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).

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PI/PD Name: Matthew C Ferner

Gender: ☒ Male ☐ Female

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

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

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

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

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PI/PD Name: Peter D Roopnarine

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

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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 13-1

NSF 13-508 **01/23/13**

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

DEB - Population and Community Ecology

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1328692

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
01/23/2013	**1**	**08010000 DEB**	**1182**	**808008122**	**01/29/2013 11:19am S**

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 **Preliminary Proposal: Linking Diversity Loss, Food Web Network Structure, and Ecosystem Function in Tidal Marshes**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **0**	**0** months	**09/01/13**	

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 _____
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
_____

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 **Matthew C Ferner**	**PhD**	**2006**	**415-338-3724**	**mferner@sfsu.edu**
CO-PI/PD **Peter D Roopnarine**	**PhD**	**1994**	**415-379-5271**	**proopnarine@calacademy.org**
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:
By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the organization has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Section IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the organization's expenditure of any funds under the award, in accordance with the organization's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

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

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

Directorate for Biological Sciences
Division of Environmental Biology
Population and Community Ecology

Proposal Classification Form
PI: Byrnes, Jarrett / Proposal Number: 1328692

CATEGORY I: INVESTIGATOR STATUS (Select ONE)

- ☑ Beginning Investigator - No previous Federal support as PI or Co-PI, excluding fellowships, dissertations, planning grants, etc.
- ☐ Prior Federal support only
- ☐ Current Federal support only
- ☐ Current & prior Federal support

CATEGORY II: FIELDS OF SCIENCE OTHER THAN BIOLOGY INVOLVED IN THIS RESEARCH (Select 1 to 3)

☐ Astronomy	☐ Engineering	☐ Psychology
☐ Chemistry	☐ Mathematics	☐ Social Sciences
☐ Computer Science	☐ Physics	☐ None of the Above
☑ Earth Science		

CATEGORY III: SUBSTANTIVE AREA (Select 1 to 4)

☐ BIOGEOGRAPHY	☐ Decomposition	☐ Molecular Evolution
☐ Island Biogeography	☐ Biogeochemistry	☐ Methodology/Theory
☐ Historical/ Evolutionary Biogeography	☐ Limnology/Hydrology	☐ Isozymes/ Electrophoresis
☐ Phylogeography	☐ Climate/Microclimate	☐ Nucleic Acid Analysis (general)
☐ Methods/Theory	☐ Whole-System Analysis	☐ Restriction Enzymes
☐ CHROMOSOME STUDIES	☐ Productivity/Biomass	☐ Nucleotide Sequencing
☐ Chromosome Evolution	☐ System Energetics	☐ Nuclear DNA
☐ Chromosome Number	☐ Landscape Dynamics	☐ Mitochondrial DNA
☐ Mutation	☐ Chemical & Biochemical Control	☐ Chloroplast DNA
☐ Mitosis and Meiosis	☐ Global Change	☐ RNA Analysis
☐ COMMUNITY ECOLOGY	☐ Climate Change	☐ DNA Hybridization
☐ Community Analysis	☐ Regional Studies	☐ Recombinant DNA
☑ Community Structure	☐ Global Studies	☐ Amino Acid Sequencing
☐ Community Stability	☐ Forestry	☐ Gene/Genome Mapping
☐ Succession	☐ Resource Management (Wildlife, Fisheries, Range, Other)	☐ Natural Products
☑ Experimental Microcosms/ Mesocosms	☐ Agricultural Ecology	☐ Serology/Immunology
☐ Disturbance	☐ EXTREMOPHILES	☐ PALEONTOLOGY
☐ Patch Dynamics	☐ GENOMICS (Genome sequence, organization, function)	☐ Floristic
☑ Food Webs/ Trophic Structure	☐ Viral	☐ Faunistic
☐ Keystone Species	☐ Microbial	☐ Paleoecology
☐ COMPUTATIONAL BIOLOGY	☐ Fungal	☐ Biostratigraphy
☐ CONSERVATION & RESTORATION BIOLOGY	☐ Plant	☐ Palynology
☐ DATABASES	☐ Animal	☐ Micropaleontology
☐ ECOSYSTEMS LEVEL	☐ MARINE MAMMALS	☐ Paleoclimatology
☐ Physical Structure	☐ MOLECULAR APPROACHES	☐ Archeozoic
		☐ Paleozoic
		☐ Mesozoic

- ☐ Cenozoic
- ☐ POPULATION DYNAMICS & LIFE HISTORY
- ☐ Demography/ Life History
- ☐ Population Cycles
- ☐ Distribution/Patchiness/ Marginal Populations
- ☐ Population Regulation
- ☐ Intraspecific Competition
- ☐ Reproductive Strategies
- ☐ Gender Allocation
- ☐ Metapopulations
- ☐ Extinction
- ☐ POPULATION GENETICS & BREEDING SYSTEMS
- ☐ Variation
- ☐ Microevolution
- ☐ Speciation
- ☐ Hybridization
- ☐ Inbreeding/Outbreeding
- ☐ Gene Flow Measurement
- ☐ Inheritance/Heritability
- ☐ Quantitative Genetics/ QTL Analysis
- ☐ Ecological Genetics
- ☐ Gender Ratios
- ☐ Apomixis/ Parthenogenesis
- ☐ Vegetative Reproduction
- ☐ SPECIES INTERACTIONS
- ☐ Predation
- ☐ Herbivory
- ☐ Omnivory
- ☐ Interspecific Competition
- ☐ Niche Relationships/ Resource Partititioning
- ☐ Pollination/ Seed Dispersal
- ☐ Parasitism
- ☐ Mutualism/ Commensalism
- ☐ Plant/Fungal/ Microbial Interactions
- ☐ Mimicry
- ☐ Animal Pathology
- ☐ Plant Pathology
- ☐ Coevolution
- ☐ Biological Control
- ☐ STATISTICS & MODELING
- ☐ Methods/ Instrumentation/ Software
- ☐ Modeling (general)
- ☐ Statistics (general)
  - ☐ Multivariate Methods
  - ☐ Spatial Statistics & Spatial Modeling
  - ☐ Sampling Design & Analysis
  - ☐ Experimental Design & Analysis
- ☐ SYSTEMATICS
- ☐ Taxonomy/Classification
- ☐ Nomenclature
- ☐ Monograph/Revision
- ☐ Phylogenetics
- ☐ Phenetics/Cladistics/ Numerical Taxonomy
- ☐ Macroevolution
- ☐ NONE OF THE ABOVE

CATEGORY IV: INFRASTRUCTURE (Select 1 to 3)

COLLECTIONS/STOCK CULTURES
- ☐ Natural History Collections
- ☑ DATABASES

FACILITIES
- ☐ Controlled Environment Facilities
- ☐ Field Stations
  - ☐ Field Facility Structure
  - ☐ Field Facility Equipment
- ☐ LTER Site
- ☐ INDUSTRY PARTICIPATION

TRACKING SYSTEMS
- ☐ Geographic Information Systems
- ☐ Remote Sensing
- ☐ NONE OF THE ABOVE

CATEGORY V: HABITAT (Select 1 to 2)

