Summary Information for Feedbacks Between Coastal New England Kelp Beds and Wave Disturbance

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Objectives

As we continue to observe increasing trends in the frequency of large wave heights worldwide with climate models predicting more in the future, we need to understand the consequences and potential mitigation strategies for nearshore ecosystems. To understand the feedbacks wave disturbance and kelps in New England, I propose the following objectives:

1) To design & build a low-cost wave sensor for widespread deployment in subtidal surveys.
2) To examine the consequences of wave action on kelp demography.
3) To provide models incorporating different wave environment scenarios with projections of impacts on kelps.
4) A high-resolution investigation of the effects of kelp abundance on potential wave disturbance.
5) Develop an accompanying online tool to help others understand the effects of kelp on disturbance mitigation.

To provide additional education about environmental sensing for both the science & management community as well as high school students, I will

1) Design & implement a workshop on building a wave sensor.
2) Work with high school teachers to educate students about the interaction between the environment and biology in our oceans.

Methodology

To examine the consequences of waves on kelp demography, I will conduct a two-year study with monthly sampling of tagged and monitored kelps in Salem Sound at sites where I deploy wave sensors. My lab has already developed prototypes of the sensor, and it will be fully calibrated and tested by the time we begin the study. The models I use to build and simulate kelp responses to different wave disturbance scenarios will be made freely available with easy to use web-based interfaces.

To sample the effect of kelps on waves, I will deploy grids of wave sensors in kelp beds and evaluate changes in waves due to the presence and densities of beds. I will translate results into web-based tools to understand how different kelp bed types interact with different wave environments to shape onshore wave exposure.

For education, as my lab finalizes our sensor design, we will both create a web-based set of instructions so that other scientists around the globe can construct their own, and we will advertise a workshop to be held at UMB for area agency and academic scientists. At Dorchester Academy, I will work with two teachers to develop a course on environmental biology in the oceans. We will focus on how temperature and waves can affect organisms in the marine environment. As a part of the course, students will build both their own temperature sensors and wave sensors over the course of the year. We will take students out into the field to deploy them, and then help them understand what their results mean.

Rationale

This project provides two major benefits. First, it will greatly enhance our understanding of the interplay between kelp beds in New England and the ever-changing climate. Buoy data from both within and outside of New England shows increasing trends in significant wave height and the frequency of large waves. Climate models predict further shifts as climate change continues. Thus, we have a clear need to understand the consequences of climate change for kelps, a key foundation species in the New England nearshore subtidal. As similar kelps in Europe have been shown to potentially baffle flow, kelp may also provide an ecosystem service that becomes increasingly vital in the shifting environment. We do not currently know whether this is the case; this study provides a first step towards quantifying a potentially valuable ecosystem service.

Second, this project enhances knowledge of ocean sensing and simple tools needed to better understand our ocean environment by both interested stakeholders and high school students. For stakeholders, we hope to put a new tool in their arsenal of approaches to get rapid and useful information about the nearshore ocean environment. For students, we hope to build a greater love of ocean science and open up new pathways towards becoming involved in STEM careers.

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Introduction

Wave disturbance can play a major role in determining the structure and health of nearshore coastal ecosystems. In particular, the effects of wave disturbance on foundation species can have strong consequences as they ripple through an ecosystem (Byrnes et al. 2011). Foundation species, such as the kelps of nearshore coastal New England, both create valuable habitat and can alter flow dynamics (Mork 1996). Changes in foundation species abundance could therefore alter both community composition and coastal responses to wave disturbance. Current climate change projections show increases in annual frequency of large storms in New England over time (IPCC AR5 2013) with likely accompanying changes in the frequency of large wave disturbance events. As climate change continues, it is imperative to understand both its potential consequences and options for mitigation along our coasts.

New England provides an ideal site to examine these issues by examining the interactions between waves and nearshore kelp beds. Along the East Coast of the U.S., maximum significant wave heights have risen over the past forty years and the distribution of significant wave heights has shifted (Komar and Allan 2008), mirroring trends seen around the globe (Wang et al. 2012, Bertin et al. 2013). In the New England, we see the same pattern. Looking at buoy 44013h east of Boston, for example, we see both an increase in the mean annual significant wave height over time and a shift in the distribution of maximum daily wave heights (Fig. 1). Other than the effect of the most extreme storm disturbances on opening patches in kelp beds, we currently have little idea how these shifts in potential wave disturbance will interact with this nearshore foundation species. Nor do we know if the comparatively short kelps in New England baffle flow like giant kelp on the West Coast (Gaylord et al. 2007), thus affecting how wave disturbance is felt on the shoreline. ***Here I propose to investigate 1) the potential effect of increases in wave disturbance on kelp demography and 2) the role kelp plays in mitigating wave disturbance by altering flow.***

