, mobile invertebrates, and the major dominant algae.

In the winter term, Lyman will offer a series of safety courses. He will offer courses in Oxygen administration via D.A.N., diving CPR and first aid, and diver rescue. These courses will be a combination of lecture, hands-on classroom work, and, for rescue, pool training. They will be offered in conjunction with UMB Environmental Health and Safety, who have helped us develop the UMB dive safety program. We will use student activities fees to offset costs to students, as well as offering them to the larger Boston dive community to help fund student participation through our College of Advancing and Professional Studies program.

These courses will prepare students for a full Underwater Research course during the month of June co-taught by Lyman and myself. Lyman has taught a similar course for four years while serving as the Dive Safety Officer at Northeastern University. This course will be offered through the Biology department as part of its summer term. *The specific course goals are as follows*: 1) To acquire an understanding of various scientific techniques, including hypothesis formulation and testing, sampling design, statistical analysis, library research, writing and presentation. 2) To acquire an understanding of commonly applied marine research methodologies. 3) To acquire an understanding of the biology, ecology and physiology of marine organisms. 4) To acquire a deeper understanding of dive physics, physiology, decompression theory and dive planning. 5) To fulfill the national training requirements for scientific diving

according to American Association of Underwater Scientists (AAUS) standards using the NOAA diving handbook as our reference.

The Underwater Research course will cover the basics of underwater safety in research, sampling techniques, experimental design, species identification, underwater sensor deployment, and construction and deployment of manipulative experiments. Classroom work – lecture and open discussion of readings from the primary literature on local subtidal ecology - will occur on campus. Dives will be held both on the cobble beds in nearby Quincy Beach, on the outer Boston Harbor Islands, and rocky reefs in Scituate. Half of gear rental and the trip to the Harbor Islands will be covered by student lab fees. This grant will provide additional funds for full rental fees for three underprivileged students. The flow of the course is as follows:

Week 1 - *Lecture:* Dive safety in the context of research, Research dive planning, Transect Sampling, Invasive crab ecology & impact, Species Identification (Mobile Invertebrates)
Field: Checkout dives at Quincy Beach, Slippershell and crab surveys in Quincy

Week 2 – *Lecture:* Quadrat sampling, Fish Quantification, Experimental Design, Species Identification (Algae and Fish)
Field: Kelp sampling around Boston Harbor Islands, Fish sampling in Quincy, Habitat surveys in Scituate

Week 3 – *Lecture/Discussion:* Statistics intro, Kelp forests and climate change, Invasive algae in New England
Field: Species ID Exam in Scituate, Transect study in Scituate, Start of Project Dives

Week 4 – *Field:* Independent project dives
Discussion: Final Project Presentations

For the final week, students will conduct their own projects in Scituate. They will give a final oral presentation on their topics to the class and invited guests on the final day. Exceptional students will be invited to join the team for summer sampling or removal efforts (see 6.4 and 6.5 below). Upper division students who have completed General Ecology and Marine Biology will be eligible for independent study in the fall towards the fulfillment of an honors thesis.

6.4. Direct Involvement of Students in Research: In the course of the basic SCUBA certification and underwater research courses, we will teach the students the basics of identification of species sampled in the fish, quadrat, and swath survey methods. As part of the Underwater Research course, I will have one unit on counting large mobile animals, such as fish, and have students conduct fish transects of different sizes on four transects in Scituate (Fig. 8). These sites will later be sampled for UPCs. I will follow this up with a lecture comparing and contrasting large swath versus small transect sampling, and have the students do their own comparison by performing the same again on those four transects. Students will also be able to use this, as well as other data we collect over the years, for their final projects. After completion of the course, I will identify one student who performed exceptionally well on the protocols, and hire them to aid in summer sampling and removal experiments. This may be separate than any potential REU (see below). I will also work with interested students after the class is completed to design and implement simple research projects as part of independent study courses for honors theses.

6.4. Assessment: This sequence seeks to enhance knowledge of local natural history, connection to life underwater, and the ability to understand how global change may affect life in nearshore

ecosystems. I will employ three tools to assess whether I am achieving my three goals. First, to assess increase in knowledge of basic natural history, before we begin transect sampling in Scituate, we will administer an 'exam under pressure,' where students are asked to identify species pointed out by an instructor while on a dive. I will employ two instruments to assess goals two and three. First, I will ask students to write short reflective dive-logs after every trip in the water – from pool test to transect sampling. These logs will be compiled into a blog that explores students increased familiarity and understanding of the subtidal world at their doorstep. Next, I will administer a questionnaire before and after each course 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 clear application of biological principles. Last, I will administer a SENCER Student Assessment of Learning Gains (Cook and Mulvihill 2008, Science Education for New Civic Engagements and Responsibilities 2006) survey at the end of each course to assess how well each course addresses these 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.

6.5. REU/RET Opportunities: If funded, I plan to apply for REU support to bring stellar students from the Underwater Research course into my lab as part of our research activities. More than participating as techs, I will train REU students and help them extend their class projects into a research project that they can use for an honors thesis. Similarly, I would like to identify high school and middle school teachers in the Boston area with dive experience who would be interested in auditing the UWR course and then participating as RETs. These teachers would be able to bring their experiences back to their classroom, and I would work with them to develop units on the biology of New England reefs. I have already identified one interested teacher, Juanita Shaffer-Ratzlaff at Dorchester Academy High School, with whom I am developing a course about the influence of temperature and waves on the life of the seashore.

6.6. Current Progress: I have put the wheels in motion to develop this sequence of courses and add subtidal opportunities to UMass Boston. Working with the University, I have created a college level Dive Safety Board. We are developing plans to fund the necessary infrastructure (e.g., equipment and a Dive Safety Officer) that this grant would speed along greatly. We are also exploring developing a formal relationship with the American Academy of Underwater Scientists (AAUS). I have located sites in Scituate for field dive and research training. I am partnering with our waterfront staff to locate sites ideal for student work in the Boston Harbor Islands. The wheels are in motion, but the speed with which we can execute this plan and the number of students we can support will be increased greatly by this grant.