TERRESTRIAL HABITATS

- ☐ GENERAL TERRESTRIAL
- ☐ TUNDRA
- ☐ BOREAL FOREST
- ☐ TEMPERATE
  - ☐ Deciduous Forest
  - ☐ Coniferous Forest
  - ☐ Rain Forest
  - ☐ Mixed Forest
  - ☐ Prairie/Grasslands
  - ☐ Desert
- ☐ SUBTROPICAL
  - ☐ Rain Forest
  - ☐ Seasonal Forest
  - ☐ Savanna
  - ☐ Thornwoods
  - ☐ Deciduous Forest
  - ☐ Coniferous Forest
  - ☐ Desert
- ☐ TROPICAL
  - ☐ Rain Forest
  - ☐ Seasonal Forest
  - ☐ Savanna
  - ☐ Thornwoods
  - ☐ Deciduous Forest
  - ☐ Coniferous Forest
  - ☐ Desert
- ☐ CHAPPARAL/ SCLEROPHYLL/ SHRUBLANDS
- ☐ ALPINE
- ☐ MONTANE
- ☐ CLOUD FOREST
- ☐ RIPARIAN ZONES
- ☐ ISLANDS (except Barrier Islands)
- ☑ BEACHES/ DUNES/ SHORES/ BARRIER ISLANDS
- ☐ CAVES/ ROCK OUTCROPS/ CLIFFS
- ☐ CROPLANDS/ FALLOW FIELDS/ PASTURES
- ☐ URBAN/SUBURBAN
- ☐ SUBTERRANEAN/ SOIL/ SEDIMENTS
- ☐ EXTREME TERRESTRIAL ENVIRONMENT
- ☐ AERIAL

AQUATIC HABITATS

- ☐ GENERAL AQUATIC
- ☐ FRESHWATER
  - ☐ Wetlands/Bogs/Swamps
  - ☐ Lakes/Ponds
  - ☐ Rivers/Streams
  - ☐ Reservoirs
- ☐ MARINE
  - ☐ Open Ocean/Continental Shelf
  - ☐ Bathyal
  - ☐ Abyssal
  - ☐ Estuarine
  - ☐ Intertidal/Tidal/Coastal
  - ☐ Coral Reef
  - ☐ HYPERSALINE
- ☐ EXTREME AQUATIC ENVIRONMENT
- ☐ CAVES/ ROCK OUTCROPS/ CLIFFS
- ☐ MANGROVES
- ☐ SUBSURFACE WATERS/ SPRINGS
- ☐ EPHEMERAL POOLS & STREAMS
- ☐ MICROPOOLS (Pitcher Plants, Tree Holes, Other)

MAN-MADE ENVIRONMENTS

- ☐ LABORATORY
- ☐ THEORETICAL SYSTEMS
- ☐ OTHER ARTIFICIAL SYSTEMS

NOT APPLICABLE

- ☐ NOT APPLICABLE

CATEGORY VI: GEOGRAPHIC AREA OF THE RESEARCH (Select 1 to 2)

- ☐ WORLDWIDE
- ☐ NORTH AMERICA
  - ☐ United States
    - ☐ Northeast US (CT, MA, ME, NH, NJ, NY, PA, RI, VT)
    - ☐ Northcentral US (IA, IL, IN, MI, MN, ND, NE, OH, SD, WI)
    - ☐ Northwest US (ID, MT, OR, WA, WY)
    - ☑ Southeast US (DC, DE, FL, GA, MD, NC, SC, WV, VA)
    - ☐ Southcentral US (AL, AR, KS, KY, LA, MO, MS, OK, TN, TX)
    - ☐ Southwest US (AZ, CA, CO, NM, NV, UT)
    - ☐ Alaska
    - ☐ Hawaii
    - ☐ Puerto Rico
    - ☐ Canada
  - ☐ Mexico
- ☐ CENTRAL AMERICA (Mainland)
  - ☐ Caribbean Islands
  - ☐ Bermuda/Bahamas
- ☐ SOUTH AMERICA
  - ☐ Eastern South America (Guyana, Fr. Guiana, Suriname, Brazil)
  - ☐ Northern South America (Colombia, Venezuela)
  - ☐ Southern South America (Chile, Argentina, Uruguay, Paraguay)
  - ☐ Western South America (Ecuador, Peru, Bolivia)
- ☐ EUROPE
  - ☐ Eastern Europe
  - ☐ Russia
  - ☐ Scandinavia
  - ☐ Western Europe
- ☐ ASIA
  - ☐ Central Asia
  - ☐ Far East
  - ☐ Middle East
  - ☐ Siberia
  - ☐ South Asia
  - ☐ Southeast Asia
- ☐ AFRICA
  - ☐ North Africa
  - ☐ African South of the Sahara
    - ☐ East Africa
    - ☐ Madagascar
    - ☐ South Africa
    - ☐ West Africa
- ☐ AUSTRALASIA
  - ☐ Australia
  - ☐ New Zealand
  - ☐ Pacific Islands
- ☐ ANTARCTICA
- ☐ ARCTIC
- ☐ ATLANTIC OCEAN
- ☐ PACIFIC OCEAN
- ☐ INDIAN OCEAN
- ☐ OTHER REGIONS (Not defined)
- ☐ NOT APPLICABLE

CATEGORY VII: CLASSIFICATION OF ORGANISMS (Select 1 to 4)

- ☐ VIRUSES
  - ☐ Bacterial
  - ☐ Plant
  - ☐ Animal
- ☐ PROKARYOTES
  - ☐ Archaebacteria
  - ☐ Cyanobacteria
  - ☐ Eubacteria
- ☐ PROTISTA (PROTOZOA)
  - ☐ Amoebae
  - ☐ Apicomplexa
  - ☐ Ciliophora
  - ☐ Flagellates
  - ☐ Foraminifera
  - ☐ Microspora
  - ☐ Radiolaria
- ☐ FUNGI
  - ☐ Ascomycota
  - ☐ Basidiomycota
  - ☐ Chytridiomycota
  - ☐ Mitosporic Fungi
  - ☐ Oomycota
  - ☐ Zygomycota
- ☐ LICHENS
- ☐ SLIME MOLDS
- ☐ ALGAE
  - ☐ Bacillariophyta (Diatoms)
  - ☐ Charophyta
  - ☐ Chlorophyta
  - ☐ Chrysophyta
  - ☐ Dinoflagellata
  - ☐ Euglenoids
  - ☐ Phaeophyta
  - ☐ Rhodophyta
- ☐ PLANTS
  - ☐ N0N-VASCULAR PLANTS
    - ☐ BRYOPHYTA
      - ☐ Anthocerotae (Hornworts)
      - ☐ Hepaticae (Liverworts)
      - ☐ Musci (Mosses)
  - ☐ VASCULAR PLANTS
    - ☐ FERNS & FERN ALLIES
    - ☐ GYMNOSPERMS
      - ☐ Coniferales (Conifers)
      - ☐ Cycadales (Cycads)

- ☐ Ginkgoales (Ginkgo)
- ☐ Gnetales (Gnetophytes)
- ☐ ANGIOSPERMS
- ☐ Monocots
- ☐ Arecaceae (Palmae)
- ☐ Cyperaceae
- ☐ Liliaceae
- ☐ Orchidaceae
- ☐ Poaceae (Graminae)
- ☐ Dicots
- ☐ Apiaceae (Umbelliferae)
- ☐ Asteraceae (Compositae)
- ☐ Brassicaceae (Cruciferae)
- ☐ Fabaceae (Leguminosae)
- ☐ Lamiaceae (Labiatae)
- ☐ Rosaceae
- ☐ Solanaceae