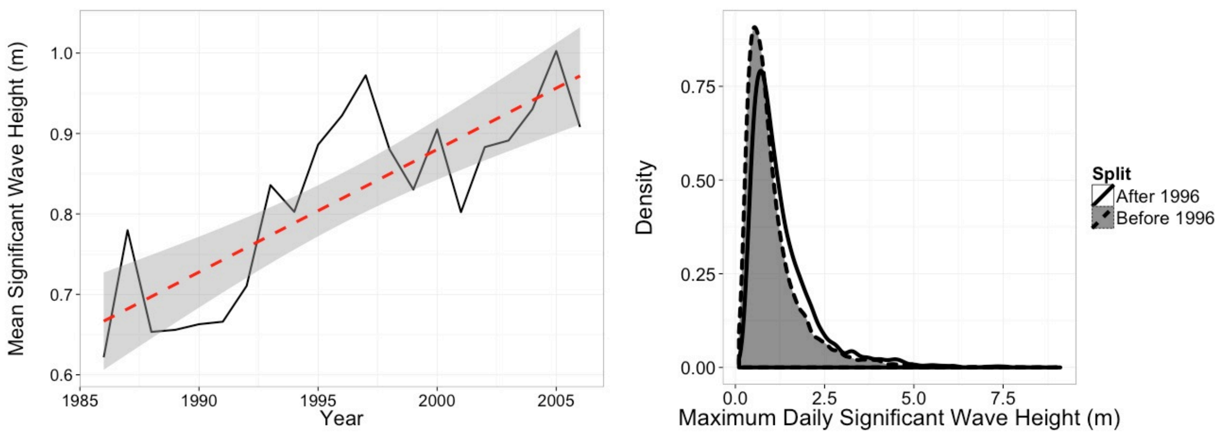

Figure 1: Changes in the wave environment from 1986 to 2013 East of Boston Harbor. Left - Mean annual significant wave height increases over time (red dashed line is bet fit from linear regression with SE in grey). Right - The distribution of hourly maximum significant wave heights before (grey dashed) and after (open solid) 1996. I used 1996 for direct comparison to Komar and Allen (2008).

Relevance to MIT SeaGrant Strategic Plan

In this project, I will 1) develop new open technologies for measuring waves in nearshore environments, 2) use this tool to examine the impacts of wave disturbance on kelp population dynamics, 3) evaluate the role of kelp in buffering shorelines from wave disturbance, and 4) create a program at a local high school in collaboration with a member of their faculty to teach students about ocean science and technology. For objectives 1-3, I will provide new tools for users interested in examining waves on their own and their interplay with nearshore kelp beds. These objectives address to MIT SeaGrant goals by a) developing tools and technologies that can help communities make more informed decisions, b) assessing the provision of unmeasured ecosystem services by marine organisms, c) assess how climate change will affect the a key species that regulates the health of nearshore coastal ecosystems, d) increase environmental literacy at the high school level, and e) educate a future workforce with an hands on approach to STEM education.

Additional Scientific Rationale

It is unclear if climate change driven increases in wave disturbance *per se* will impact kelp populations beyond its ability to create more days of the most extreme disturbance. Wave disturbance is major source of kelp mortality worldwide (Wernberg and Connell 2008, Reed et al. 2008). Waves from intense New

England winter storms can remove large patches of kelps (Witman 1987). However, the actual impact non-catastrophic wave disturbance is not clear for the subcanopy kelps of New England, unlike canopy forming species in California (Reed et al. 2008). *Saccharina* and *Laminaria* kelps often change aspects of their morphology in high wave energy environments, making them resistant to removal (Sjøtun et al. 1998, Kawamata 2001). While extreme waves, such as those generated by Nor'easters or hurricanes may remove kelps, waves might be otherwise relatively unimportant as a direct source of mortality. Or they may exhibit threshold dynamics that are critical to understand in the face of predicted climate shifts.

Conversely, kelps may also buffer shorelines from climate driven increases in wave disturbance. Even subsurface kelp beds still have the potential to baffle flow and reduce wave energy that could lead to shoreline erosion. Modeling shows that even these 'subcanopy' kelps should have a significant effect on flow (Asano et al. 1992). In nature, *Laminaria hyperborea* for example, slows flow within a bed (Mork 1996). It likely affects coastal dune erosion (Løvås and Tørum 2001). Similarly, artificial kelps can enhance beach build-up (Price et al. 1968). The extent to which kelps in New England actually reduce significant wave heights and the size of beds necessary to affect change is not currently known.

