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: David Johnson

Gender: ☐ Male ☐ Female

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

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

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

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

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Race Definitions:
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Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
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PI/PD Name: Jarrett Byrnes

Gender: ☐ Male ☐ Female

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

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

Disability Status: (Select one or more)
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☐ Visual Impairment
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☐ Other
☒ None

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

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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:
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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 13-1

NSF 14-503 **01/23/14**

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

DEB - Ecosystem Studies

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

AWARDEE ORGANIZATION CODE (IF KNOWN)

0021626000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

Marine Biological Laboratory
7 M B L ST
WOODS HOLE, MA. 025431015

NAME OF PRIMARY PLACE OF PERF

Marine Biological Laboratory

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

Marine Biological Laboratory

Woods Hole ,MA ,025431015 ,US.

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TITLE OF PROPOSED PROJECT **Preliminary Proposal: Multi-stressor impacts on saltmarsh persistence**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **0**	**0** months		

CHECK APPROPRIATE BOX(ES) IF 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)
☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date _____
PHS Animal Welfare Assurance Number _____

☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
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PI/PD DEPARTMENT

PI/PD POSTAL ADDRESS
7 M B L ST

WOODS HOLE, MA 025431015
United States

PI/PD FAX NUMBER
508-457-1548

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **David Johnson**	**ScD**	**2008**	**508-548-3705**	**dsjohnson@mbl.edu**
CO-PI/PD **Jarrett Byrnes**	**PhD**	**2008**	**401-529-4104**	**jarrett.byrnes@umb.edu**
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).

Conflict of Interest Certification

When the proposing organization employs more than fifty persons, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Conflict of Interest:
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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 ☒

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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.

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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.

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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:
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(2) building (and any related equipment) is covered by adequate flood insurance.

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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.

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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:
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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

* EAGER - EArly-concept Grants for Exploratory Research
** RAPID - Grants for Rapid Response Research

PROJECT SUMMARY

Overview:

Human activities continue to accelerate saltmarsh loss. While multiple drivers of marsh loss have been identified - including nutrient enrichment, sea-level rise and overgrazing - we know little about potential interactions among these stressors, which often occur simultaneously. Here we propose to examine the potential interaction of two recently identified marsh-loss drivers - nutrient enrichment and ecosystem engineers (burrowing crabs) - as a model to evaluate how multiple stressors could synergistically affect marsh persistence. Nutrient enrichment, herbivory, and burrowing by crabs all stimulate decomposition processes and reduce belowground live organic matter and alter marsh sediment stability. We hypothesize that through a series of interactions and feedbacks, the impact of nutrient enrichment and burrowing herbivorous crabs will synergistically increase marsh susceptibility to loss. We propose to test this idea with a combination of field and laboratory manipulations and models to test the following hypotheses:

H1: Ecosystem engineers exacerbate the effects of nutrient enrichment with increased penetration of both O_2 and NO_3^- via burrows which in turn leads to increased decomposition of sediment organic matter.
H2: Increased nutrients alter plant stoichiometry to increase per capita grazing by crab consumers, which in turn can decrease sediment deposition.
H3: Increased nutrients decrease sediment strength, which facilitates burrowing activity.

Intellectual Merit :

We propose to test fundamental questions about the role of multiple stressors in altering on ecosystem structure and function in coastal wetlands. Like other detritus-based ecosystems worldwide (boreal, tundra, and fresh-water wetlands), coastal wetlands are experiencing radical shifts in stability and function in response to multiple drivers of global change. The ubiquity of these shifts suggests a need to solidify our theories and understanding of how multiple stressors affect ecosystems. Our project will contribute to developing a predictive framework for the effect of multiple interacting stressors on detritus-dominated ecosystems. Furthermore, given the reliance of human infrastructure and economies on coastal wetlands (billions of dollars are spent each year in restoration in the face of global change to enhance ecosystem service provision), there is an immediate need to understand multistressor impacts on these ecosystems.