☐ ANIMALS

- ☐ INVERTEBRATES
- ☐ MESOZOA/PLACOZOA
- ☐ PORIFERA (Sponges)
- ☐ CNIDARIA
- ☐ Hydrozoa (Hydra, etc.)
- ☐ Scyphozoa (Jellyfish)
- ☐ Anthozoa (Corals, Sea Anemones)
- ☐ CTENOPHORA (Comb Jellies)
- ☐ PLATYHELMINTHES (Flatworms)
- ☐ Turbellaria (Planarians)
- ☐ Trematoda (Flukes)
- ☐ Cestoda (Tapeworms)
- ☐ Monogenea (Flukes)
- ☐ GNATHOSTOMULIDA
- ☐ NEMERTINEA (Rynchocoela) (Ribbon Worms)
- ☐ ENTOPROCTA (Bryozoa) (Plant-like Animals)
- ☐ ASCHELMINTHES
- ☐ Gastrotricha
- ☐ Kinorhyncha
- ☐ Loricifera
- ☐ Nematoda (Roundworms)
- ☐ Nematomorpha (Horsehair Worms)
- ☐ Rotifera (Rotatoria)
- ☐ ACANTHOCEPHALA (Spiny-headed Worms)
- ☐ PRIAPULOIDEA
- ☐ BRYOZOA (Ectoprocta) (Plant-like Animals)
- ☐ PHORONIDEA (Lophophorates)
- ☐ BRACHIOPODA (Lamp Shells)
- ☐ MOLLUSCA
- ☐ Monoplacophora
- ☐ Aplacophora (Solenogasters)
- ☐ Polyplacophora (Chitons)
- ☐ Scaphopoda (Tooth Shells)
- ☐ Gastropoda (Snails, Slugs, Limpets)
- ☐ Pelecypoda (Bivalvia) (Clams, Mussels, Oysters, Scallops)
- ☐ Cephalopoda (Squid, Octopus, Nautilus)
- ☐ ANNELIDA (Segmented Worms)
- ☐ Polychaeta (Parapodial Worms)
- ☐ Oligochaeta (Earthworms)
- ☐ Hirudinida (Leeches)
- ☐ POGONOPHORA (Beard Worms)
- ☐ SIPUNCULOIDEA (Peanut Worms)
- ☐ ECHIUROIDEA (Spoon Worms)
- ☐ ARTHROPODA
- ☐ Cheliceriformes
- ☐ Merostomata (Horseshoe Crabs)
- ☐ Pycnogonida (Sea Spiders)
- ☐ Scorpionida (Scorpions)
- ☐ Araneae (True Spiders)
- ☐ Pseudoscorpionida (Pseudoscorpions)
- ☐ Acarina (Free-living Mites)
- ☐ Parasitiformes (Parasitic Ticks & Mites)
- ☑ Crustacea
- ☐ Branchiopoda (Fairy Shrimp, Water Flea)
- ☐ Ostracoda (Sea Lice)
- ☐ Copepoda
- ☐ Cirripedia (Barnacles)
- ☐ Amphipoda (Skeleton Shrimp, Whale Lice, Freshwater Shrimp)
- ☐ Isopoda (Wood Lice, Pillbugs)
- ☐ Decapoda (Lobster, Crayfish, Crabs, Shrimp)
- ☑ Hexapoda (Insecta) (Insects)
- ☐ Apterygota (Springtails, Silverfish, etc.)
- ☐ Odonata (Dragonflies, Damselflies)
- ☐ Ephemeroptera (Mayflies)
- ☐ Orthoptera (Grasshoppers, Crickets)
- ☐ Dictyoptera (Cockroaches, Mantids, Phasmids)
- ☐ Isoptera (Termites)
- ☐ Plecoptera (Stoneflies)
- ☐ Phthiraptera (Mallophaga & Anoplura) (Lice)
- ☐ Hemiptera (including Heteroptera) (True Bugs)
- ☐ Homoptera (Cicadas, Scale Insects, Leafhoppers)
- ☐ Thysanoptera (Thrips)
- ☐ Neuroptera (Lacewings, Dobsonflies, Snakeflies)
- ☐ Trichoptera (Caddisflies)
- ☐ Lepidoptera (Moths, Butterflies)
- ☐ Diptera (Flies, Mosquitoes)
- ☐ Siphonaptera (Fleas)
- ☐ Coleoptera (Beetles)
- ☐ Hymenoptera (Ants, Bees, Wasps, Sawflies)
- ☐ Chilopoda (Centipedes)
- ☐ Diplopoda (Millipedes)
- ☐ Pauropoda
- ☐ Symphyta (Symphyla)
- ☐ PENTASTOMIDA (Linguatulida) (Tongue Worms)
- ☐ TARDIGRADA (Tardigrades, Water Bears)
- ☐ ONYCHOPHORA (Peripatus)
- ☐ CHAETOGNATHA (Arrow Worms)
- ☐ ECHINODERMATA
- ☐ Crinoidea (Sea Lilies, Feather Stars)
- ☐ Asteroidea (Starfish, Sea Stars)
- ☐ Ophiuroidea (Brittle Stars, Serpent Stars)
- ☐ Echinoidea (Sea Urchins, Sand Dollars)
- ☐ Holothuroidea (Sea Cucumbers)
- ☐ HEMICHORDATA (Acorn Worms, Pterobranchs)
- ☐ UROCHORDATA (Tunicata) (Tunicates, Sea Squirts, Salps, Ascideans)
- ☐ CEPHALOCHORDATA (Amphioxus/Lancelet)
- ☐ VERTEBRATES
- ☐ AGNATHA (Hagfish, Lamprey)
- ☐ FISHES
- ☐ Chondrichthyes (Cartilaginous Fishes) (Sharks, Rays, Ratfish)
- ☐ Osteichthyes (Bony Fishes)
- ☐ AMPHIBIA
- ☐ Anura (Frogs, Toads)
- ☐ Urodela (Salamanders, Newts)
- ☐ Gymnophiona (Apoda) (Caecilians)
- ☐ REPTILIA
- ☐ Chelonia (Turtles, Tortoises)
- ☐ Serpentes (Snakes)
- ☐ Sauria (Lizards)
- ☐ Crocodylia (Crocodilians)
- ☐ AVES (Birds)
- ☐ Passeriformes (Passerines)
- ☐ MAMMALIA
- ☐ Monotremata (Platypus, Echidna)
- ☐ Marsupalia (Marsupials)
- ☐ Eutheria (Placentals)
- ☐ Insectivora (Hedgehogs, Moles, Shrews, Tenrec, etc.)
- ☐ Chiroptera (Bats)
- ☐ Primates
- ☐ Humans
- ☐ Rodentia
- ☐ Lagomorphs (Rabbits, Hares, Pikas)
- ☐ Carnivora (Bears, Canids, Felids, Mustelids, Viverrids, Hyena, Procyonids)
- ☐ Perissodactyla (Odd-toed Ungulates) (Horses, Rhinos, Tapirs, etc.)

☐ Artiodactyla (Even-toed Ungulates) (Cattle, Sheep, Deer, Pigs, etc.) ☐ Marine Mammals (Seals, Walrus, Whales, Otters, Dolphins, Porpoises)	☐ TRANSGENIC ORGANISMS ☐ FOSSIL OR EXTINCT ORGANISMS	☐ NO ORGANISMS

CATEGORY VIII: MODEL ORGANISM (Select ONE)		
☑ NO MODEL ORGANISM MODEL ORGANISM (Choose from the list)	☐ Escherichia coli ☐ Mouse-Ear Cress (Arabidopsis thaliana)	☐ Fruitfly (Drosophila melanogaster)

PROJECT SUMMARY

Overview:

The project will contribute to the unification of the fields of biodiversity-ecosystem function and food web network theory. It will lead to a broader understanding of how human caused extinctions of predators may lead to changes in ecosystem function. It will bridge our understanding of terrestrial and marine processes in tidal marshes.