To address both of my main aims – understanding the impact of waves on kelp and kelp on waves – I need to be able to measure wave disturbance. While tools such as accelerometers on floats provide excellent measures of disturbance, they are prone to fouling or, worse, loss during extreme disturbance events. Pressure-based sensors can be deployed with a low profile, but are prohibitively expensive for widespread or long-term deployment. However, the availability of the components to construct sensors has decreased exponentially in recent years, alongside the rise of a community of citizen scientists eagerly developing tools and code for sensing of the terrestrial environment (Gertz and Di Justo 2012) – even at the high school level (e.g., http://airpi.es/). The development of similar marine tools – the OpenCTD (http://www.southernfriedscience.com/?p=15296) and the OpenROV (http://openrov.com/) - have opened up ocean sensing and exploration to ocean enthusiasts, students in the classroom, and more. Given its simplicity and my lab's early developmental efforts, we're committed to a similar solution to wave height measurements that can be used for both research and education.

Research Objectives and Approach

Objective 1: Creating an inexpensive open source wave sensor

Over the past year, my lab has begun development on a simple wave pressure sensor using widely accessible parts and a simple construction design. With the growth modern constructivist movements uniting technology, art, and citizen science, small inexpensive electronics have become easy to source and use for the average person. Our sensor design leverages this by using cost effective, easy to find, "off the shelf" components. By using off the shelf components that can be easily and cheaply sourced nearly anywhere, we are creating a sensor that nearly anyone can build and deploy. Its simple design and simple programming allow for a diverse range of groups to be able to use it.

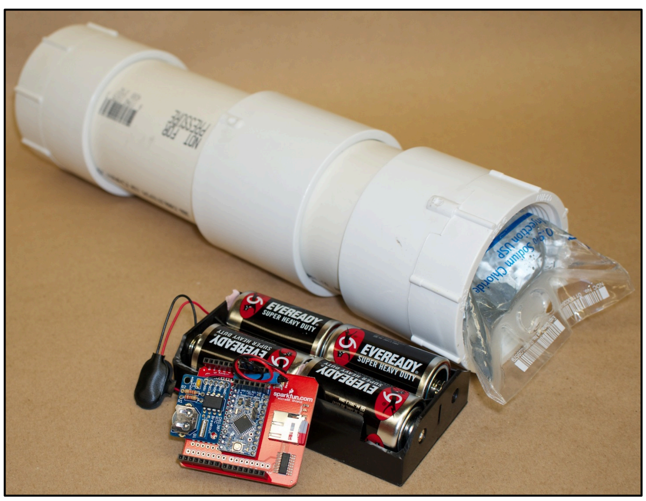

Figure 2: An early prototype of the sensor (the bag has been since replaced by a sealed silicone tubing).

The heart of our wave sensor is the open source Arduino microcontroller. The Arduino has large community following and a wide variety of prebuilt sensor systems designed for its use and code for its deployment. It is also used extensively in education. The Arduino microcontroller we have chosen to use has very low power consumption, good durability and comes in a very small form factor. This makes the Arduino platform a natural choice for this project, where our sensor package maybe deployed underwater for months at a time.

Our current wave sensor design (Fig. 2) uses easy to find and durable PVC plumbing as a housing. Standard 4” PVC drainage pipe and fittings found in most home improvement stores will fit the needed 4-12 D cell batteries (deployment length depending) that will run the Arduino, the pressure sensor and SD memory card data logger for an extend deployment time. These components are isolated within the housing by simple cut sheets of Plexiglas attached by epoxy to the housing. This isolates any specific section from water damage in the event of a failure in another section. Scaling the battery pack size increases the time that the unit can be deployed for. Our design can currently be built using resources found in most high school settings such as a wood shop (drill press & band saw) and items commonly found in any beginners electronics tool kits (soldering iron, wire strippers & crimpers).

The pressure sensor we are using is commonly found as a sensor for altimeter watches and dive computers (Measurement Specialties MS 5803-14). It is small and inexpensive and in general fairly durable, however it is not rated for continuous, long-term exposure to salt water. The pressure sensor is isolated from the ambient environment using a simple oil filled reservoir. Our reservoir is a short piece of soft silicone tubing attached to a hose barb in front of our sensor mounting plate. This tubing acts as an external ‘pressure plate’ for wave pressure to act upon. This design is also found in high-end commercially available systems.