Broader Impacts :

We will enhance STEM education by training one graduate student, several REUs, and work with two K12 marsh biology programs in New England. The high-school program programs have mud-in-your boots field components for hands-on experience. We will promote diversity via targeted solicitations at schools that service predominately underserved/underprivileged students (e.g., UMASS-Boston, PI Byrnes employer, U. of Central Arkansas-PI Johnson's undergrad). In addition, PI Byrnes will lead a regional workshop on Structural Equation Modeling. Data for the project will be publicly available and will feed into management by the South Shore Branch of the Massachusetts Bays National Estuary Program. PIs Byrnes and Johnson will also conduct extensive online outreach efforts, using platforms they have already established involving blogging, online recorded conversations, and virtual field trips to experimental sites.

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.

Personnel

David S. Johnson: PI, Assistant Research Scientist, The Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts. dsjohnson@mbl.edu
Johnson will lead project coordination and implementation, sample plant and sediment stability responses, and supervise interns.

Jarrett Byrnes: Co-PI, Assistant Professor, Department of Biology, University of Massachusetts – Boston, Jarrett.Byrnes@umb.edu
Byrnes will conduct modelling analysis, coordinate high-school outreach programs and supervise the graduate student.

Conceptual Framework

Current theory states that detritus-dominated ecosystems, such as salt marshes and tundras, should be highly resistant to perturbations. This is due to the large pools of recalcitrant detrital organic matter and slow vascular plant turnover that stabilize biogeochemical cycles (Cebrian and Duarte 1995, Cebrian and Lartigue 2004). However, many detritus-based ecosystems have succumb rapidly to anthropogenic perturbations (Deegan et al. 2012, Mack et al. 2011), suggesting that these ecosystems are more susceptible to anthropogenic impacts than previously thought.

Salt marshes are ecosystems that are increasingly susceptible to anthropogenic impacts (Deegan et al. 2007, Deegan et al. 2012, Kirwan and Megonigal). Despite the importance of these coastal wetlands to coastal economies and communities, human activities have accelerated saltmarsh loss globally (Reid et al. 2005), which in turn has reduced their ecosystem services including storm protection, carbon storage, food production, and tourism (Barbier et al. 2011). Marshes face an array of stressors that can lead to loss including sea-level rise (Kirwan and Megonigal 2013), nutrient enrichment (Deegan et al. 2012), predator over-harvest (Altieri et al. 2012), reduced sediment supply (Fagherazzi et al. 2013a), and hydrocarbon extraction (Morton et al. 2006). While many of these stressors occur simultaneously, little is known about the potential interactions of these stressors on the marsh persistence. Here, we propose to examine two potential marsh-loss drivers as a model to evaluate how multiple stressors could affect marsh persistence.

Background and Rationale

We seek to synthesize and unify disparate and often disagreeing lines of inquiry into saltmarsh loss under the conceptual framework of multiple interacting stressors. Recently, two previously unknown drivers of marsh loss have been identified. One is loss driven by nutrient enrichment (Deegan et al. 2012). The other is loss due to anomalously high densities of an herbivorous ecosystem engineer (i.e., sesarmid crabs, Cloverdale et al. 2013). Though these two drivers have different proximate mechanisms through which they operate, both result in decreased belowground organic matter inputs and may potentially increase peat decomposition, which reduces soil strength. Further, both drivers affect aboveground production (Deegan et al. 2012, Cloverdale 2012) which can affect sediment deposition and thus accretion, an important process in maintaining elevation. Thus, in combination, these drivers might act synergistically to accelerate marsh loss. Based on experimental data of these two drivers in isolation, we have developed a model of how the two likely interact (Fig. 1). The model is based on the following:

PI Johnson's work has experimentally demonstrated that coastal nutrient enrichment, a global issue, can lead to marsh loss (Deegan et al. 2012). The mechanisms proposed for nutrient-induced loss include decreases in belowground production as energy shifts from belowground to aboveground production (Deegan et al. 2012, Darby and Turner 2008). Simultaneously, altered microbial activity results in increased sediment respirations as peat is metabolized (nitrate is an electron acceptor in denitrification) and higher water content in sediments (Deegan et al. 2012). Combined, the reductions in new carbon sources and increased peat respiration result in weakened soil strength, increase bank instability, and ultimately leads to marsh loss (Deegan et al. 2012). This experimentally demonstrated pattern of marsh loss parallels observations for anthropogenically nutrient-enriched marshes worldwide (MacGarvin 2001, Hartig et al. 2002, Tiner 2006).

Similarly, the burrowing herbivorous crab *Sesarma reticulatum* reduces soil organic content (and thus potentially soil strength) via multiple pathways. Direct consumption of *Spartina alterniflora* reduces new organic matter inputs (Holdredge et al. 2009; Coverdale et al. 2012). Bioturbation by these ecosystem engineers alters both the physical structure and the biogeochemical nature of the soil thereby increasing exchange fluxes at the sediment–water interface (Bouma et al. 2009, Wang et al. 2010). Crab burrowing in salt marshes increases soil-water content and decreases bulk density, accelerates decomposition (Fanjul

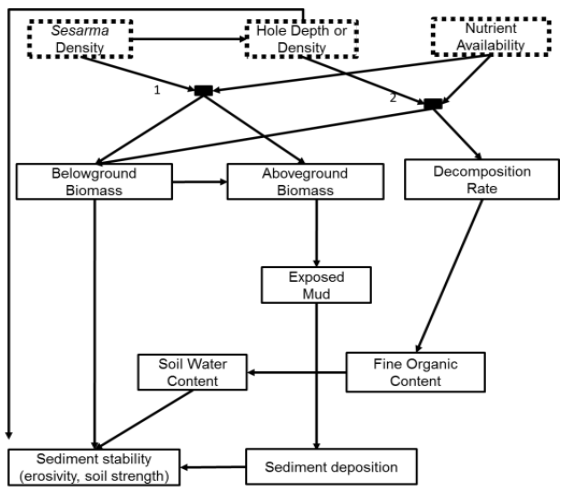

Figure 1: Causal model of interactions that can compromise marsh stability. Node 1 represents interactions with direct grazing effects and Node 2 represents interactive effects on the availability of electron acceptors (O_2, NO_3^-)

et al. 2007) and mineralization of carbon and nitrogen (Wang et al. 2010). The crab burrows themselves promote the mineralization of soil organic matter via denitrification that leads to increased effluxes of inorganic carbon (i.e., CO_2) (McHeuga and Tsuchiya 2008). Moreover, crabs remove peat from the system directly by removing material during burrow excavation. Thus, via direct consumption of live biomass, accelerating biogeochemical cycling, and physical engineering of sediment, *Sesarma* may weaken sediment strength and promote marsh loss.

While previous work suggests no interaction between *Sesarma* and nutrient fertilization (Bertness et al. 2009), this work relied on short-term (<1 year) nutrient manipulations relative to the time it takes for marsh sediments to be altered by eutrophication ($\geq$ 2 year, Darby and Turner 2008). Furthermore, this study did not fully explore the mechanisms by which physical engineering by crabs may amplify nutrient effects.

Research Plan

To understand how multiple stressors impact marsh persistence we propose to conduct a 3-year study with a combination of experimental manipulations and observational studies that allow us to parameterize our model in Fig. 1. First, we will conduct experimental manipulations of three factors (H1) – nutrient enrichment, altered densities of the marsh ecosystem engineer *Sesarma reticulatum*, and artificially created burrows – and assess the independent and interactive effects on sediment properties related to persistence (e.g., sediment strength, peat particle size). Second, field experiments will be coupled to a causal model of saltmarsh processes that will be fit using Structural Equation Modeling. Third, to validate the generality of our model and experimental results we will use data from PI Byrnes ongoing transect surveys from a range of marshes with variable densities of burrowing crabs and nutrient levels. Fourth, we will conduct targeted lab and field manipulations to look at how specific interactions (H2, H3) influence marsh stability. Broadly, we hypothesize that through a series of synergistic interactions and feedbacks, the impact of nutrient enrichment and burrowing crabs will significantly decrease marsh sustainability in combination versus alone. Specifically we will test the following hypotheses:

Hypothesis 1: *Ecosystem engineers exacerbate the effects of nutrient enrichment via increased penetration of both O_2 and NO_3^- via burrows which in turn leads to increased decomposition of sediment organic matter.*

As discussed above, nutrients and crabs have a variety of direct and indirect pathways by which they can impact marsh stability. Burrowing activity by crabs should increase water and oxygen penetration into marsh sediments, accelerating biogeochemical processes and increasing decomposition (Fanjul et al. 2007). These burrows should allow deeper penetration of NO_3^- into the sediments, accelerating denitrification, which can reduce peat particle size (Deegan et al. 2013). Additionally, direct grazing of belowground plant structures, which may be accelerated with nutrient enrichment (see H2), removes new contributions of organic matter to the sediment (Cloverdale et al. 2012). Thus, via both direct and indirect pathways, crab activities may reduce marsh sediment stability. We have built a causal model of how these synergisms and indirect interactions should function (Fig. 1). To test these hypotheses and fit our causal model, we will conduct a 3-way factorial manipulation of nutrients, crab density (inclusion and exclusion cages), and artificially created burrow densities in Cohasset Marsh, Massachusetts, a low-sesarmid

density marsh. The artificial burrows allow us to differentiate the direct (grazing) and indirect effects (deeper penetration of O_2 and NO_3^-) of crabs. We will implement 4 levels of each factor (n=10/treatment combination, total N=120). Treatments will be maintained for three years to account for the temporal scale needed to manifest treatment effects (Darby and Turner 2008). With these data, we will fit our multivariate model using Structural Equation Modeling (Grace 2006, Grace et al. 2010). To determine how treatment effects change over time, we will use multi-group analysis (Grace and Pugesek 1998) with each year of the experiment as a separate group.

To parameterize the model, every year we will assess the following variables: aboveground plant production (end-of-season harvests) and belowground production (in-growth bags; cores), the C:N of plant leaves (see H2), changes in carbon storage using decomposition bags (Kirwan and Blum 2011), sediment respiration chambers (Wigand et al. 2009) and potential denitrification (Deegan et al. 2012). We will also measure the following properties from sediment cores: bulk density, water content, percent organics (loss-on-ignition). Changes in sediment strength at multiple depth intervals – as measured by a shear-vane (Turner 2011) – will indicate marsh stability as a function of belowground processes.

To verify these experimental results, we will partner with PI Byrnes's marsh surveys funded by MIT SeaGrant around Massachusetts. These surveys (5 marshes, n=8 transects per marsh), funded to start in summer of 2014, are already collecting all of the data in our model above. While the sample size is low enough that we will not be able to use SEM, we can test predictions from our experimental results using our experimental data, regressing marsh nutrient load and *Sesarma* densities with all relevant marsh properties using appropriate multilevel models (Bolker et al. 2009).

Hypothesis 2: *Increased nutrients alter plant stoichiometry to increase per capita grazing by crab consumers, which in turn can decrease sediment deposition.*

Marsh accretion, which is necessary to maintain elevation with sea-level rise, relies in part on mineral sediment deposition, which is affected by plant production (shoots baffle water and trap sediment, Redfield 1972, Gleason et al. 1979, Morris et al. 2002, Kirwan and Megonigal 2013). Crabs can affect aboveground plant production, and in turn sediment deposition, via two pathways: 1) direct grazing of young shoots or 2) belowground grazing which can lead to total plant death (Cloverdale et al. 2012). Nutrients, by contrast, can increase sediment trapping by increasing aboveground productivity (Morris et al. 2002). In the presence of consumers, however, nutrients may lower sediment trapping if nutrients increase per capita grazing of live biomass (Bertness et al. 2008) that in turn reduces overall macrophyte productivity (Altieri et al. 2012, Cloverdale et al. 2012).