Intellectual Merit :

As ecologists struggle to understand the consequences of human-driven species extinctions, we have come to an impasse. First, while ecologists understand the consequences of primary producer extinctions quite well, the impacts of consumer or predator species loss appear to be contingent on food web structure with little predictability to date. Second, while we have focused on the consequences of species loss for production and resource use, natural ecosystems perform a wide variety of other functions and services that we have ignored. This project proposes to (1) evaluate how the structure of a food web can predictably influence the effects of predator species loss in nature, and (2) link this loss to a suite of societally relevant ecosystem functions that will be impacted by climate change.

We propose to create a series of investigations to explicitly link food web structure to changes in the functioning of salt marsh ecosystems on both coasts of the contiguous United States. To achieve our goals, this project will be one of the first ever to simultaneously examine the properties and function of terrestrial and marine salt marsh food webs. The project will lead to (1) an extensive understanding of the similarities and differences in the coupled marine-terrestrial food webs of East and West Coast salt marshes, (2) an intensive sampling effort within the marshes to examine change over time in U.S. salt marshes linked with ongoing efforts of the National Estuarine Research Reserve System, and (3) a series of manipulative experiments altering both the predator species richness and food web structure to explore how food web structure alters the consequences of extinction.

Broader Impacts :

This project will have broader impacts on the local and global scientific and public communities by: (1) training and mentoring graduate students and undergraduate research technicians (drawn from a pool at UMB where 57% were female and 44% were minorities), (2) constructing a publicly available U.S. salt marsh food web database, (3) standardizing how to create a food web database for any ecosystem using publicly available software created with the help of undergraduate students at UMB, (4) creating an online outreach project blog and Twitter feed, (5) having project scientists participate in local science-oriented education events, (6) conducting short training courses in the application of multivariate statistics to ecological problems.

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.

Title

Preliminary Proposal: Linking Diversity Loss, Food Web Network Structure, and Ecosystem Function in Tidal Marshes

Personnel

Jarrett Byrnes: PI, Assistant Professor, University of Massachusetts Boston. Byrnes will create the New England tidal marsh food web, conduct field surveys, assemble, and perform the food web manipulations.

Matthew Ferner: Co-PI. Research Coordinator, San Francisco Bay National Estuarine Research Reserve. Ferner will conduct surveys and field manipulations in California and co-ordinate with the NERR long-term sampling programs.

Peter Roopnarine: Co-PI, Curator, California Academy of Sciences. Roopnarine will create the San Francisco Bay tidal marsh food web, perform food web manipulations, and co-ordinate the project and outreach.

Jennifer Bowen: Senior Staff, Assistant Professor, University of Massachusetts Boston. Bowen will assist students in conducting assays of soil respiration and microbial production as part of observational and manipulative experiments.

Conceptual Framework

As rates of extinction accelerate to match the magnitudes of geological mass extinction events (Barnosky et al. 2011), ecologists have come to understand that reductions in primary producer diversity will reduce primary production and accompanying functions in nature (Cardinale et al. 2011). The earth, however, is not composed solely of plants and algae. **When considering the consequences of consumer extinctions, the field of biodiversity-ecosystem function research has largely failed to find general conclusions for any function measured.** Both theoretical (Thebault and Loreau 2006) and experimental (Finke and Denno 2004, Dang et al. 2005, Byrnes et al. 2006) explorations of changes to animal diversity – be it herbivore, predator, or otherwise – have yielded wildly different predictions even for simple phenomena such as trophic cascades. At first glance this discrepancy seem to result from idiosyncrasies of manipulated species. On further examination, we have begun to discern that certain properties of food webs – the balance of generalists and specialists, the frequency of intraguild predation and omnivory, the number of trophic levels – appear to have predictable effects on the probability that extinction of animals will have cascading effects on ecosystem function (Roopnarine and Angielczyk 2011). However, we do not as of yet have a single framework that addresses the simultaneous effects of changes in trophic complexity and species richness for ecosystem function (Loreau 2009). Nor do we understand how predator extinctions will influence functions other than the raw abundances of species involved in trophic cascades, despite their effect on a variety of ecosystem functions.

Here we propose to conduct a series of observational and manipulative experiments to examine how food web structure alters the effect of local predator extinctions on multiple ecosystem functions in tidal marshes. We will do this in marshes on both coasts of the U.S. to utilize the large variation in food web structure both within and between coasts in similar systems to better enable us to tease out the role of food web structure *per se*. We will use marshes because they are a unique blend of terrestrial and marine food webs, making them a compelling system to look at the connection between trophic webs and ecosystem services. Furthermore, little work has been done that evaluates the joint effects of marine and terrestrial marsh food webs on ecosystem functions.

Background & Rationale

We are seeking to broaden the field of *biodiversity-ecosystem function research* to incorporate ideas from *food web network theory.* The two have advanced in parallel over the past two decades with little communication between them. Biodiversity Ecosystem Function (BEF) research explores the consequences of species extinctions for the flux of energy and nutrients within ecosystems (Hooper et al. 2005) while food web network theory seeks to characterize the network topology (i.e., species as nodes and feeding relationships as links on a directed graph) of food webs (Dunne 2006) and their robustness to perturbations (Roopnarine 2006, Dunne and Williams 2009). The two fields of research are in fact both examining how the removal of nodes, or species, affects the functioning of ecological networks, from different perspectives. We propose to explore how biodiversity ecosystem function research and food web network theory can be unified by examining the variation in ecosystem functions in food webs that differ in aspects of their topology – both species richness and connectance.

We seek to expand the focus of BEF research beyond the estimation of the relationship between diversity and one function to truly quantify the effect of food web topology on

ecosystem multifunctionality (Zavaleta et al. 2010)**.** Only a handful of studies currently examine the effect of reducing diversity on more than one function (Byrnes et al. In Review). Yet the effects of diversity on multiple functions have been suggested to be stronger than their effects on any single function alone (Duffy et al. 2003). With marsh ecosystems providing multiple important ecosystem services – shoreline protection, nursery habitat, runoff filtration, food for commercially important nearshore species, carbon storage and potentially others (Millenium Ecosystem Assessment 2005), we seek to quantify how diversity and connectance influence multiple functions simultaneously.

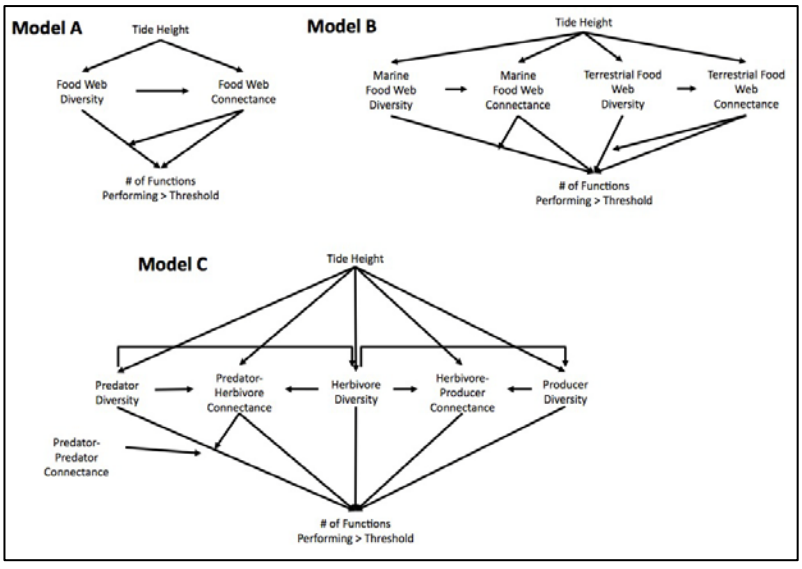
Research Questions & Approach

1) Who eats whom in tidal marshes?