7. Broader Impacts: The Academic Community

7.1. Analyzing Complexity: SEM Course: **As part of this grant, I will run annual January workshops in SEM for 15-20 people.** Structural Equation Modeling is a powerful technique for analyzing complex systems. It is a branch of statistics seldom taught in ocean science or ecology programs. I know, as I have spent the past four years teaching workshops from Sweden to Mexico for interested groups (http://byrneslab.net/teaching/sem) and declined numerous other invitations. To enhance the dissemination of knowledge about SEM, I will teach workshops each January at UMass Boston. These workshops will be widely advertised and open to the entire

academic community. Those having immediate analytical needs will have first priority. I will assess the success of this course by the number of research projects incorporating SEM that result from it. Thus far, I count five papers in the primary that have incorporated analyses either begun or discussed in my workshops (Sorte and Stachowicz 2011, Elahi and Sebens 2012, Alsterberg et al. 2013, Frainer et al. 2014, Stewart et al. 2014) and four more in preparation or review.

7.2. Software Development for Multifunctional Analyses: **As part of this grant, I will continue development of the package to look at multifunctionality in the context of 1) multiple predictors and 2) SEM analyses.** I have spent the past two years developing the *multifunc* package for R in order to analyze simple biodiversity ecosystem multifunctionality experiments (Byrnes et al. 2014). From inquiries on the mailing list, it is already in use to look at mussel abundance in marshes and multifunctionality (Angelini et al. In Review), multifunctionality of pollination, forest conservation, and more. Continued development of the package in the context of the analyses for this grant will broaden the types of questions that we can ask and answer using multifunctionality. Once complete, I will publish an article in the Journal of Statistical Software in order to spread the idea of analysis of multifunctionality to a wider community. The fundamental ideas underlying multifunctionality can be used in any scientific discipline looking to measure multiple functions – from biology to economics. I will assess success of this effort by the number of citations to the package in the primary literature over time.

8. Personnel & Timeline

This proposal will support 75% of a research technician (Lyman) with the rest of the support coming via teaching and Dive Safety Officer activities. It will support one graduate student RA for the duration of the grant. It will provide summer support for one undergraduate field technician. The grant will start in January of 2015. Sampling for objective 1 will take place in July and August. Experimental removals start in June and will be resampled in September.

	Activity	Year 1	Year 2	Year 3	Year 4	Year 5
Research	Sampling for Objective 1	x	x	x	x	x
	Experiment for Objective 2	x	x	x	x	
	Analysis of Kelp Model		x			
	Analysis of Habitat & Food Web Model			x		
	Analysis of Holistic Ecosystem Model					x
	Analysis of Experimental Results				x	
Education	Basic Certification Class	x	x	x	x	x
	Underwater Research Class		x	x	x	x
	SEM Winter Course	x		x		x
	Multifunc Package Development		x			

References

Alsterberg, C., J. S. Eklof, L. Gamfeldt, J. N. Havenhand, and K. Sundback. 2013. Consumers mediate the effects of experimental ocean acidification and warming on primary producers. PNAS 110:8603–8608.

Altieri, A. H., and J. van de Koppel. 2014. Foundation species in marine ecosystems. *in* M. D. Bertness, J. F. Bruno, and J. J. Stachowicz, editors. *Marine Community Ecology and Conservation*. Sinauer Associates Inc.

Andrew, N. L., Y. Agatsuma, E. Ballesteros, A. G. Bazhin, E. P. Creaser, D. Barnes, L. W. Botsford, A. Bradbury, A. Campbell, and J. D. Dixon. 2002. Status and management of world sea urchin fisheries. Oceanogr. Mar. Biol. Annu. Rev 40:343–425.

Andrews, S. B., and L. Stocker. 2010. Underwater photoelicitation: a new experiential marine education technique. Pages 8–22 *in*. Proceedings of the 16th Biennial Australian Association for Environmental Education Conference – Leading Change: Living for One Planet. Canberra, Australian Capital Territory.

Angelini, C., and B. R. Silliman. 2014. Secondary foundation species as drivers of trophic and functional diversity: evidence from a tree–epiphyte system. Ecology 95:185–196.

Balch, W. M., D. T. Drapeau, B. C. Bowler, and T. G. Huntington. 2012. Step-changes in the physical, chemical and biological characteristics of the Gulf of Maine, as documented by the GNATS time series. Marine Ecology Progress Series 450:11–35.

Balvanera, P., A. B. Pfisterer, N. Buchmann, J.-S. He, T. Nakashizuka, D. Raffaelli, and B. Schmid. 2006. Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecology letters 9:1146–1156.

Bertin, X., E. Prouteau, and C. Letetrel. 2013. A significant increase in wave height in the North Atlantic Ocean over the 20th century. Global and Planetary Change 106:77–83.

Bishop, M. J., T. Morgan, M. A. Coleman, B. P. Kelaher, L. K. Hardstaff, and R. W. Evenden. 2009. Facilitation of molluscan assemblages in mangroves by the fucalean alga *Hormosira banksii*. Marine Ecology Progress Series 392:111–122.

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

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

Boyer, K. E., J. S. Kertesz, and J. F. Bruno. 2009. Biodiversity effects on productivity and stability of marine macroalgal communities: the role of environmental context. Oikos 118:1062–1072.

Bracken, M. E. S., C. A. Gonzalez-Dorantes, and J. J. Stachowicz. 2007. Whole-community mutualism: associated invertebrates facilitate a dominant habitat-forming seaweed. Ecology 88:2211–2219.

Bruno, J. F., J. J. Stachowicz, and M. D. Bertness. 2003. Inclusion of facilitation into ecological theory. Trends in Ecology & Evolution 18:119–125.

Bruno, J. F., S. C. Lee, J. S. Kertesz, R. C. Carpenter, Z. T. Long, and J. E. Duffy. 2006. Partitioning the effects of algal species identity and richness on benthic marine primary production. Oikos 115:170–178.

Burkepile, D. E., and M. E. Hay. 2008. Herbivore species richness and feeding complementarity affect community structure and function on a coral reef.