We will measure how nutrients affect plant stoichiometry and thus shoot and root/rhizome palatability to sesarmid crabs with laboratory and field studies. To assess per-capita grazing rates we will use lab-reared plants in Year 1 reared in different nutrient concentrations and plant shoots and roots/rhizomes harvested from control and fertilized plots (no crabs present) in Year 3. Increased grazing should lead to decreased sediment deposition. To assess the effects of treatments on sediment deposition mediated by changes in plant production in the field, we will use sediment deposition plates (LeMay 2007) at the end of Year 3 in the cages used in the experiment above for H1 (all caging structures will be removed to reduce artificial baffling). We predict that sediment deposition will be lower in nutrient-crab and crab treatments as a result of decreased aboveground productivity and higher in nutrient only treatments as a result of aboveground increased productivity.

Hypothesis 3*: Increased nutrients decrease sediment strength, which facilitates burrowing activity.*

Given that substrate softness is a key predictor of crab burrowing ability (Bertness et al. 2009), we hypothesize that there is a positive feedback between nutrients and crab burrowing such that nutrients

decrease sediment stability, which in turn facilitates crab burrowing activity. To test this hypothesis, during surveys in Year 1, we will identify marshes with high *Sesarma* densities (e.g., on Cape Cod), but spatially variable in marsh sediment stability. We will mark 40 areas of similar sediment properties (e.g., grain size, bulk density) and high sediment strength (as measured by shear vane) and low crab burrowing activity as open cages (crabs will have access to these plots). Ten will be randomly assigned as nutrient addition plots and receive nutrient fertilization over the course of the following two years. Ten others will be randomly selected to have artificial burrows that match high density burrow areas drilled (burrowing activity itself may facilitate burrowing). Ten others will be assigned with both artificial burrows and nutrients. During summer and fall months, we will assess 1) sediment stability, 2) sediment grain properties, and 3) burrow density.

Broader Impacts

Community outreach: We will pursue several different avenues to disseminate our work to the broader public. First, PI Johnson will use his position as a guest columnist for the Newburyport *Daily News* to talk about natural history and scientific observations generated by this work. PI Byrnes and Johnson will lecture at the New England Aquarium (Boston, MA) regarding outcomes of the work as it progresses. Both PI Byrnes and Johnson will participate in Google Hangouts discussing the work as part of PI Byrnes's new outreach program using G+ Hangouts to discuss for salt marsh ecology with prominent marsh scientists. We will use these Hangouts to conduct virtual field trips to our study sites. Finally, we will create a video for submission to the *Beneath the Waves Film Festival*, which has worldwide showings of the top entrants. Policy makers/managers: We will leverage existing relationships with agencies such as the EPA, Coastal Zone Management, the Waquoit Bay NERR, and Parker River National Wildlife Refuge to present seminars to the public and managers. Data from this project will be publicly available. PI Byrnes will contribute it directly to the South Shore Branch of the Massachusetts Bays National Estuary Program where he currently collaborates with their regional manager, Sara Grady. Education: In addition to training one graduate student, we will enhance STEM education through REU training and K12 engagement. REU's from programs at MBL and UMASS-Boston (which serves primarily underprivileged/minority students) will receive not only scientific training, but also participate in ethics training and career-advice workshops that PI Johnson has developed. We will continue K12 education by working with our existing relationships with the Gulf of Maine Institute (a non-profit that provides environmental science training to high-school students from Cape Cod to Nova Scotia) and the Cohasset Foundation's high-school marsh sampling program for mud-in-your-boots sampling with south shore high-school students.