As a first step in this work, we will compile a database of who eats whom in the California and New England marshes (both marine and terrestrial). Although there has been great deal of work done in individual systems, with the exception of Hechinger et al. 2011, no where has there been a unified regional collection of this information, nor is there much that unifies terrestrial and marine portions of the food web. Our starting point in California will be established Southern California Webs (Hechinger et al. 2011), and a database of trophic links compiled by co-PI Roopnarine based on collections at the California Academy of Sciences. The latter database currently comprises 1,283 invertebrate species, 125 fish species (bony and cartilaginous), 117 bird species and 12 mammal species. In New England, we will build our web from the literature (Bertness 1998), consulting additional experts where necessary (as in Byrnes et al. 2011). Information will be input into an online publicly available food web database adapted from a similar kelp forest database being developed at UC Santa Cruz on which PI Byrnes has collaborated (http://kelpforest.ucsc.edu/). We will build trophic group structures *de novo* based on our results (Allesina and Pascual 2009)

2) Does food web structure modify multifunctionality in tidal marsh ecosystems?

Figure 1: Path models to be fit with SEM describing links between food web structure and multifunctionality.



To determine relationships between tidal marsh food web structure and multifunctionality, we will first model results from surveys in National Estuarine Research Reserve (NERR) sites on both coasts of the U.S. We will sample multiple marshes within the San Francisco Bay NERR, the Wells NERR in Maine and the Waquoit Bay NERR in Massachusetts. We will use multiple NERR sites on both coasts in order to sample across a wide array of abiotic conditions and food web structures. We will conduct our sampling in conjunction with ongoing permanent

vegetation, groundwater, and soil property transects at NERR sites in order to supplement their current publically available data collection effort. We will supplement their efforts by subsampling adjacent marsh areas with visual species counts, destructive sampling (e.g., using a D-vac suction sampler for insects), detrital collectors, and animal traps to quantify the presence/absence and abundance of all invertebrate herbivores and predators and marine primary producers (Whitcraft et al. 2011, Robinson et al. 2011). We will also perform bird surveys at the site level. In concert with our food web database, we will then evaluate the local food web structure and the distribution of organisms between different trophic groups. **We will the perform assays for the following ecosystem functions: predation rates on snails, crabs, and beetles, grazing on algal detritus and live cordgrass, decomposition of *Spartina*, soil respiration at low tide, and surface microbial production (Bowen et al. 2009)**.

With these data, we will use Structural Equation Models(Grace et al. 2012)to compare four alternate models relating food web structure to ecosystem multifunctionality – the number of functions performing at some fraction of their maximum (Zavaleta et al. 2010). We will compare the explanatory power of models (Figure 1) that look at a) whole web topology, b) partition webs into terrestrial and marine topologies separately, c) look at toplogical features at the level of trophic groups, or d) look at toplogical features at the level of trophic groups separating terrestrial and marine components of the food web (not shown). We will also conduct a multigroup analysis(Grace 2006) to evaluate the effects of coast on parameters.

3) How does food web structure alter the impact of predator diversity on multifunctionality?

To explore how food web structure can alter the consequences of predator extinctions for multifunctionality in tidal marshes, we will conduct a manipulative experiment that evaluates the interaction between changing diversity and food web structure on both coasts. We will manipulate both the marine and terrestrial portions of a food web consisting of predatory crabs, spiders, beetles, herbivorous crabs, snails, and insects, and a base of algae and tidal marsh plants (e.g., Fig. 2 for San Francisco Bay). Manipulating both food webs gives us the ability to create a wide variety of food web structures.

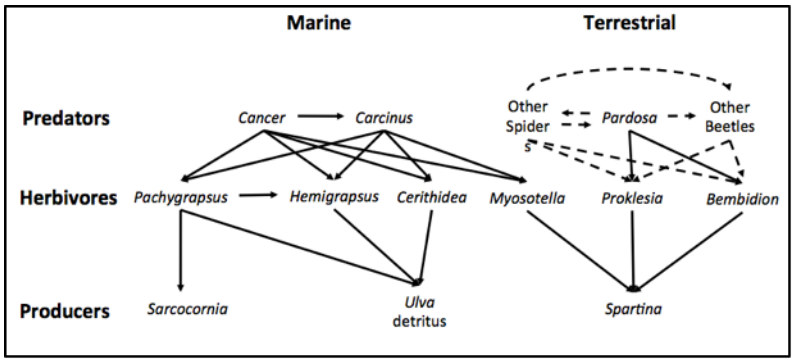


Figure 2: Potential tidal marsh food web for manipulation in experiments (Barnby et al. 1985; Daehler 1995; Hechinger et al. 2011). Species are listed by genus name. Solid lines indicate a feeding relationship. Dashed lines indicate a feeding relationship suggested by the literature.

In our food web manipulations, we will assemble multiple community types and evaluate how food web structure alters the impacts of species loss by comparing specific pairs of community types. We will repeat this experiment at three marshes on each coast. The exact species being manipulated will depend on the baseline data collected from surveys at that site, thus leading to a wide variety of food web configurations across all experiments. All communities will be assembled in 1x0.5m cages in the low marsh. On the East coast, this will be in the *Spartina* zone. In San Francisco marshes, we will replicate this in both the low *Spartina* marsh and *Sarcocornia* marshes. After all animals are cleared, cages will be stocked regularly with green algae from the

genus *Ulva*, all herbivores, and one of the following predator treatments using a replacement design: 4 predator species, both marine predators only, both terrestrial predators only, all combinations of one marine and one terrestrial predator, monocultures of each predator, and a no predator control. At the end of the experiment (2 months), we will evaluate multifunctionality in cages using the assays described in the survey section above as well as recording total standing stock of all species in cages. By comparing the 4-species treatment to each 2-species treatment, we can evaluate how simultaneous shifts in food web structure along with diversity alter multifunctionality. By comparing each 2-species treatment to its component monocultures, we can further evaluate how initial food web structure modifies the relative impacts of extinction. We will repeat this experiment twice over 2 years with n=3 per trial using 3 marsh sites per coast. We will pool all of the experiments together and evaluate the relative role of food web structure for multifunctionality using the modeling framework from surveys.

Broader Impacts

Our project focuses on three types of outreach: building new tools for science, public outreach, and academic training. **With respect to new tools, we hope that our food web database will become a new standard format in ecology.** We are currently building a set of tools in collaboration with an UMB undergraduate software design course to create a generalized food web database for any system. This will be freely available to the scientific community.