Analysis and Calibration

The sensor will sample at 4hz at varying durations and intervals depending on the task for which it is being used. We will post-process pressure data by adapting code supplied by Libe Washburn at UCSB based on a similar sensor his lab constructed for the Santa Barbara Coastal LTER. To assess wave heights, both methodologies use standard linear wave theory to determine depth after correcting for barometric pressure and tide and spectral analysis to determine wave heights (Gibbons et al. 2005). The code for both the sensor itself and for post-processing the data will be made publically available via Github for any other users.

To calibrate and evaluate sensor performance, I will to first test it in the controlled environment of the University of New Hampshire's Wave Tank at the Center for Coastal and Ocean Mapping. This tank can generate waves with a maximum height of half a meter in 2-5 second intervals. In the tank, we will sample at 4Hz continuously. After ensuring the accuracy of the device in the tank, I will deploy it alongside a Seabird wave gauge already deployed at Halfway Rock at the edge of Salem Sound (Fig. 3) by the Helmuth lab at Northeastern. I'll match the sample intervals to their sensor in order to make a direct comparison between the data from each sensor. Prototype construction and initial pool tests are already underway, and I hope to formally test the prototype at UNH by August of 2014, and deploy it at Halfway Rock in the fall. During the first few months of the grant, I would refine a final version of the sensor based on lessons learned from the prototype and publish all relevant information for other groups to replicate our work and build their own sensors.

Connecting the Sensor to the Larger Community

In addition to using this sensor to teach high school students about marine science and engineering (see below), the sensor and its development process will have wide utility beyond just my lab. I plan to make all plans and code fully open source and accessible, meaning that anyone can build one. The lab will host a workshop on build-your-own sensor that will be advertised through the UMass Boston School for the Environment that recently hosted the successful Fish Hackathon in partnership with the New England Aquarium (http://fishackathonboston.splashthat.com/). We will directly contact interested partners in New England area universities, the Massachusetts Bays Program, Gulf of Maine Ocean Observing System's Sentinel Monitoring Program, the National Estuarine Research Reserve System, Massachusetts Water Resources Agency, the USGS, and the Massachusetts Department of Environmental Protection. We hope to hold the workshop at the Cambridge Artisan's Asylum, a center for Boston area 'makers', and thus may involve other members of the public with marine science, and have them work side-by-side with members of agencies and universities they might not otherwise meet.

Last, I will create a website for the sensor with step-by-step instructions, a parts list, a forum, and a video tutorial. This will better enable other scientists around the globe to use this low-cost sensor for their own work. I look forward to the many opportunities the development of this sensor will bring, both to our lab and other scientists, managers, and students.

Objective 2: Assess the influence of wave energy on kelp bed population dynamics

To assess the impact of wave exposure on kelp population demography, I will conduct a two-year study evaluating the relationship between kelp demography and the local wave environment. Using data from this study, I will parameterize demographic models and evaluate the differences in kelp population growth rates under wave regimes that reflect current, past, and future conditions, taking into account local differences in wave exposure. To parameterize models, I will establish four sites that have the potential to vary in wave exposure in Salem Sound (Fig. 3). I surveyed these sites in July and August of 2013 at a depth of 8-12m. Kelp (*Saccharina latissima*) density at the sites ranged from 20-80 kelp stipes per m^2 and typically had a dense (80-100% cover) canopy even at the $20/m^2$ density. Due to their differing exposure to the open ocean (e.g., Eagle Island is further back in the channel and may be shielded by other islands from swell) and difference in direction of exposure (approaching swell from the Northeast v. Southeast on Baker), they likely have very different wave disturbance regimes.

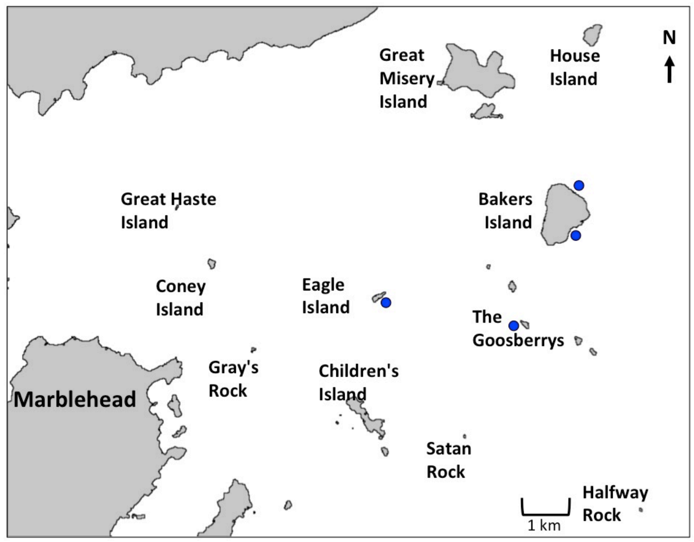

Figure 3: Map of Salem Sound with sample sites marked in blue.