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PROFESSIONAL PREPARATION

University of Central Arkansas, Conway, AR.	Environ. Science	B.S, 2003
Louisiana State University, Baton Rouge, LA.	Biological Science	Ph.D., 2008

APPOINTMENTS

The Ecosystems Center, MBL, Woods Hole, MA.	Asst. Res. Scientist	2013– present
Department of Biology, Sewanee, TN	Visiting Asst. Prof	2012
The Ecosystems Center, MBL, Woods Hole, MA.	Research Associate	2010-2013
The Ecosystems Center, MBL, Woods Hole, MA.	Post-doc	2009-2010

FIVE RECENT AND RELEVANT PRODUCTS (out of 15 publications)

1. Deegan, L. A. **D. S. Johnson**, R. S. Warren, B. J. Peterson, J. W. Fleeger, S. Fagherazzi, W. Wollheim. 2012. Coastal eutrophication as a driver of salt marsh loss. *Nature* 490:388-392. Selected as an outstanding paper by the Faculty of 1000 and featured in NSF News (http://www.nsf.gov/news/news_summ.jsp?cntn_id=125739).

2. Fagherazzi S., D.M. FitzGerald D.M., R.W Fulweiler, Z. Hughes, P.L. Wiberg, K.J. McGlathery, J.T. Morris, T.J. Tolhurst, L.A. Deegan, and **D.S. Johnson**. 2013. Ecogeomorphology of Salt Marshes. In: John F. Shroder (ed.) *Treatise on Geomorphology*, Volume 12: 180-200.

3. **Johnson, D.S.** 2011. High-marsh invertebrate communities are susceptible to eutrophication. *Marine Ecology Progress Series* 438:143-152.

4. **Johnson, D.S.** and M. I. Short. 2013. Chronic nutrient enrichment increases the density and biomass of the eastern mudsnail, *Nassarius obsoletus*. *Estuaries and Coasts* 36: 28-35.

5. **Johnson, D.S.**, J.W. Fleeger, and L.A. Deegan. 2009. Large-scale manipulations reveal top-down and bottom-up controls interact to alter habitat utilization by saltmarsh fauna. *Marine Ecology Progress Series* 377: 33-41.

FIVE OTHER RELEVANT PRODUCTS

6. Fagherazzi S., D.M. FitzGerald D.M., R.W Fulweiler, Z. Hughes, P.L. Wiberg, K.J. McGlathery, J.T. Morris, T.J. Tolhurst, L.A. Deegan, and **D.S. Johnson**. 2013. Ecogeomorphology of Tidal Flats. In: John F. Shroder (ed.) *Treatise on Geomorphology*, Volume 12: 201-220.

7. Fleeger, J.W., **D.S. Johnson**, K. A. Galván, and L. A. Deegan. 2008. Top-down and bottom-up control of infauna varies across the saltmarsh landscape. *Journal of Experimental Marine Biology and Ecology* 357:20-34.

8. **Johnson, D.S**., and J.W. Fleeger. 2009. The effect of large-scale nutrient enrichment and predator reduction on macroinfauna in a Massachusetts salt marsh: a four-year study. *Journal of Experimental Marine Biology and Ecology* 373:35-44.

9. **Johnson, D.S**., and B. J. Jessen. 2008. Do spur-throated grasshoppers, *Melanoplus* spp. (Orthoptera: Acrididae), exert top-down control on smooth cordgrass *Spartina alterniflora* in northern New England? *Estuaries and Coasts* 31:912-919.
10. Fleeger, J.W., **D.S. Johnson**, K.R. Carman, P.B. Weisenhorn, A. Gabriele, D. Thistle, and J.P. Barry. 2010. The response of nematodes to deep-sea CO2 sequestration: A quantile regression approach. *Deep Sea Research I* 57:696-707.

