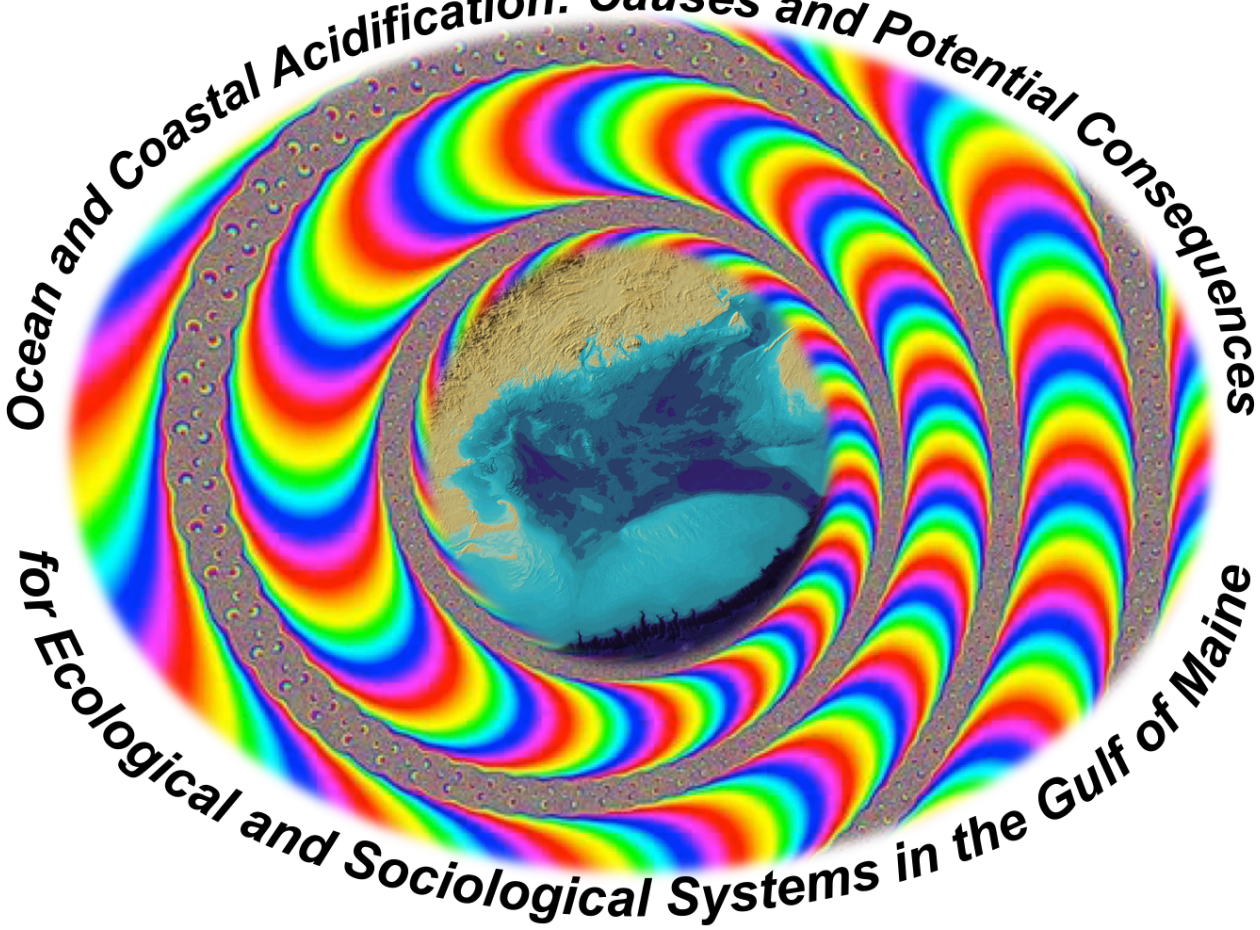
2017 RARGOM Annual Science Meeting



PROGRAM

RARGOM Annual Science Meeting

Ocean and Coastal Acidification: Causes and Potential Consequences for Ecological and Sociological Systems in the Gulf of Maine

Date: October 12, 2017
Location: Hannaford Hall, University of Southern Maine, Portland, ME

Featured keynote speakers:
***Libby Jewett**, Director of the NOAA Ocean Acidification Program*
***Joseph Salisbury**, Professor at the UNH Ocean Processes Analyses Lab*