Proceedings of the National Academy of Sciences of the United States of America 105:16201–16206.

Byrnes, J. E. K., L. Gamfeldt, F. Isbell, J. S. Lefcheck, J. N. Griffin, A. Hector, B. J. Cardinale, D. U. Hooper, L. E. Dee, and J. Emmett Duffy. 2014. Investigating the relationship between biodiversity and ecosystem multifunctionality: challenges and solutions. Methods in Ecology and Evolution5 :111-124.

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

Cardinale, B. J., D. M. Bennett, C. E. Nelson, and K. Gross. 2009. Does productivity drive diversity or vice versa? A test of the multivariate productivity-diversity hypothesis in streams. Ecology 90:1227–1241.

Cardinale, B. J., D. S. Srivastava, J. E. Duffy, J. P. Wright, A. L. Downing, M. Sankaran, and C. Jouseau. 2006. Effects of biodiversity on the functioning of trophic groups and ecosystems. Nature 443:989–992.

Cardinale, B. J., J. E. Duffy, A. Gonzalez, D. U. Hooper, C. Perrings, P. Venail, A. Narwani, G. M. Mace, D. Tilman, D. A. Wardle, A. P. Kinzig, G. C. Daily, M. Loreau, J. B. Grace, A. Larigauderie, D. S. Srivastava, and S. Naeem. 2012. Biodiversity loss and its impact on humanity. Nature 486:59–67.

Cardinale, B. J., K. L. Matulich, D. U. Hooper, J. E. Byrnes, E. Duffy, L. Gamfeldt, P. Balvanera, M. I. O'Connor, and A. Gonzalez. 2011. The functional role of producer diversity in ecosystems. American journal of botany 98:572–592.

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

Davenport, A. C., and T. W. Anderson. 2007. Positive indirect effects of reef fishes on kelp performance: The importance of mesograzers. Ecology 88:1548–1561.

Dayton, P. K. 1971. Toward an understanding of community resilience and the potential effects of enrichments to the benthos at McMurdo Sound Antarctica. *in* B. C. Parker, editor. Proceedings of the Colloquium on Conservation Problems in Antarctica. Allen Press.

Deegan, L. A., D. S. Johnson, R. S. Warren, B. J. Peterson, J. W. Fleeger, S. Fagherazzi, and W. M. Wollheim. 2012. Coastal eutrophication as a driver of salt marsh loss. Nature 490:388–392.

Duffy, J. E., J. P. Richardson, and E. A. Canuel. 2003. Grazer diversity effects on ecosystem functioning in seagrass beds. Ecology letters 6:637–645.

Elahi, R., and K. P. Sebens. 2012. Consumers mediate natural variation between prey richness and resource use in a benthic marine community. Marine Ecology Progress Series 452:131–143.

Finke, D. L., and W. E. Snyder. 2008. Niche partitioning increases resource exploitation by diverse communities. Science 321:1488–1490.

Foster, M. S., M. S. Edwards, D. C. Reed, D. R. Schiel, and R. C. Zimmerman. 2006. Top-down vs. bottom-up effects in kelp forests. Science 313:1737–1738.

Fox, J. W. 2005. Interpreting the “selection effect” of biodiversity on ecosystem function. Ecology letters 8:846–856.

Frainer, A., B. G. McKie, and B. Malmqvist. 2014. When does diversity matter? Species

functional diversity and ecosystem functioning across habitats and seasons in a field experiment. Journal of Animal Ecology 83:460–469.

Grace, J. B. 2006. Structural Equation Modeling and Natural Systems. Cambridge University Press.

Grace, J. B., and K. A. Bollen. 2008. Representing general theoretical concepts in structural equation models: the role of composite variables. Environmental and Ecological Statistics 15:191–213.

Grace, J. B., D. R. Schoolmaster Jr., G. R. Guntenspergen, A. M. Little, B. R. Mitchell, K. M. Miller, and E. W. Schweiger. 2012. Guidelines for a graph-theoretic implementation of structural equation modeling. Ecosphere 3:art73.

Hector, A., and R. Bagchi. 2007. Biodiversity and ecosystem multifunctionality. Nature 448:188–190.

Hooper, D. U., E. C. Adair, B. J. Cardinale, J. E. K. Byrnes, B. A. Hungate, K. L. Matulich, A. Gonzalez, J. E. Duffy, L. Gamfeldt, and M. I. O'Connor. 2012. A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature 486:105–108.

Hooper, D. U., F. S. I. Chapin, J. J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J. H. Lawton, D. M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setälä, A. J. Symstad, J. Vandermeer, and D. A. Wardle. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs 75:3–35.

Hudson, M., and J. Peros. 2013. Preparing for Emerging Fisheries: An Overview of Mid-Atlantic Stocks on the Move. gmri.org. Gulf of Maine Research Institute.

Isbell, F., V. Calcagno, A. Hector, J. Connolly, W. S. Harpole, P. B. Reich, M. Scherer-Lorenzen, B. Schmid, D. Tilman, J. van Ruijven, A. Weigelt, B. J. Wilsey, E. S. Zavaleta, and M. Loreau. 2011. High plant diversity is needed to maintain ecosystem services. Nature 477:199–202.

Jiang, L. 2007. Negative selection effects suppress relationships between bacterial diversity and ecosystem functioning. Ecology 88:1075–1085.

Komar, P. D., and J. C. Allan. 2008. Increasing hurricane generated wave heights along the U.S. East Coast and their climate controls. Journal of Coastal Research 242:479–488.

Levin, P. S., J. A. Coyer, R. Petrik, and T. P. Good. 2002. Community-wide effects of nonindigenous species on temperate rocky reefs. Ecology 83:3182–3193.

Loreau, M. 1998. Biodiversity and ecosystem functioning: a mechanistic model. Proceedings of the National Academy of Sciences, USA 95:5632–5636.

Loreau, M., and A. Hector. 2001. Partitioning selection and complementarity in biodiversity experiments. Nature 412:72–76.