SYNERGISTIC ACTIVITIES

1. *Workshops and sessions:* Session organizer for Enriching our coasts: The past, present, and future of fertilization studies as a management guide, Coastal and Estuarine Research Federation, San Diego, CA; Session organizer for, Special Session on Estuarine Ecology, North American Benthological Society meeting, Providence, RI.; Participant to the Climate Ready Estuaries working group, Sponsored by the Massachusetts Bay Program and Environmental Protection Agency.
2. *Outreach activities:* Social Media: Personal blog on science and writing, www.manayunkia.com ; Project blog on nutrient loading in salt marshes, www.tideproject.wordpress.com. Traditional media: Interviews with *Boston Globe* and *Cape Cod Times*; Invited lectures at Environmental Protection Agency, U. of Rhode Island, Sewanee: University of the South, Roanoke College, U. of North Carolina Wilmington, Chesapeake Biological Laboratory, U. of South Carolina, and Amherst College
3. *Mentoring:* 24 Undergraduate and graduate students (including 6 undergraduate theses). Five undergraduate mentees are co-authors on publications including two from above (Johnson and Jessen 2008, Johnson and Short 2013)
4. *Reviewing activities:* Proposals: NSF Science, Engineering and Education for Sustainability (SEES), NSF Graduate Research Fellowship Program, Maine Sea Grant, Maryland Sea Grant. Manuscripts (30+): Including *Global Change Biology, Ecology*, *Ecology Letters*, *Ecological Applications*, *Ecological Monographs*, *Marine Ecology Progress Series*, *Journal of Experimental Marine Biology and Ecology*, *Estuaries and Coasts, Journal of Sea Research*, *Estuarine, Coastal and Shelf Science*

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Professional Preparation

Brown University, Providence, RI.	Biology	B.S., 2001
UC Davis	Population Biology	M.S., 2003
UC Davis	Population Biology	Ph.D., 2008

Appointments

U. of Massachusetts Boston, MA.	Assistant Professor	2012-Present
Nat. Center for Ecological Analysis/Synthesis	Postdoctoral Fellow	2010-2012
Santa Barbara LTER	Postdoctoral Fellow	2008-2012

Five Recent and 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. In Press. Investigating the relationship between biodiversity and ecosystem multifunctionality: Challenges and solutions. *Methods in Ecology and Evolution* [arXiv preprint]

2. Bowen, J. L., **Byrnes, J.E.K.**, Weisman, D., and C. Colaneri. 2013. Functional gene pyrosequencing and network analysis: an approach to examine the response of denitrifying bacteria to increased nitrogen supply in salt marsh sediments. *Frontiers in Microbiology* 4. [doi]

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

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

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List of Five Other Relevant Products

1. Griffin, J. N., **Byrnes, J. E. K.,** and Cardinale, B. J. 2013. Effects of predator richness on prey suppression: a meta-analysis. *Ecology*. 94:2180-2187. [doi]

2. O'Connor, M.I. and **Byrnes, J. E.K.** Biodiversity and Ecosystem Function in Marine Ecosystems. In Press. In Marine Community Ecology and Conservation, M. Bertness, J. Stachowicz, and B. Silliman, eds.

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. Hooper, D.U., Adair, E.C., Cardinale, B.J., **Byrnes, J.E.K.**, Hungate, B.A., Matulich, K.L., Gonzalez, A., Duffy, J.E., Gamfeldt, L., O'Connor, M.I. 2012. Biodiversity loss ranks as a major driver of ecosystem change. *Nature*. 286: 105-108. [doi]