We have a four-point plan for outreach. *First, we will maintain and promote a project blog* intended for public outreach. Every week we will post one or more of three types of items: photos from the sites with accompanying natural history notes, stories from the field, or a discussion of environmental issues in tidal marshes. We will actively promote this blog through online social media, where PI Byrnes has been active since 2005 and co-PI Roopnarine since 2007 (see synergistic activities). *Second, PIs will maintain an active voice in the online discussion of science via Twitter* (e.g., see http://twitter.com/jebyrnes). Information tweeted by scientists influences both the public scientific discussion and the development of science itself, with tweeted papers increasing their citation rates (Eysenbach 2011). *Third, project scientists will speak at local science cafes* around Boston and the San Francisco Bay Area (e.g., http://www.askascientistsf.com/) about the natural history and novel ecological aspects of the work. *Finally, PIs will use the public programming infrastructure of the California Academy of Sciences*, a natural history museum with ~2 million annual visitors, to present results to the public as part of the Morrison Planetarium's "Earth Update" series, the public floor's "Science in Action" venue, and the online series "Science Today."

Our project presents several opportunities for training. The project will fund a PhD student in PI Byrnes's lab who will conduct field and lab work on both coasts. PI Ferner will host the graduate student at the Romberg Tiburon Center. At the RTC and UMB, our project will hire and train undergraduate research technicians. Co-PI Roopnarine will advise one Masters student in the joint Academy/SFSU graduate program as part of the project who will work on the food web construction and analysis. One quarter of the student's time will be spent working with the Academy's Public Programs department on the dissemination of this project's results. We also plan to offer a short summer course in Structural Equation Modeling at both UMB and Tiburon taught by PI Byrnes.

References Cited

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Barnosky, A. D., N. Matzke, S. Tomiya, G. O. U. Wogan, B. Swartz, T. B. Quental, C. Marshall, J. L. McGuire, E. L. Lindsey, K. C. Maguire, Ben Mersey, and E. A. Ferrer. 2011. Has the Earth's sixth mass extinction already arrived? Nature 471:51–57.

Bertness, M. D. 1998. The Ecology of Atlantic Shorelines. Sinauer Associates Inc.

Bowen, J. L., B. C. Crump, L. A. Deegan, and J. E. Hobbie. 2009. Increased supply of ambient nitrogen has minimal effect on salt marsh bacterial production. Limnology and Oceanography 54:713–722.

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.

Byrnes, J. E., J. J. Stachowicz, K. M. Hultgren, A. R. Hughes, S. V. Olyarnik, and C. S. Thornber. 2006. Predator diversity strengthens trophic cascades in kelp forests by modifying herbivore behavior. Ecology letters 9:61–71.

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.

Dang, C. K., E. Chauvet, and M. O. Gessner. 2005. Magnitude and variability of process rates in fungal diversity-litter decomposition relationships. Ecology letters 8:1129–1137.

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.

Dunne, J. A. 2006. The network structure of food webs. Pages 27–86 *in* M. Pascual and J. A. Dunne, editors. Ecological Networks: Linking Structure to Dynamics in Food Webs. Oxford University Press.

Dunne, J. A., and R. J. Williams. 2009. Cascading extinctions and community collapse in model food webs. Philosophical Transactions of the Royal Society B: Biological Sciences 364:1711–1723.

Finke, D. L., and R. F. Denno. 2004. Predator diversity dampens trophic cascades. Nature 429:407–410.

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

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.

Hechinger, R. F., K. D. Lafferty, J. P. McLaughlin, B. L. Fredensborg, T. C. Huspeni, J. Lorda, P. K. Sandhu, J. C. Shaw, M. E. Torchin, K. L. Whitney, and A. M. Kuris. 2011. Food webs including parasites, biomass, body sizes, and life stages for three California/Baja California estuaries. Ecology 92:791–791.

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.

Loreau, M. 2009. Linking biodiversity and ecosystems: towards a unifying ecological theory. Philosophical Transactions of the Royal Society B: Biological Sciences 365:49–60.
Robinson, A., A. N. Cohen, B. Lindsey, and L. Grenier. 2011. Distribution of Macroinvertebrates Across a Tidal Gradient, Marin County, California. San Francisco Estuary and Watershed Science 9:1–14.
Roopnarine, P. D. 2006. Extinction cascades and catastrophe in ancient food webs. Paleobiology 32:1–19.
Roopnarine, P. D., and K. D. Angielczyk. 2011. The evolutionary palaeoecology of species and the tragedy of the commons. Biology Letters.
Thebault, E., and M. Loreau. 2006. The relationship between biodiversity and ecosystem functioning in food webs. Ecological Research 21:17–25.
Whitcraft, C., B. J. Grewell, and P. R. Baye. 2011. Estuarine Vegetation at Rush Ranch Open Space Preserve, San Francisco Bay National Estuarine Research Reserve, California. San Francisco Estuary and Watershed Science 9.
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.

Biographical Sketch

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Expertise as Related to the Proposed Research

PI Byrnes has been conducting research in the field of predator biodiversity and ecosystem function for the past ten years. He has conducted predator diversity manipulations in rocky intertidal, kelp forest, fouling community, and laboratory settings. He assembled and published one of the first large-scale kelp forest food webs. He recently authored a new work unifying out approaches for measuring the relationship between biodiversity and ecosystem multifunctionality. Additionally, he is an active participant in online science activities that he uses as a tool both for communication within and outside of science.

Professional Preparation & Appointments

2012 – Present Assistant Professor, University of Massachusetts Boston
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.

List of Five Relevant Publications

1. Byrnes, J.E.K., Gamfeldt, L., Isbell, F., Lefcheck, J.S., Griffin, J.N., Hector, A., Cardinale, B.J., Hooper, D.U., and Duffy, J.E. In Review. Investigating the relationship between biodiversity and ecosystem multi-functionality: Challenges and solutions.

2. 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.

3. 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]

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 Other Publications

1. Byrnes, J.E.K., Cardinale, B.J., and Reed, D.R. In Press. Sea urchin grazing increases with prey diversity on temperate rocky reefs. *Ecology*.

2. Hooper, D.U., Adair, E.C., Cardinale, B.J., **Byrnes, J.E.K.**, Hungate, B.A., Matulich, KL., Gonzalez, A., Duffy, J.E., Gamfeldt, L., O'Connor, M.I. 2012. Biodiversity loss ranks as a major driver of ecosystem change. *Nature*.

3. Cardinale, B.J., Matulich, K., Hooper, D.U., **Byrnes, J.E.**, Duffy, E., Gamfeldt, L., Balvanera, P., O'Connor, M.I., Gonzalez, A. 2011. The functional role of producer diversity in ecosystems. *American Journal of Botany*. 98: 572-592. [doi]

4. Byrnes, J.E. and Stachowicz, J.J. 2009. Short and Long Term consequences of increases in exotic species richness on water filtration by marine invertebrates. *Ecology Letters*. 8: 830-841. [doi]

5. Hughes A.R., **Byrnes J.E.**, Kimbro D.L. & Stachowicz J.J. 2007. Reciprocal relationships and potential feedbacks between biodiversity and disturbance. *Ecology Letters*. 10: 849-864. [doi]

Synergistic Activities

1. 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.

2. Contributing Developer for Lavaan - Analysis of latent variable structural equation models in R. http://lavaan.org

3. 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

4. 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.

5. Participant in Dissertation Initiative for the advancement of Climate Change ReSearch (DISCCRS) participant. Interdisciplinary workshop in climate change communication.