Loreau, M., S. Naeem, P. Inchausti, J. Bengtsson, J. P. Grime, A. Hector, D. U. Hooper, M. A. Huston, D. Raffaelli, B. Schmid, D. Tilman, and D. A. Wardle. 2001. Biodiversity and ecosystem functioning: current knowledge and future challenges. Science 294:804–808.

McNaught, D. C. 1999. The indirect effects of macroalgae and micropredation on the post-settlement success of the green sea urchin in Maine. Ph.D. Dissertation. University of Maine.

Menge, B. A., and J. P. Sutherland. 1976. Species diversity gradients: synthesis of the roles of predation, competition, and temporal heterogeneity. American Naturalist

110:351–369.
Naeem, S. 2012. Ecological consequences of declining biodiversity: a biodiversity–ecosystem function (BEF) framework for marine systems. Marine Biodiversity and Ecosystem Functioning: Frameworks, methodologies, and integration:34.
Naeem, S., L. J. Thompson, S. P. Lawler, J. H. Lawton, and R. M. Woodfin. 1995. Empirical-evidence that declining species diversity may alter the performance of terrestrial ecosystems. Philosophical Transactions Of The Royal Society Of London Series B-Biological Sciences 347:249–262.
Newton, C., M. E. S. Bracken, M. McConville, K. Rodrigue, and C. S. Thornber. 2013. Invasion of the Red Seaweed Heterosiphonia japonica Spans Biogeographic Provinces in the Western North Atlantic Ocean. PloS one 8:e62261.
O'Connor, M. I., and J. E. K. Byrnes. 2013. Biodiversity and Ecosystem Function: Does Pattern Influence Process? Pages 109–130 *in* M. D. Bertness, J. F. Bruno, B. R. Silliman, and J. J. Stachowicz, editors. *Marine Community Ecology and Conservation*. Sinauer, Sunderland, MA.
O'Gorman, E. J., R. A. Enright, and M. C. Emmerson. 2008. Predator diversity enhances secondary production and decreases the likelihood of trophic cascades. Oecologia 158:557–567.
Orwig, D. A., A. A. B. Plotkin, E. A. Davidson, H. Lux, K. E. Savage, and A. M. Ellison. 2013. Foundation species loss affects vegetation structure more than ecosystem function in a northeastern USA forest. PeerJ 1:e41.
Petchey, O. L. 2003. Integrating methods that investigate how complementarity influences ecosystem functioning. Oikos 101:323–330.
Pinsky, M. L., B. Worm, M. J. Fogarty, J. L. Sarmiento, and S. A. Levin. 2013. Marine taxa track local climate velocities. Science 341:1239–1242.
Poisot, T., N. Mouquet, and D. Gravel. 2013. Trophic complementarity drives the biodiversity–ecosystem functioning relationship in food webs. Ecology letters 16:853–861.
Russell, C. 1997. Approaches to environmental education. Holistic Education Review 10:34–39.
Scheibling, R. 1986. Increased macroalgal abundance following mass mortalities of sea urchins (*Strongylocentrotus droebachiensis*) along the Atlantic coast of Nova Scotia. Oecologia 68:186–198.
Scheibling, R. E., A. W. Hennigar, and T. Balch. 1999. Destructive grazing, epiphytism, and disease: the dynamics of sea urchin-kelp interactions in Nova Scotia. Canadian Journal of Fisheries and Aquatic Sciences 56:2300–2314.
Scheibling, R. E., and J. S. Lauzon-Guay. 2010. Killer storms: North Atlantic hurricanes and disease outbreaks in sea urchins. Limnology and Oceanography 55:2331–2338.
Scheibling, R. E., and P. Gagnon. 2009. Temperature-mediated outbreak dynamics of the invasive bryozoan Membranipora membranacea in Nova Scotian kelp beds. Marine Ecology Progress Series 390:1–13.
Scheibling, R. E., and R. L. Stephenson. 1984. Mass mortality of *Strongylocentrotus droebachiensis* (Echinodermata: Echinoidea) off Nova Scotia, Canada. Marine Biology 78:153–164.
Schöb, C., B. J. Butterfield, and F. I. Pugnaire. 2012. Foundation species influence trait-based community assembly 196:824–834.

Science Education for New Civic Engagements and Responsibilities. 2006. The SENCER-SALG. http://www.sencer.net/Assessment/sencersalg.cfm. Accessed April 2014

Shipley, B. 2000. A new inferential test for path models based on Directed Acyclic Graphs. Structural Equation Modeling: A Multidisciplinary Journal 7:206–218.

Shipley, B. 2009. Confirmatory path analysis in a generalized multilevel context. Ecology 90:363–368.

Snyder, W. E., G. B. Snyder, D. L. Finke, and C. S. Straub. 2006. Predator biodiversity strengthens herbivore suppression. Ecology letters 9:789–796.

Sorte, C., and J. J. Stachowicz. 2011. Patterns and processes of compositional change in a California epibenthic community. Marine Ecology Progress Series 435:63–74.

Spehn, E. M., A. Hector, J. Joshi, M. Scherer-Lorenzen, B. Schmid, E. Bazeley-White, C. Beierkuhnlein, M. C. Caldeira, M. Diemer, P. G. Dimitrakopoulos, J. A. Finn, H. Freitas, P. S. Giller, J. Good, R. Harris, P. Högberg, K. Huss-Danell, A. Jumpponen, J. Koricheva, P. W. Leadley, M. Loreau, A. Minns, C. P. H. Mulder, G. O'Donovan, S. J. Otway, C. Palmborg, J. S. Pereira, A. B. Pfisterer, A. Prinz, D. J. Read, E. D. Schulze, A. S. Siamantziouras, A. C. Terry, A. Y. Troumbis, F. I. Woodward, S. Yachi, and J. H. Lawton. 2005. Ecosystem effects of biodiversity manipulations in European grasslands. Ecological Monographs 75:37–63.

Stachowicz, J. J., and J. E. Byrnes. 2006. Species diversity, invasion success, and ecosystem functioning: disentangling the influence of resource competition, facilitation, and extrinsic factors. Marine Ecology Progress Series 311:251–262.