Sampling Design

At each site, in the mid-spring of year 1, I will mark a permanent 20m transect parallel to shore in an area that contains kelp in the depth zone between 8-12m. Every 5 meters, I will place one $0.5m^2$ quadrats on the seaward side of the transect. Within each quadrat, I will tag and count all kelps. To tag kelps, I will use a system of colored cables ties around the stipe marked with two colored strips of electrical tape specific to the month of tagging. I will also count all urchins present, as they are a potential serious source of kelp mortality. Temperature sensors will be deployed at all sites recording hourly measurements.

To evaluate kelp demography, I will revisit each site and quadrat monthly for at least the duration of the grant to examine kelp mortality under a wide range of possible wave heights. I will count all of the kelps that are tagged for each cohort, the number of new recruits <10cm, and count and tag all of the kelps >10cm with a new color combination. I will count all urchins. I will only tag these larger kelps so as not to incur any additional mortality on new recruits. However, I will be able to estimate recruit mortality based on untagged recruits in one month and kelps ready for tagging in the next.

I will deploy three sensors on each transect – at the beginning, middle, and end. Sensors will sample at 4Hz for 10 minutes once an hour. I will replace the sensors monthly. I will take average measurements of significant wave height from each sensor for the period of deployment calculated using developed software.

Modeling Kelp Populations

To establish the link between waves and kelp demographics, I will simulate population dynamics based on the fit of three models. 1) I will perform hierarchical mixed model analyses looking at both mean hourly significant wave height and maximum significant wave height between sampling periods as predictors of mortality in separate sets of models with kelp density as a covariate and potential interaction effect with waves. Site and quadrat within site will be included as random effects to account for using the same sites. I will evaluate three functional forms for the relationship: linear, a broken stick function

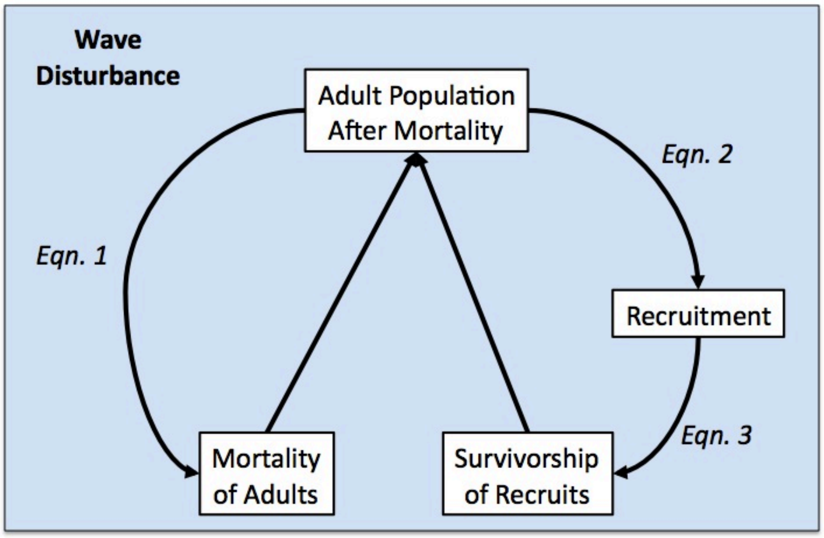

Figure 4: Graphical representation of the simulation model for kelp population dynamics. The relationships at any time step are influences by wave disturbance.

allowing for flexibility of linear or flat relationships on either side of the threshold, and an exponential relationship. As I'm evaluating mortality, each model will be fit using a binomial error structure. All models will include urchins as a covariate. I will assess whether both forms of disturbance need to be included using an AIC analysis to compare the predictive power of models with different disturbance predictors. 2) I will perform the same analysis looking at kelp recruitment, incorporating waves, kelp abundance, urchins, and temperature as predictors. This will enable me to control for covariation between predictors. I will include temperature as it is an important predictor of when kelp gametophytes can reproduce (Bartsch et al. 2008). 3) I will use the same modeling framework to look at survivorship of kelp recruits, with waves, urchins, and kelp adult density as predictors.