Contents

Meeting Schedule and Oral Presentations

8:30 AM	0:30		**REGISTRATION and poster set up**
9:00 AM	0:05		**WELCOME**
9:05 AM	0:15	Woods	Microplastic fiber uptake, ingestion, and egestion rates in the blue mussel (*Mytilus edulis*)
9:20 AM	0:15	Valentine	The shallow, mobile sand ecosystem of Stellwagen Bank and the fish species it supports, based on long line, gill net, and otter trawl catch data
9:35 AM	0:15	Farr	How do fishermen understand the ecosystem in eastern Maine?
9:50 AM	0:15	Willis	Lessons for artisanal fisheries from Penobscot Bay: 1800 - 1960
10:05 AM	0:40		**BREAK & POSTERS**
10:45 AM	0:45	Jewett	**Keynote 1**: Responding to Ocean Acidification in the US and Beyond
11:30 AM	0:15	Chambers	Scope for response of an estuarine forage fish, Atlantic Silverside (*Menidia menidia*), to elevated CO2 regimes
11:45 AM	0:15	Randall	Interactive effects of sediment buffering and predator exclusion on recruitment of two commercial intertidal bivalves in northern Casco Bay: Results from field experiments (2014-2016)
12:00 PM	1:30		**LUNCH & POSTERS**
1:30 PM	0:45	Salisbury	**Keynote 2**: Where does ocean acidification hide in the Gulf of Maine? Time scales and drivers of variability of the carbonate system
2:15 PM	0:15	Hunt	Is the Gulf of Maine Especially Vulnerable to Coastal Ocean Acidification?
2:30 PM	0:15	Liebman	Installation of carbonate chemistry sensors in National Estuary Program waters
2:45 PM	0:30		**BREAK & POSTERS**
3:15 PM	0:15	Honisch	Growing resilient: kelp farming as a potential remediation strategy for coastal acidification
3:30 PM	0:15	Morrison	NECAN—The Northeast Coastal Acidification Network—in Action
3:45 PM	0:15	Strong	Acid Justice: Adaptive capacity and social vulnerability to ocean and coastal acidification in the Gulf of Maine
4:00 PM	0:45		Facilitated Discussion
4:45 PM			**Adjourn**

Poster Session: Titles and Presenters

Kylla Benes	Long-term Data Identifies Declines in Cover and Differences in Interannual Variability of Foundation Species on Appledore Island, ME
Ian Breslow	Population Assessment of Harbor (*Phoca vitulina concolor*) and Gray Seals (*Halichoerus grypus*) at Duck Island Ledges, ME
Ian Breslow	Environmental and Anthropogenic Factors Contributing to Harbor (*Phoca vitulina concolor*) Seal and Gray (*Halichoerus grypus*) Seal Counts on Duck Island Ledges, ME
Andre F. Bucci	Remote sensing data linkages to interannual variability of toxic Alexandrium fundyense blooms in the Bay of Fundy (Canada)
Kate Coupland	Biological and physical drivers of pH change in the Damariscotta River and implications for shellfish aquaculture
R. Michael Doan	Deployment of a continuous water quality and coastal acidification monitoring station in Casco Bay, ME
Annie Evankow	Ocean Genome Legacy: Preserving marine biodiversity through DNA biobanking
Parker Gassett	Disseminating OCA Citizen Science Monitoring Guidelines and Resources
Brianna King	Multispectral classification of Gulf of Maine water mass types and their seasonal and interannual variability
Collin C. Love	Altered Behavior of Parasitized Carcinus maenas Decreases Susceptibility to Predation by Definitive Bird Hosts
Rachel Marshall	Incidental catch of Atlantic halibut in Cape Cod commercial fisheries
Christopher S. Murray	A preliminary study testing the effects of high CO2 on the early life stages of the northern sand lance *Ammodytes dubius*
Peter Murdoch	Modeling and Measuring Change in the Gulf of Maine: The Legacy of the EcoSystem Indicators Partnership (ESIP)
Jennifer Seavey	Networking across the Gulf of Maine
Kadie Tommasi	Interspecific Interactions and Habitat Preferences of Harbor Seals (*Phoca vitulina concolor*) and Gray Seals (*Halichoerus grypus*) on Duck Island and Ledges, ME
Tyler Van Kirk	Infection dynamics of an Acanthocephalan parasite, *Profilicollis botulus*, in the green crab, *Carcinus maenas*, on the coast of Maine
Mark Whiting	Monitoring marine sediment as an indicator of a changing ocean

Abstracts: Oral presentations

Scope for response of an estuarine forage fish, Atlantic Silverside (*Menidia menidia*), to elevated CO2 regimes

Chambers, R.C. Boyce, D.J., Habeck, E.A., Habeck, K.M., Drown, M., Poach, M.E.

Presented by: Christopher Chambers, chris.chambers@noaa.gov

Elevated levels of atmospheric CO2, due largely to hydrocarbon combustion, accelerate climate change and acidify coastal and ocean waters. Variable and increasing global temperatures and CO2 levels are expected to affect the ocean's biota in ways ranging from minimal and subtle to strong and pervasive with outcomes that may be either negative or positive. Marine scientists largely lack a predictive understanding of the patterns of responses and the downstream consequences of these effects. Poor predictive capability may be due in part to the fact that prior experimental assessments of CO2 effects on marine fauna typically use a small number of elevated CO2 environments into which experimental subjects are placed and evaluated for responses. While appropriate for determining whether CO2 has an effect on the responses measured, this approach reveals little about the scope and shape of the biological responses, the resilience of the organism, and its adaptive potential. Here we describe experimental studies that achieve a large number of different CO2 environments among experimental tanks at one time, and report effects of these multiple environments on early life-stages of Atlantic silverside (*Menidia menidia*), a common forage fish of coastal habitats throughout the Atlantic Coast of the USA and the Canadian Maritimes. We have also compared outcomes between constant and highly variable CO2 regimes, the interactions between CO2 and dissolved oxygen, and the potential for adaptive responses of this species to future CO2 conditions. Overall, these high-frequency treatment systems reveal the organismal responses to CO2 variations in a uniquely useful way. Such data are needed in order to establish a quantitative understanding of CO2 effects on our living marine resources in future CO2-impacted environments.