Stachowicz, J. J., and R. B. Whitlatch. 2005. Multiple mutualists provide complementary benefits to their seaweed host. Ecology 86:2418–2427.

Stachowicz, J. J., J. F. Bruno, and J. E. Duffy. 2007. Understanding the Effects of Marine Biodiversity on Communities and Ecosystems. Annual Review of Ecology Evolution and Systematics 38:739–766.

Steele, M. A., S. C. Schroeter, R. C. Carpenter, and D. J. Kushner. 2006. Top-down vs. bottom-up effects in kelp forests. Science 313:1737–9– author reply 1737–9.

Steneck, R. S. 1997. Fisheries-induced biological changes to the structure and function of the Gulf of Maine ecosystem. Pages 151–165. *in* Proceedings of the Gulf of Maine Ecosystem Dynamics Scientific Symposium and Workshop. RARGOM Report, 91 - 1.

Steneck, R. S., A. Leland, D. C. McNaught, and J. Vavrinec. 2013. Ecosystem Flips, Locks, and Feedbacks: the Lasting Effects of Fisheries on Maine's Kelp Forest Ecosystem. Bulletin of Marine Science 89:31–55.

Steneck, R. S., J. Vavrinec, and A. V. Leland. 2004. Accelerating trophic-level dysfunction in kelp forest ecosystems of the western North Atlantic. Ecosystems 7:323–332.

Stewart, J. S., E. L. Hazen, S. J. Bograd, J. E. K. Byrnes, D. G. Foley, W. F. Gilly, B. H. Robison, and J. C. Field. 2014. Combined climate- and prey-mediated range expansion of Humboldt squid (Dosidicus gigas), a large marine predator in the California Current System. Global Change Biology:n/a–n/a.

Sumi, C. B. T., and R. E. Scheibling. 2005. Role of grazing by sea urchins Strongylocentrotus droebachiensis in regulating the invasive alga *Codium fragile ssp tomentosoides* in Nova Scotia. Marine Ecology Progress Series 292:203–212.

Tilman, D. 1999. The ecological consequences of changes in biodiversity: a search for general principles. Ecology 80:1455–1474.

Vanelslander, B., A. De Wever, N. Van Oostende, P. Kaewnuratchadasorn, P. Vanormelingen, F. Hendrickx, K. Sabbe, and W. Vyverman. 2009. Complementarity effects drive positive diversity effects on biomass production in experimental benthic diatom biofilms. Journal of Ecology 97:1075–1082.

Witman, J. D. 1980. Community structure of subtidal *Modiolus modiolus* (L) beds. American Zoologist 20:807–807.

Witman, J. D. 1985. Refuges, Biological Disturbance, and Rocky Subtidal Community Structure in New-England. Ecological Monographs 55:421–445.

Witman, J. D., S. J. Genovese, J. F. Bruno, J. W. McLaughlin, and B. I. Pavlin. 2003. Massive prey recruitment and the control of rocky subtidal communities on large spatial scales. Ecological Monographs 73:441–462.

Worm, B., E. B. Barbier, N. Beaumont, J. E. Duffy, C. Folke, B. S. Halpern, J. B. C. Jackson, H. K. Lotze, F. Micheli, S. R. Palumbi, E. Sala, K. A. Selkoe, J. J. Stachowicz, and R. Watson. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314:787–790.

Young, I. R., S. Zieger, and A. V. Babanin. 2011. Global trends in wind speed and wave height. Science 332:451–455.

Zavaleta, E. S., J. R. Pasari, K. B. Hulvey, and G. D. Tilman. 2010. Sustaining multiple ecosystem functions in grassland communities requires higher biodiversity. Proceedings of the National Academy of Sciences 107:1443–1446.

Jarrett E. K. Byrnes

Department of Biology; University of Massachusetts Boston
100 Morrissey Blvd; Boston, MA 02125-3393
Phone: 401.529.4104 Email: jarrett.byrnes@umb.edu
URL: http://byrneslab.net Twitter: @jebyrnes

Professional Preparation

2010 - 2012 Postdoctoral Fellow, National Center for Ecological Analysis and Synthesis
2008 - 2010 Postdoctoral Fellow, Santa Barbara Long Term Ecological Research Project
2002-2008, UC Davis, Population Biology, M.S. 2003, Ph.D. 2008
1997-2001 Brown University, Bachelor of Science in Biology.

Appointments

2012 – Present Assistant Professor, University of Massachusetts Boston

List of Five Relevant Products

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

2. O'Connor, M.I. and **Byrnes, J. E.K.** Biodiversity and Ecosystem Function in Marine Ecosystems. 2014. In *Marine Community Ecology and Conservation*, M. Bertness, J. Stachowicz, and B. Silliman, eds. Sinauer. Sunderland, MA. pg.109-130.

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

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

5. 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. [doi]

List of Five Other Products

1. Byrnes J.E., Johnson L.E., Connell S.D. et al. 2014. The sea urchin – the ultimate herbivore and biogeographic variability in its ability to deforest kelp ecosystems. PeerJ PrePrints, 1, e174v1. [doi]

2. Stewart, J.S**.** Hazen, E.L., Bograd, S.J., **Byrnes, J.E.K.**, Foley, D.G., Gilly, W.F., Robison, B.H., Field, J.C. 2014. Combined climate and prey-mediated range expansion of Humboldt squid (Dosidicus gigas), a large marine predator in the California Current System. Global Change Biology. 20:1832-1843. [doi] *This is a product of my SEM class.*

3. Fox, J., **Byrnes, J.**, Boker, S., and Neale, M. 2012. Structural equation modeling in R with the **sem** and **OpenMX** packages. In *Handbook of Structural Equation Modeling*. Rick H. Hoyle, David Kaplan, George Marcoulides, and Steve West, eds.

4. Byrnes, J.E. and Stachowicz, J.J. 2009. The consequences of consumer diversity loss: different answers from different designs. *Ecology*. 90: 2879-2888. [doi]

5. Byrnes, J.E., Reynolds, P.L., Stachowicz, J.J. 2007. Invasions and extinctions reshape coastal marine food webs. *PLoS One*. 2: e295. [doi]

List of Five Synergistic Activities

1. Floating Forests. http://floatingforests.org. A massive citizen science project in collaboration with Zooniverse, the citizen science arm of the Adler Planetarium, to look at change in kelp from satellite records.