To look at long-term projected consequences, I will use the three equations above to run a discrete time simulation model (Fig. 4). After seeding it with an initial kelp density, the model will consist of applying mortality using eqn. 1, then using the resulting density to determine recruitment to the population using eqn. 2. Then assessing the adult population at the next time step by applying eqn. 3 to recruits and eqn. 2 to adults. This process can be repeated for each time step, and can incorporate different wave regimes at each step, allowing me to create annual models with fluctuating wave environments. I can begin each simulation in the summer, and apply wave exposure regimes based on data from the relationship between nearby buoy wave heights and wave heights measured at each site.

To validate the model, I will conduct a cross-validation analysis, leaving out one site at a time to fit the three equations, run the model for the site that had been left out using measured wave heights, and then compare the relationship between observed versus predicted kelp quadrats at the remaining site.

Once validated, I will run the model under three scenarios: 1) wave regimes in the 1980s from buoy data, 2) wave regimes in the mid 2000s, and 3) projected future wave regimes based on statistical fits to trends in monthly wave heights from buoy data (e.g., in preliminary wave analyses, there appears to be little trend in early summer wave heights, but a positive trend in winter wave heights). For each scenario, I will run 1,000 simulations with draws from the distribution of wave height scenarios and calculate the August kelp abundance after ten years and the population growth rate over that time period. I will then compare simulated results to evaluate the net effect of wave disturbance on kelp populations.

Additional Products for Management & Education

All data collected in this study will be made publically available after publication. Quality controlled data and metadata will be made available via our lab's website, and will be deposited at the Knowledge Network for Biocomplexity (https://knb.ecoinformatics.org/). This data can be used by any interested party for management or for illustrative teaching purposes. We will also include code for analysis of the data and to run the simulation model. To make the simulations more widely accessible, we will develop a web application using the R Shiny library (http://shiny.rstudio.com/) with the simulation model so that interested managers can set up additional wave-height scenarios of interest, and evaluate population dynamics over time. The tool will allow them to select parameters describing the wave height distribution over time, and then create simulated population trajectories.

Objective 3: Build an understanding of how kelp beds influence wave intensity

To examine the role of kelp beds on wave disturbance mitigation, I plan use grids of wave sensors to evaluate how waves change across areas dominated by differing abundances of kelp during the summer and fall of years one and two. Previous work has shown that kelp beds can decrease wave energy as it approaches shorelines (Mork 1996) and may increase the rate of beach buildup as erosion is reduced (Price et al. 1968); (Løvås and Tørum 2001). I will examine the hypothesis that kelp beds damp wave energy using grids of sensors to look at wave heights in front of and behind areas dominated by kelps versus other algae.

Sampling Design

I will begin by sampling twelve 40m transects spaced evenly around the wave exposed side of Baker Island (see Fig. 3). Transect start coordinates will be pre-selected before sampling, and the transect will be arranged parallel to shore. Every 10m, divers will swim out two lines perpendicular to the transects - one inshore and one offshore - and record the distance from the transect line and depths where the kelp zone ends. Along transects, divers will conduct kelp counts in $1m^2$ quadrats every 8m to estimate kelp density within the bed, as well as the abundance of other algal species (e.g., the invasive *Heterosiphonia japonica* that forms algal mats with little vertical structure). I will then replicate the following experiment in each of these sites over the course of two years during the late summer/early fall; half of the samples will be taken in year one and half in year two (resampling to ensure correct measurement of bed size in year two), to assess wave dampening.

To test whether kelp beds attenuate waves, at each bed I will deploy twelve sensors in a grid of four rows and three columns centered on the transects. The front row will be placed 1m below the seaward edge of the bed. The next two will be evenly spaced apart within the bed. The final row will be placed just past or on (depending in depth) the shoreward edge of the bed. Columns will be spaced 10m apart. Divers will swim over the sensors with a GPS on a surface float to note the location of each sensor. Sensors will burst sample for 30 minutes at 4Hz once an hour. Each column will sample during the same interval in order to create 2-D visualizations of waves passing through the area. Sensors will be retrieved after 5 days so that they might experience a variety of wave conditions.