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PROFESSIONAL PREPARATION:
University of Louisville, Biology, B.A., 1989-1993.
University of Washington, Oceanography, M.S., 1993-1996.
Georgia Institute of Technology, Applied Biology, Ph.D., 2000-2006.
University of California-Davis, Evolution and Ecology, Postdoctoral Scholar, 2006-2008.

CURRENT APPOINTMENTS:
Adjunct Assistant Professor, School of Biology, San Francisco State University, 2008-present.
Research Coordinator, San Francisco Bay National Estuarine Research Reserve, 2008-present.

CURRENT RESEARCH INTERESTS:
climate change effects on estuaries, coastal oceanography, hydrodynamics, larval settlement, nonlethal predator effects, pelagic-benthic linkages, sensory ecology, tidal marsh ecology

5 RELEVANT PUBLICATIONS:
Ferner MC. 2012. Research reserves as a model for conservation science and management of tidal marshes. In *Ecology, conservation and restoration of tidal marshes: the San Francisco Estuary* (A. Palaima, Ed.). University of California Press, Berkeley, California.
Ferner MC. 2012. Conclusion to the Special Issue: Ecology and regional context of tidal wetlands in the San Francisco Bay National Estuarine Research Reserve. *San Francisco Estuary and Watershed Science* 10(2). http://escholarship.org/uc/item/91815085
Smee DL, Ferner MC, Weissburg MJ. 2010. Hydrodynamic sensory stressors produce nonlinear predation patterns. *Ecology* 91: 1391-1400.
Ferner MC, Smee DL, Weissburg MJ. 2009. Habitat complexity alters lethal and nonlethal olfactory interactions between predators and prey. *Marine Ecology Progress Series* 374: 13-22.
Smee DL, Ferner MC, Weissburg MJ. 2008. Alteration of sensory abilities regulates the spatial scale of nonlethal predator effects. *Oecologia* 156: 399-409.

5 ADDITIONAL PUBLICATIONS:
Ferner MC, Gaylord B. 2008. Flexibility foils filter function: structural constraints on benthic suspension feeding. *Journal of Experimental Biology* 211: 3563-3572.
Ferner MC, Smee DL, Chang YP. 2005. Cannibalistic crabs respond to the scent of injured conspecifics: danger or dinner? *Marine Ecology Progress Series* 300: 193-200.
Ferner MC, Weissburg MJ. 2005. Slow-moving predatory gastropods track prey odors in fast and turbulent flow. *Journal of Experimental Biology* 208: 809-819.
Weissburg MJ, Ferner MC, Pisut DP, Smee DL. 2002. Ecological consequences of chemically mediated prey perception. *Journal of Chemical Ecology* 28: 1933-1970.
Ferner MC, Jumars PA. 1999. Responses of spionid polychaetes to dissolved chemical cues. *Journal of Experimental Marine Biology and Ecology* 236: 89-106.

PROFESSIONAL HONORS AND AWARDS:

Principal Investigator, Managing for resilience in the face of climate change: a scientific approach to targeted oyster restoration in San Francisco Bay and Elkhorn Slough, CA, 2011.
Invited lecturer, University of California-Davis, 2008-2010.
Invited lab instructor, University of California-Davis, Bodega Marine Laboratory, 2006.
IGERT Special Award for research progress, Georgia Institute of Technology, 2005.
Invited lecturer, Georgia Institute of Technology, 2004-2005.
Invited participant, NSF working group on "Coastal Benthic Exchange Dynamics," Coastal Ocean Processes (CoOP) Program Workshop, 2004.
Invited lecturer, Savannah State University, 2003-2004.
People's Choice Award for scientific poster, Estuarine Research Federation, 2003.
IGERT Student Research Grant, Georgia Institute of Technology, 2002.
Focused Research Program Grant, Georgia Institute of Technology, 2001.
Lovell Award in Biology, University of Louisville, 1993.

SYNERGISTIC ACTIVITIES:

Co-Chair of the NERRS System-Wide Monitoring Program Guidance Committee, 2012-2013.
Member of the NERRS System-Wide Monitoring Program Guidance Committee, 2009-2012.
Member of the NERRS Habitat Mapping and Change Technical Committee, 2010-2013.
Graduate Committee Member for multiple SF State and UC Berkeley students, 2009-2013.
Summer Session Instructor for *Mechanical Design in Organisms* (EVE106), *Marine Environmental Issues* (EVE111), and *Coastal Marine Research* (BIS124), University of California-Davis, Bodega Marine Laboratory, 2010.
Science Fair Judge for California public schools (grades 6-12), 2007.
Outreach educator with *OceanDiscovery!* facilitating scientific literacy in under-represented middle-school students, 2006-2007.
Resource Scientist for Teacher's Workshop on *Estuary Ecology* run by San Francisco Bay National Estuarine Research Reserve, 2006, 2011.
Wetland Scientist for *EstuariesLive* broadcast to over 15,000 K-12 students, 2005.
High School Science Faculty, Kentucky Country Day School, Louisville, Kentucky 1997-2000.

Department of Invertebrate Zoology & Geology
California Academy of Sciences
55 Music Concourse Drive
San Francisco CA 94118

Professional Preparation

Mount Allison University, New Brunswick, Canada	Biology	B.Sc., 1984
Nova Southeastern University, Davie, Florida	Ocean Sciences	M.S., 1988
University of California Davis	Geology	Ph.D., 1994

Appointments

CURATOR; Department of Invertebrate Zoology & Geology, California Academy of Sciences. 2008 - present.
CHAIR; Department of Invertebrate Zoology & Geology, California Academy of Sciences. 2008 - present.
RESEARCH ASSOCIATE; University of California Museum of Paleontology, University of California Berkeley. 2005 - present.
RESEARCH PROFESSOR; Department of Biology, San Francisco State University. 2001 - present.
ADJUNCT PROFESSOR; Department of Geosciences, San Francisco State University. 2001 - present.
Associate Curator, California Academy of Sciences, 2004-2008
Chair, Dept. of Invertebrate Zoology & Geology, June, 2001-2004
Assistant Curator, California Academy of Sciences, 1999-2004
Research Associate, University of Arizona, 1997-1998
Assistant Professor, Southeast Missouri State University, 1994-1999

Professional Service

2002-present.	Board of Directors, *Paleontologia Electronica*.
2004-present.	Biology Representative, Affiliated Institutes, American Association for the Advancement of Science.
2010-2011.	Academic Editor, *PLoS One*.
2010.	Co-Editor, *Proc. California Academy of Sciences*.
2002-2011.	Special Issues Editor, *Paleontologia Electronica*.
2007.	Chair, Organizing Committee, CalPaleo Annual Meeting.
2005.	Co-Organizer, Annual Meetings of the American Malacological Society and the Western Society of Malacologists.
2005.	President, Western Society of Malacologists.
2004.	President-Elect and Council Member, Western Society of Malacologists.
2003-2004.	Associate Editor, Journal of Paleontology.
2000-2004.	Councilor-At-Large, American Malacological Society.

Relevant expertise

- Food web modeling and numerical analysis.
- Ecological data analysis.
- Expertise in San Francisco Bay marine fauna.

- Expertise in San Francisco Bay oceanography.

Five publications related to this project

Roopnarine, P. D. 2012. Red queen for a day: models of symmetry and selection in paleoecology. *Evolutionary Ecology*, 26:1-10. DOI: 10.1007/s10682-011-9494-6

Roopnarine, P. D. and Angielczyk, K. D. 2012. The evolutionary palaeoecology of species and the tragedy of the commons. *Biology Letters*, 8:147-150. DOI:10.1098/rsbl.2011.0662

Roopnarine, P. D. and R. Hertog. 2012. Detailed food web networks of three Greater Antillean coral reef systems: The Cayman Islands, Cuba and Jamaica. *Dataset Papers in Ecology*, Vol. 23, 9 p.