2. Kelp Ecosystem Ecology Network (http://kelpecosystems.org). Network coordinator.

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

4. Author of I'm a Chordata! Urochordata! http://www.imachordata.com/. A science blog discussing ecology, marine biology, and the culture of science in the modern age.

5. Contributing Developer for *lavaan* - Analysis of latent variable Structural Equation Models in R. http://lavaan.org

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

Thesis Advisor: John J. Stachowicz, UC Davis.e

Graduate Advisors and Postdoctoral Sponsors: Bradley J. Cardinale, University of Michigan. Daniel C. Reed, UC Santa Barbara.

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	1.00	**8,126**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**8,126**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	8.00	0.00	0.00	**30,538**	
3. (**1**) GRADUATE STUDENTS				**30,000**	
4. (**1**) UNDERGRADUATE STUDENTS				**5,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**73,664**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**9,726**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**83,390**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**5,634**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **2,100**					
TOTAL NUMBER OF PARTICIPANTS (**3**) TOTAL PARTICIPANT COSTS				**2,100**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**9,020**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**8,380**	
TOTAL OTHER DIRECT COSTS				**17,400**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**108,524**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 106424)**					
TOTAL INDIRECT COSTS (F&A)				**55,873**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**164,397**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**164,397**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*

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	1.00	**8,370**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**8,370**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	8.00	0.00	0.00	**31,455**	
3. (**1**) GRADUATE STUDENTS				**30,000**	
4. (**1**) UNDERGRADUATE STUDENTS				**5,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**74,825**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**9,999**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**84,824**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**7,319**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **2,100**					
TOTAL NUMBER OF PARTICIPANTS (**3**) TOTAL PARTICIPANT COSTS				**2,100**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**7,380**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**2,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**8,380**	
TOTAL OTHER DIRECT COSTS				**17,760**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**112,003**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 109903)**					
TOTAL INDIRECT COSTS (F&A)				**57,699**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**169,702**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**169,702**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*

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	1.00	**8,621**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**8,621**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	8.00	0.00	0.00	**32,398**	
3. (**1**) GRADUATE STUDENTS				**30,000**	
4. (**1**) UNDERGRADUATE STUDENTS				**5,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**76,019**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**10,280**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**86,299**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**7,319**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **2,100**					
TOTAL NUMBER OF PARTICIPANTS (**3**) TOTAL PARTICIPANT COSTS				**2,100**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**8,020**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**2,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**8,380**	
TOTAL OTHER DIRECT COSTS				**18,400**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**114,118**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 112018)**					
TOTAL INDIRECT COSTS (F&A)				**58,809**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**172,927**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**172,927**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*

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 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	1.00	**8,879**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**8,879**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	8.00	0.00	0.00	**33,370**	
3. (**1**) GRADUATE STUDENTS				**30,000**	
4. (**1**) UNDERGRADUATE STUDENTS				**5,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**77,249**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**10,568**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**87,817**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**7,319**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **2,100**					
TOTAL NUMBER OF PARTICIPANTS (**3**) TOTAL PARTICIPANT COSTS				**2,100**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**7,380**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**2,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**7,980**	
TOTAL OTHER DIRECT COSTS				**17,360**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**114,596**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 112496)**					
TOTAL INDIRECT COSTS (F&A)				**59,060**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**173,656**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**173,656**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*

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 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	1.00	**9,146**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**9,146**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	8.00	0.00	0.00	**34,371**	
3. (**1**) GRADUATE STUDENTS				**30,000**	
4. (**1**) UNDERGRADUATE STUDENTS				**5,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**78,517**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**10,866**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**89,383**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**7,319**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **2,100**					
TOTAL NUMBER OF PARTICIPANTS (**3**) TOTAL PARTICIPANT COSTS				**2,100**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**7,920**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**2,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**8,380**	
TOTAL OTHER DIRECT COSTS				**18,300**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**117,102**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 115002)**					
TOTAL INDIRECT COSTS (F&A)				**60,376**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**177,478**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**177,478**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*

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

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

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

ORGANIZATION
University of Massachusetts Boston

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Jarrett Byrnes

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Jarrett Byrnes - PI**	0.00	0.00	5.00	**43,142**	
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	5.00	**43,142**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**5**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	40.00	0.00	0.00	**162,132**	
3. (**5**) GRADUATE STUDENTS				**150,000**	
4. (**5**) UNDERGRADUATE STUDENTS				**25,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**380,274**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**51,439**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**431,713**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**34,910**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **10,500**					
TOTAL NUMBER OF PARTICIPANTS (**15**) TOTAL PARTICIPANT COSTS				**10,500**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**39,720**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**8,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**41,500**	
TOTAL OTHER DIRECT COSTS				**89,220**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**566,343**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**291,817**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**858,160**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**858,160**	

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

PI/PD NAME
Jarrett Byrnes

ORG. REP. NAME*

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

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

Budget and Justification

A. Senior Personnel: We one month of summer support for the PI. This will enable the PI to conduct summer experiments and supervise students and REU/RET participants.

	Year 1	Year 2	Year 3	Year 4	Year 5
9 Months Research Technician	30,538.00	31,455.00	32,398.00	33,370.00	34,371.00
Grad Student Stipend	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00
1 month for PI	8,126.00	8,370.00	8,621.00	8,879.00	9,146.00
Summer Undergraduate Technician	5000	5000	5000	5000	5000

B. Other Personnel: We request nine months of support for a research technician Ted Lyman for five years. Additional funds will be made up for via teaching activities at the University. Rates are based on his current salary and raise schedule. He has worked at the Byrnes lab manager for two years, and before was the Dive Safety Officer at Northeastern University's Marine Science Center, and is currently assisting PI Byrnes in developing a dive safety program here at UMB. He also has a background in IT support at biomedical startups. This technician position will encompass several duties: 1) assisting in conducting the experiments, 2) building and maintaining sensors, 3) co-ordination of lab dive activities, 5) management of project data.