Data Analysis

I will fit a linear mixed model with hourly significant wave height at each sensor as a response variable and with distance from front edge of the line of sensors, density of bed, amplitude of waves, difference in orientation of the sensor grid relative to the direction of the mean wave direction as calculated by the Boston Approach Light buoy (44013h), and two-way interactions between all four as fixed effects. I will include a random effect of site, row, and individual sensor (to accommodate any measurement error). I am using random effects rather than averaging, in order to obtain an estimate of variability between sites and within zones. I will then test pared down versions of the model removing two-way interactions, and select the best model based on Akaike's Information Criterion.

I hypothesize that the baffling effect of kelp beds will lead to a significant reduction in wave height at greater distanced from the front edge of the array, and that this effect will be stronger in areas with higher kelp density. The attenuation effect will also be strongest when the mean wave direction lines up with the orientation of the sensors. This would indicate that kelps play a potentially important role in protecting shorelines from increasingly intense wave exposure. From this and our bed surveys, we will be able to calculate the amount of attenuation per meter width of kelp forest at a given density.

Additional Products for Management & Education

In addition to making data publically available as described above, we will create an online tool using the R Shiny library (http://shiny.rstudio.com/) that allows users to create a virtual kelp bed and examine how it will affect wave forces. Users will be able to setup a forest of arbitrary length, width and variation in width. They can then setup an incoming set of waves of chosen heights, amplitudes, and variation in both approaching the bed at an angle of their choosing. The web application will run and report the change in wave heights and associated properties (e.g., energy) behind the forest based on the fit model above.

Ourtreach: A project-based course introducing high school students to sensing the oceans

In collaboration with Stephen Nixon and Juanita Shaffer-Ratzlaff, science teachers at Dorchester Academy, we want to create a hands-on project based ocean science elective called Sensing the Oceans. High school students, and especially students from high poverty backgrounds, have little idea of the processes that go on in the ocean. Unlike their casual knowledge of the weather outside, the 'weather' under the waterline is invisible. The tools and techniques used to understand the physical processes in the ocean are often quite different from those on land. There are few opportunities for students to discover the technology behind ocean science.

We plan to construct a two-semester sequence for the 2015-2016 school year, in accordance with the timing of the grant (starting in February would be too late for the school semester). Once developed, we will make our course plans and materials publically available for use by other educators, as well as continuing it at Dorchester Academy.

Semester one will focus on temperature change in the ocean. We will teach students about regional, seasonal and interannual patterns of temperature in the ocean. We will begin teaching them about seasonal fluctuations in New England by introducing them to temperature observations I am currently collecting in Salem Sound. By the start of the course, we will have two years of data to work with. We'll teach them the basics of graphing, comparisons of differences in means, minima, and maxima. We'll introduce them to the technology behind temperature sensors, and have them construct simple temperature sensors using the Arduino microcontroller as a platform for development, and simple casing design that they will have to troubleshoot to provide protection from water. From there, we'll look at how the sea buffers fluctuations in temperature. We'll have them deploy sensors in nearby salt marsh creeks in both the creek bank and fully submerged channels. When they collect the sensors, we'll use the data to compare and contrast the effects of being constantly versus only periodically submerged in the context of organismal biology.

Semester two will focus on the science of waves in the ocean. Students will begin using data gathered by one of our field sensors. We'll teach them about how to translate pressure measurements into wave heights, and then look at the effects of seasonality. We'll also look at comparisons with the wave heights measured by the buoy just east of Salem Sound to talk about the difference between open ocean and nearshore waves. We will ask them to devise a hypothesis about how and why different sites in Salem Sound will alter wave exposure. We'll then move on to building a wave sensor, using our design as a starting point, but allowing them to modify it as they see fit. Once they build their sensors, we'll take them out to the field for sensor deployment and retrieval several days later. Back in the classroom, they'll use their own data to test their hypotheses.

Relevance to SeaGrant Goals and Massachusetts Science Standards

This effort addresses multiple MIT SeaGrant Environmental Literacy and Workforce Development goals and outcomes as well as tying into parts of the Massachusetts Next Generation Science Standards (NGSS) as follows:

From NGSS *HS-LS2-6*: "Evaluate the claims, evidence, and reasoning that in stable conditions the dynamic interactions within an ecosystem tend to maintain relatively consistent numbers and types of organisms even when small changes in conditions occur but that extreme fluctuations in conditions may result in a new ecosystem."

From *HS-LS2-7*: "Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health."

This project also incorporates the following Science and Engineering Practices of the NGSS: Asking Questions and Defining Problems, Developing and Using Models, Planning and Carrying Out Investigations, Analyzing and Interpreting Data, Using Mathematics and Computational Thinking, Constructing Explanations and Designing Solutions, Engaging in Argument from Evidence, and last Obtaining, Evaluating, and Communicating Information.