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SYNERGISTIC ACTIVITIES

1) *Workshops:* Global Impacts of Climate Change on Kelp Forests. Leader, National Center for Ecological Analysis and Synthesis working group; The future of publishing in ecology, evolution, and environmental sciences. Leader, National Center for Ecological Analysis and Synthesis working group; Participant in Biodiversity and the functioning of ecosystems: translating results from model experiments to functional reality. National Center for Ecological Analysis and Synthesis working group.
2) *Online Social Media:* 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.
3) *Software Dvelopment:* Contributing Developer for Lavaan - Analysis of latent variable Structural Equation Models in R. http://lavaan.org; Developer for Multifunc - Analysis of multifunctionality in ecological models. http://github.com/jebyrnes/mulfunc
4) *Science Communication & Culture:* Co-Creator of The #SciFund Challenge. A large-scale effort for scientists to teach outreach to scientists by getting them to crowdfund their research. $252K raised to date http://scifundchallenge.org; Participant in Dissertation Initiative for the advancement of Climate Change ReSearch (DISCCRS) participant. Interdisciplinary workshop in climate change communication.
5) *Mentoring:* Two graduate students, one postdoc. One undergraduate thesis in progress, two previous undergraduate theses.

Combined Conflict of Interest

COI Last Name	COI First Name	Institution	Conflicted With	Type of Conflict
Balvanera	Patricia	UNAM	Jarrett Byrnes	Collaborator
Barry	Jim	Monterrey Bay Aquarium Research Institute	David Johnson	Co-Author
Brown	Ken	Louisiana State University	David Johnson	Ph.D. Advisor
Cardinale	Bradley J.	University of Michigan	Jarrett Byrnes	Ph.D. Advisor
Carman	Kevin	Louisiana State University	David Johnson	Ph.D. Advisor
Cavanaugh	Kyle	Smithsonian Environmental Research Center	Jarrett Byrnes	Collaborator
Day	John	Louisiana State University	David Johnson	Ph.D. Advisor
Duffy	J. Emmett	Virginia Institute of Marine Sciences	Jarrett Byrnes	Collaborator
Edwards	Kyle	University of Michigan	Jarrett Byrnes	Collaborator
Fleeger	John	Louisiana State University	David Johnson	Ph.D. Advisor
Fulweiler	Robinson	Boston University	David Johnson	Collaborator
Gamfeldt	Lars	University of Gothenburg, Sweden	Jarrett Byrnes	Collaborator
Gonzalez	Andrew	McGill University	Jarrett Byrnes	Collaborator
Harms	Kyle	Louisiana State University	David Johnson	Ph.D. Advisor
Harris	Lora	Chesapeake Biological Laboratory	David Johnson	Collaborator
Heard	Richard	Gulf Coast Research Laboratory	David Johnson	Collaborator
Holbrook	Sally	University of California Santa Barbara	Jarrett Byrnes	Collaborator
Hooper	David	Western Washington University	Jarrett Byrnes	Collaborator
Hughes	Zoe	Boston University	David Johnson	Co-Author
Hughes	Anne (Randall)	Northeastern University	David Johnson	Collaborator
Hughes	A. Randall	Northeastern University	Jarrett Byrnes	Collaborator
Isbell	Forest	University of Minnesota	Jarrett Byrnes	Collaborator
Jessen	Brita	University of Rhode Island	David Johnson	Collaborator
Kimbro	David	Northeastern University	David Johnson	Collaborator
Kimbro	David	Northeastern University	Jarrett Byrnes	Collaborator
Moseman	Serena	University of Rhode Island	David Johnson	Collaborator
O'Connor	Mary	University of British Columbia	Jarrett Byrnes	Collaborator
Reed	Daniel C.	University of California Santa Barbara	Jarrett Byrnes	Ph.D. Advisor
Reynolds	Pamela	Virginia Institute of Marine Sciences	Jarrett Byrnes	Collaborator
Schmitt	Russ	University of California Santa Barbara	Jarrett Byrnes	Collaborator
Sheldon	Sallie	Middlebury College	David Johnson	Collaborator
Stachowicz	John J.	University of California Davis	Jarrett Byrnes	Thesis Advisor
Warren	Scott	Connecticut College	David Johnson	Co-Author
Wigand	Cathleen	Environmental Protection Agency	David Johnson	Collaborator
Wollheim	William	University of New Hampshire	David Johnson	Co-Author