Roopnarine, P. D. 2010. Networks, extinction and paleocommunity food webs in J. Alroy and G. Hunt, eds., *Quantitative Methods in Paleobiology*, The Paleontological Society Papers, 16: 143-161.

Simons, J. D. et al. 2013. Building a fisheries trophic interaction database for management and modeling research in the Gulf of Mexico large marine ecosystem. *Bulletin of Marine Science* (in press).

Five other publications

Barnosky, A. et al. 2012. Approaching a state-shift in Earth's biosphere. *Nature*, 486:52-58.

Goodwin, D. H., D. Gillkin and P. Roopnarine. 2013. Preliminary evaluation of potential stable isotope and trace element productivity proxies in the oyster *Crassostrea gigas*. *Palaeogeography, Palaeoclimatology, Palaeoecology* (in press).

Goodwin, D. H., A. N. Cohen and P. D. Roopnarine 2010. Forensics on the half shell: A sclerochronological investigation of a modern biological invasion in San Francisco Bay, United States. *Palaios*, 25:742-753.

Mindell DP, Fisher BL, Roopnarine P, Eisen J, Mace GM, et al. 2011. Aggregating, Tagging and Integrating Biodiversity Research. *PLoS ONE* 6(8): e19491. doi:10.1371/journal.pone.0019491

Mitchell, J. S., P. D. Roopnarine and K. D. Angielczyk. 2012. Late Cretaceous restructuring of terrestrial communities facilitated the End-Cretaceous mass extinction in North America. *Proceedings of the National Academy of Sciences*, DOI:10.1073/pnas.1202196109.

Synergistic Activities

Primary author, "Roopnarine's Food Weblog", Wordpress, 2008-present.
Primary author, "Climate Change Blog", California Academy of Sciences, 2007-present.
Organizer, Annual CalPaleo Conference, California Academy of Sciences, 2007.
Instructor, "Historical Geology", San Francisco State University, Winter 2006.
Co-organizer, Joint Annual Meeting, American Society of Malacologists & Western Society of Malacologists, Asilomar, 2005.
Co-organizer, "Biodiversity: Past, Present, and Future", AAAS Special. Symposium, Pacific Division Annual Meeting, San Francisco, 2003.

BIOGRAPHICAL SKETCH **Jennifer L. Bowen**

Biology Department
University of Massachusetts at Boston
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A. Professional preparation

Colby College, Waterville, ME	B.A., 1994
Boston University, Boston, MA	PhD., 2005
Ecosystems Center, MBL, Woods Hole, MA	Post-doc, 2005-2007

B. Appointments

Assistant Professor of Biology, University of Massachusetts at Boston	2010-
Council on Science and Technology Teaching Fellow, Princeton University	2007-2010
Post-doctoral scientist, The Ecosystems Center, Marine Biological Laboratory	2005-2007
Visiting Instructor, *Microbiology*, Connecticut College	2007
Visiting Instructor, *Wetlands*, Marine Science Consortium, Wellesley College	2006
Graduate Student, Boston University Marine Program	1998-2005

C. Ten representative publications

Bowen, J. L., D. Weisman, and M. Yasuda. Submitted. Distribution and diversity of the *nirS* gene in fertilized marsh sediments revealed by functional gene pyrosequencing. *The ISME Journal.*

Bowen, J. L., M. Holcomb, and B. B. Ward. In revision. Ocean acidification reduces diversity and alters species composition of nitrifying bacterial communities. *Nature Climate Change.*

Bowen, J. L., H. G. Morrison, J. E. Hobbie, and M. L. Sogin. In press. Salt marsh sediment diversity: a test of the variability of the rare biosphere over small spatial scales. *The ISME Journal.*

Bowen, J. L., B. B. Ward, H. G. Morrison, J. E. Hobbie, I. Valiela, L. A. Deegan and M. L. Sogin. 2011. Microbial community composition in salt marsh sediments resists perturbation by nutrient enrichment. *The ISME Journal* 5: 1540-1548.

Bowen, J. L., B. C. Crump, L. A. Deegan, and J. E. Hobbie. 2009. Response of salt marsh sediment bacteria to external nitrogen inputs as measured by denaturing gradient gel electrophoresis. *The ISME Journal* 3: 924-934.

Bowen, J. L., B. C. Crump, L. A. Deegan, and J. E. Hobbie. 2009. Increased supply of ambient nitrogen has minimal effect on salt marsh bacterial production. *Limnology and Oceanography* 54: 713-722

Bowen, J. L., J. M. Ramstack, S. Mazzilli, and I. Valiela. 2007. NLOAD: An interactive, web-based modeling tool to estimate nitrogen loads and concentrations, and explore options for nitrogen management in estuaries. *Ecological Applications* 17: S17-S30.

Bowen, **J. L.**, K. D. Kroeger, G. Tomasky, W. J. Pabich, M. L. Cole, R. H. Carmichael, and I. Valiela. 2007. A review of land-estuary coupling by ground water discharge: Mechanisms and effects. *Applied Geochemistry* 22: 175-191.

Bowen, J. L., and I. Valiela. 2004. Nitrogen loads to estuaries: Using loading models to assess the effectiveness of management options to restore estuarine water quality. *Estuaries* 27: 482-500.

Bowen, J. L., and I. Valiela. 2001. The ecological effects of urbanization of coastal watersheds: Historical increases in nitrogen loads and eutrophication of Waquoit Bay estuaries. *Canadian Journal of Fisheries and Aquatic Sciences* 58: 1489-1500.

D. Synergistic activities

Memberships: American Society for Limnology and Oceanography, Coastal and Estuarine Research Federation, American Society for Microbiology, International Society for Microbial Ecology, American Geophysical Union

Reviewer for: Sea Grant (New York, Maryland, South Carolina), National Science Foundation, *Estuarine, Coastal and Shelf Science*, *Biological Bulletin, Wetlands, Marine Pollution Bulletin, Journal of Coastal Research, Molecular Ecology, Aquatic Biology, Geochemica Cosmochemica Acta, Limnology and Oceanography, Marine and Freshwater Behavior and Physiology, Marine Environmental Research, FEMS Microbial Ecology, Biogeochemistry, Microbial Ecology, Biogeochemistry*

Education and outreach: 1) Leader of the Environmental Studies Block in the Student Success Initiative at UMss Boston, designed to increase participation and retention of underrepresented students in environmental Biology (2012-present). 2) Developed experiential learning initiatives for teaching of quantitative skills, risk assessment, and data quality and evaluation for non-majors Introductory Environmental Science as well as modules on global warming and sea-level rise modeling, and wetlands biogeochemistry for a Global Change Freshman Seminar at Princeton University (2007-2010). Advisory board member for the Waquoit Bay National Estuarine Research Reserve Coastal Training Program (2011-present).

Recent awards: Strategies for Analyzing Microbial Population Structures (STAMPS) short course participant (2011). OCB Ocean Acidification Short Course (WHOI, 2009), Princeton University Council on Science and Technology Teaching Fellowship (2007), NSF Postdoctoral Fellowship in Microbial Biology (2005), DIALOG ASLO Recent Dissertations Conference (2005)