Project Timeline

During the winter and spring of year one, I will complete the development of the sensor based on what I learn from the prototype this summer. My lab will construct sensors for the following season. Working with my lab, during the summer of year 1, we will setup the kelp demographic study and survey sites around Salem Sound. During late summer and fall, we will conduct the first half of the kelp attenuation study. We will continue sampling for demography throughout the year. We will complete the attenuation study during the summer and fall of year two. During year one, I will work with Steve Nixon and Juanita Shaffer-Ratzlaff to develop the ocean science elective. We will implement it in the fall of year 1 and winter/spring of year two. We will hold a wave-sensor building course in the fall of year 2.

Personnel and Training

In addition to providing my time and time of the teachers involved in the high school class as in-kind support, this grant will support my lab technician, Ted Lyman, who has been primarily responsible for the wave sensor development. It will support one graduate summer or fall research assistantship for the duration of the grant who will assist in sampling year-round.

With respect to training, the grant will support a course for interested parties in the construction of their own wave sensor (see section on the sensor). This will introduce them to not only how to make their own low-cost wave sensor, but the basic concepts needed to build other environmental sensors for the marine environment. It will also introduce high school students to ocean science and engineering and hopefully help to build a life-long love of both.

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Project Timeline: Feedbacks Between Coastal New England Kelp Beds and Wave Disturbance

Jarrett E.K. Byrnes, University of Massachusetts Boston

		Winter/Spring 2015	Summer/Fall 2015	Winter/Spring 2016	Summer/Fall 2016
Objective 1	Finalize Sensor Design	x			
	Construct Sensors	x			
	Sensor Building Workshop			x	
Object 2	Sample Kelp Beds	x	x		
	Deploy Sensors		x		
	Re-Sample Kelp & Swap Sensors		x	x	x
	Begin Demographic Model Development			x	
Objective 3	Deploy Sensor Grids		x		x
	Model Grid Results				x
Objective 4: High School Class	Curriculum Development Meetings		x		
	Ocean Temperature Sensing Class		x		x
	Wave Sensing Class			x	

Data Management Plan: Feedbacks Between Coastal New England Kelp Beds and Wave Disturbance

Jarrett E.K. Byrnes, University of Massachusetts Boston

1) Description of data to be generated by the project, including file format, likely size, etc.

This project will generate several kinds of data. The development of the wave sensor will generate a full set of plans, multiple documents, and instructional videos. We will bring these together into a single hosted website.

Subtidal sampling data sheets will first be scanned and saved into a shared Dropbox (see below). Original data sheets will then be archived. Data will be transcribed from scanned copies, ensuring that the scans are good enough to be legible. Data will be saved as comma delimited spreadsheets.

Sensor data will be text and comma delimted text files.

Last, the project will generate several sets of code for data analysis

See below for short and long-term storage plans of electronic data.

2) A tentative date by which data will be shared

Data will be shared no later than fall of 2017. It will be shared sooner if work utilizing the data is published.

3) Standards to be used for data/metadata format and content

Tabular data will be accompanied by meta-data compliant with the Ecological Metadata Language (EML) Standard (https://knb.ecoinformatics.org/). Metadata will be generated either using the KNB Tool Morpho (https://knb.ecoinformatics.org/#tools/eml) or with the DataUp Excel plugin for easy meta-data creation (http://dataup.cdlib.org/).

Code will be accompanied by instructional How-To files and accompanying videos and screencasts where necessary so that users can easily utilize the code for their own purposes.

4) Policies on data stewardship and preservation

Short-term, all data will be saved on lab shared Dropbox (http://dropbox.com) ensuring access by all members of the team as well as regular backups to an offsite server. Lab computers are also backed up nightly onto external hard-drives.

Long-term, the data will be archived permanently at either the Knowledge Network for Biocomplexity or Data Dryad. This will ensure that they are fully searchable and usable beyond the lifespan of the project and beyond that of my lab itself.

Similarly, code will a) posted on Github, a service for sharing of code projects so that other users can download and easily modify it to their liking and b) archived along with accompanying data sets. This means that all code for analyses will be fully open, documented, and preserved in perpetuity.

5) Procedures for providing access, sharing, and security

All data and code will be fully open either at the time of publication or by the fall of 2017. While users will be suggested to contact the authors of datasets for additional information, there will be no restrictions placed on data reuse.