We request support for a graduate student for the five years of the grant for five years of the grant. The graduate student will assist in summer sampling and the removal experiments. The graduate student will use the unsampled areas of the clearance plots as a potential site to conduct additional experiments related to the project.

Undergraduate personnel to assist in summer manipulations, surveys, and independent research will be paid a summer stipend of $5,000/each per year. They will be dedicated to the project, as opposed to any REU/RET participants who will have the freedom to explore their own research projects.

C. Fringe: 1.90% rate applies to PI for summer compensation. 29.17% applies to the benefited technician and 1.59% applies to the Graduate undergraduate students stipend in the summer only. Fringe Rate is negotiated between DHHS and the Commonwealth of Massachusetts. Fringe rates includes: General Fringe, Health & Welfare, Medicare, Unemployment Insurance, Universal Health Insurance and Worker's Compensation Insurance.

D. Equipment: n/a

E. Travel – Domestic Travel:
SML: During the grant, we will require travel to and from the Shoals Marine Lab ($66 ferry trip/person and $50 for gas and tolls = $314/year) and lodging for 10 days for 1 faculty, 1 tech, and 2 students ($532/night). Total travel to SML per year $5634 per year.

Travel is also requested for PI and 1 graduate student to travel to the Benthic Ecology Meeting in years 2 through 5. Roundtrip airfare $250/per person; Registration PI $250 and graduate student $150; 3 nights hotel $175 per night; 2 Taxi rides $40 per ride and per diem $45/day for 2 days. Total travel for meetings is $1685 per year for four years.

F. Participant Support Cost:
Other: As part of the educational program, I ask for $2100 per year to support three underprivileged students with gear rental. This will enable three full sets of gear for the basic certification class ($450/person) and three full sets of gear for the Underwater Research Class ($250/person).

G. Other direct costs:

G1. Supplies*:* In year 1,3, and 5, I request $120 for the purchase of gypsum dental cement for flow blocks. In those years, I also request $420 for a two-gallon set of marine epoxy (A-788 Splash Zone Compound) for site markers and hardware installation for ecosystem function trials. In years 1 and 3, I request $100 for 200' of 1/2" Rebar for Site Markers at $10 for 20' for site markers. I request $50/year for hardware cloth for short-term cages and flow-block deployments, and $50/year for zip-ties. Dropbox file sharing subscription $1080 per year for all five years. Last, I request $5200/year for 800 tank fills (200 dives/year for 4 divers) every year at $6.50/fill. In year 1, I request material costs for wave sensors to be built in my lab. Based on our prototypes, this should cost $200/sensor, so, $2000 total. In subsequent years, I request $1000 per year to build up to five replacement sensors, given potential losses.

Total supplies requested in Year 1: $9020; Year 2; $7380; Year 3 $8020; Year 4 $7380; Year 5 $7920

G2. Publication*:* We also include $2,000 during years 2-5 for Open Access publication costs.

G6a. Equipment Repair*:* Annual servicing of five sets of dive gear at $200/set is $1000 per year. I request $600 per year for dive equipment and field gear replacements based on averages from the last two years. In years 1-3 and 5, we request funds for tank inspections of our 16 tanks at $25 per tank for $400.

Totals Year 1: $2000; Year 2: $2000; Year 3: $2000; Year 4: $1600; and Year 5: $2000

G6b. Rental and Leasing*:* We request funds for annual leasing costs as follows to take care of our lab truck, trailer, and 20’ Maritime Dauntless Skiff, the M/S Botryllid. Costs are based on current and estimated use in the 2014 field season.

Item	**Annual Cost**
Truck Insurance	$1100
Trailer Insurance	$600
Boat Repairs & Equipment Replacement	$1000
Trailer Repairs (lights, axel grease, etc.)	$200
Gas for Boat	$350
Oil for Boat	$100
Gas for Truck for Summer	$1000
Winter Boat Storage ($500 for shrink wrap, $900 for storage at $45/ft)	$1400

For the class trip to the Harbor Islands, I request $630/year to rent the R/V John F. Looney for Students for 6 hrs ($270 for 2 hrs, $90 each additional hour).
Total $6380 per year for 5 years for leasing.

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

Current and Pending Support

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

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

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

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

Project/Proposal Title: CAREER: Foundation Species and Biodiversity as Drivers of Ecosystem Multifunctionality in Temperate Rocky Reef Ecosystems

Source of Support: NSF

Total Award Amount: $ 858,161 Total Award Period Covered: 02/01/15 - 01/31/20

Location of Project: Boston, MA

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

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

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

Source of Support: MIT SeaGrant

Total Award Amount: $ 137,369 Total Award Period Covered: 02/01/14 - 01/31/16

Location of Project: Boston, MA

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

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

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

Source of Support: MIT SeaGrant

Total Award Amount: $ 200,000 Total Award Period Covered: 02/01/15 - 12/31/17

Location of Project: Boston, MA

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

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

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

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

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

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

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

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

Facilities, Equipment and Other Resources

UMB Laboratory: On the UMB campus, students will be placed in the PI's fully equipped research laboratory in UMB's new Integrated Sciences Complex. His 600 sq. ft. lab is fully supplied with computers, a fume hood for sample processing, and sample freezer, a full range of shop tools, dissecting scopes, drying ovens, balances, and other equipment for lab work.

UMB Computer: UMass Boston has extensive computer resources for this project. Each research lab has an array of internet- connected Macs and PCs. UMB has 10 computer labs with over 250 PCs and printers available for student use, as well as specialty computer facilities and computer teaching laboratories. Students and technicians in PI Byrnes's lab are equipped with iMacs that regularly backup to external drives. In addition, the lab supplies an unlimited Dropbox account to all students for off-site data backup and easy sharing.

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

UMB Field Equipment: PI Byrnes's lab is currently equipped with the necessary equipment for a subtidal research program: wet and dry suits for lab personnel, 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.

UMB Waterfront Support: The UMass Boston Marine Operations group provides dock and mooring facilities. They also have an array of vessels for charter, including the large 110 passenger M/V Columbia Point and 46' Buoy tender, the R/V John F. Looney.

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

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

Data Management Plan

1. Types of data

Data from experimental and observational sampling will be collected by divers on SCUBA. Data will consist of quadrat, swath, fish, and point count data of species abundances. In general, data sheet formats will include identifying information for individual quadrat or transect, taxon name being sampled, and the abundance recorded of the relevant taxon. Units of data (% or count) will be set by sampling method and taxon and unique to each survey or experiment. All data sheets will be scanned and archived once dry. Data entry will be performed using printouts of scanned data to ensure legibility of scans. If scans are illegible, the original data sheets will be located and rescanned so that they are legible. Data will be Quality Assured by interns reading back data from sheets to check for consistency. Data will be spot checked by lab technicians as a final QA step.

We will also keep a field log of all geospatial information of plot locations for future resurveys and for meta-data purposes.

The final data will comprise a collection of comma separated files that will include entries for part of the project, site, project name, measurement type, and measurement value. R scripts used to create derived data sets for analysis will be archived separately and have their workflows documented. Derived data files will be stored in a separate directory from the original data. Further R scripts for analyses will be archived separately from data processing scripts.

2. Data and metadata standards

All data files will have metadata stored in accompanying text files. Text files will fully document the spatial and temporal information regarding each data set. Text files will include a full description of the methodology used to collect data, and a description of the measurements contained in each column. A second meta-data table will the full taxonomy of each taxon sampled in the data as well as a brief description and references to Encyclopedia of Life ID numbers. All data will be permanently archived using Morpho at KNB (see below) to facilitate the creation of meta-data conforming to the EML standard.

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

3. Policies for access and sharing

All derived and raw data will be made publicly available via the Knowledge Network for Biocomoplexity (KNB). The PI has previously participated in depositing data sets at KNB while a postdoctoral fellow at NCEAS. All metadata will be supplied with data sets, as will scripts for creating derived data sets. Scripts for analysis will be made public

as appendices to published papers. When possible, data will also accompany published paper as appendices (e.g., for PLoS One). Data will be fully open access with the only requirement being citation to the data product.

Data from biodiversity observations will also be deposited with the Kelp Ecosystem Ecology Network for use with their growing data archive of kelp removal experiments. This data will be archived and managed by the Australia Oceans Data Network.

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

Experimental and ecosystem function data will be made available upon publication of the first paper using the data with the requirement that the data product and paper be properly cited. While future authors will be encouraged to contact the PI and co-authors with questions about the data, no requirements or restrictions will be placed on the use of the data. Data from biodiversity surveys will be made available as soon as data is quality controlled. This data will be published as a data product, and will require only citation of the data product itself.

5. Plans for archiving and preservation of access

Short-term

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

Long-term

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

UNIVERSITY of
MASSACHUSETTS
BOSTON
100 Morrissey Blvd.
Boston, MA 02125-3393

Rick Kesseli
Department of Biology
Tele: 617.287.6600
Fax: 617.287.6650
rick.kesseli@umb.edu

July 20, 2014

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 new, tenure-track member in Biology and is submitting this one CAREER proposal, so he is eligible for this NSF program. His proposed research and educational activities parallel, and are extremely well integrated into, the educational and research missions of the Department and UMB. We are committed to supporting Dr. Byrnes' professional development. Dr. Byrnes' proposal links his University mandated research, teaching and service responsibilities to each other and 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. 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 have the most diverse student body of any major 4-year university in our region. This diversity includes a wide ethnic and racial distribution but also many other factors such as age and economic and educational backgrounds. Many of our students come from working class backgrounds with no previous college education in their families. Many are attracted to the biological sciences and our majors have increased by more than 50% in the last 5 years. 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 lab experiences that will make them marketable to graduate programs or to private businesses with science based careers in the region. Prior to UMB, most of these students have little understanding of the role of scientists in society or knowledge of possible careers in science other than medical programs. We are constantly interested in expanding the opportunities and success of our students and Dr. Byrnes' proposed integration of research, teaching and outreach fits wonderfully into this plan.

Dr. Byrnes 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. Despite having arrived less than 2 years ago, he has taught at both the undergraduate and graduate levels within the Department and had a significant impact. He created and taught an upper level Marine Ecology course for majors. He has also taken an active role in our recent efforts to upgrade and invigorate our second semester introductory biology course which focuses on the higher scales of biological organization and disciplines such as physiology, evolution, population biology and

community ecology. He has also developed and taught a new Biological Data Analysis graduate course. The word has spread on this course and based on preregistration for this fall it now stands as the most popular graduate course in the fall line-up. Most recently, he developed a new exciting field course in Underwater Research Techniques which will get students in the water and conducting research. This course will be fully implemented next summer. Dr. Byrnes has brought many new tools and analytical techniques to our department. He is enhancing our strength in statistics and modeling and, is providing much needed training for our graduate students. He is also attracting undergraduates to his lab for training and has been introducing them to his field work throughout the region.

Dr. Byrnes' career goals and job responsibilities have developing a sustained and nationally recognized research program at its core and it is clear that his research program is already flourishing. He is a very strong computational evolutionary 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. He has also released well-received and 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 support, graduate student support and start-up funding to his program. We have assigned Dr. Ron Etter, a full professor within our department with overlapping interests in evolutionary ecology to be his direct mentor. We will help Dr. Byrnes maintain a proper balance of activities that will lead to a successful tenure decision. The Department will institutionalize and support the innovative field experiences that Dr. Byrnes has brought to his new course. We plan to have his Underwater Research Methods course firmly established next summer and hope to attract a strong cohort of motivated young scientists to this course with the aim of stimulating their interests into research fields in environmental biology and ecology. These students likely had little knowledge of careers in these areas prior to UMB and will be exposed to life changing opportunities. We will continue to support Dr. Byrnes's graduate students, supply research funds, prioritize his equipment needs and relieve him of excess teaching and service duties. Dr. Byrnes has demonstrated that this support has been 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