How do fishermen understand the ecosystem in eastern Maine?

Farr, E., Stoll, J.

Presented by: Emily Farr, efarr@coastalfisheries.org

Maine's commercial fishing sector has a collective body of local ecological knowledge (LEK) that is high-resolution, continuous, and place-based, and can meaningfully contribute to fisheries science

and management. However, fishermen's knowledge is often patchy and constrained by the institutional arrangements that shape their interactions with the environment. We are exploring this tension through research on LEK in the eastern Gulf of Maine, working toward a theoretical middle ground that is sensitive to the uneven nature of fishermen's knowledge while simultaneously recognizing its immense value. Through ongoing semi-structured interviews with commercial fishermen, we use a network approach to map the ecosystem structure, ecosystem dynamics, and environmental changes as described by individuals and the community. These interviews have provided insight into local fluctuations in water temperature and weather patterns, predator prey dynamics, interactions of species of commercial interest with their predators, competitors, and prey species, and the complex interactions between fisheries and their habitat. Preliminary data also points to an important relationship between diversified access to fisheries and the production of LEK. Namely, fishermen who hold or have held licenses for multiple fisheries seem to develop a more holistic understanding of the marine environment and its dynamics because of regular interactions with different components of the system. This has important implications for both the kinds of information fishermen can contribute to ecosystem science, and the capacity of those fishermen to engage in the management of a complex and multi-scalar ecosystem.

Growing resilient: kelp farming as a potential remediation strategy for coastal acidification

Honisch, B., Price, N.N., Arnold, S.N., Salisbury, J., Dobbins, P., Hunt, C., Shellito, S., Meléndez, M., and Fachon, E.

Presented by: Brittney L. Honisch, bhonisch@bigelow.org

The Gulf of Maine has a vibrant shellfish aquaculture industry. Coastal acidification presents a serious threat to shellfish development and survival, making Maine ecologically and economically vulnerable to changing ocean conditions. Recent expansion of the kelp farming industry provides nutritious consumer products and vital economic growth and diversification. Kelp farming may improve water quality, or 'phytoremediate' marine coastal waters in the immediate area, providing a possible local mitigation strategy for coastal acidification. Through the act of growing and photosynthesizing, these small marine forests remove carbon dioxide (CO_2) from seawater, creating a 'halo' of higher seawater pH and saturation state (Ω). Laboratory and field evidence show that farmed sugar kelp are effective at remediating acidification. At Bigelow Laboratory, we exposed five species of macrophytes (*Saccharina latissima, Ascophyllum nodosum, Fucus vesiculosus, Ulva lactuca,* and *Zostera marina*) to past, current and future pCO_2 and temperature levels. Seawater CO_2 consumption rates and ability to raise seawater pH and Ω differed across species, but increased at higher pCO_2 treatments, with sugar kelp taking up the most CO_2. In the field, instruments measuring pCO_2, pH, dissolved oxygen, salinity, temperature, and depth were deployed inside and outside of the Ocean Approved sugar kelp farm in Casco Bay, Maine. From the

time of deployment in early January through mid-February 2016, CO2 was lower inside the farm, and as a result, pH and Ω were 13% and 23% higher, respectively. We repeated instrument deployments in 2017 and added cruises mapping the seawater pCO2 around the kelp farm to estimate the spatial extent of the remediated 'halo', which appears to be concentrated within 100m from the kelp farm. We report initial 2017 results here and describe our upcoming field efforts to improve our understanding of the halo's spatiotemporal patterns and capacity to enhance shellfish growth.

Is the Gulf of Maine Especially Vulnerable to Coastal Ocean Acidification?

Hunt, C., Salisbury, J., Vandemark, D.

Presented by: Chris Hunt, chunt@unh.edu

Ocean acidification is driven by atmospheric carbon dioxide (CO2) absorption on a global scale; however, individual coastal areas may be exposed to very different acidification pressures due to unique circumstances of local biogeochemical processes, physical settings, circulation, and terrestrial influences. Predictions of coastal acidification need to take this geographic variability into account to better forecast future conditions. Past observations have shown the Gulf of Maine to be colder, fresher, and more poorly buffered than other East Coast regions- all factors which influence the acid-base system and provide cause for concern under warmer, higher-CO2 future scenarios. New studies in the region are providing better understanding of the complex set of controls on coastal acidification in the Gulf of Maine, as well as baseline data for future evaluations. These studies are taking advantage of technological advances to study Gulf of Maine waters and those of surrounding regions at previously unknown resolution, and may offer new insights into factors which will dictate acidification effects. In this presentation I will discuss the circumstances which make the chemistry of the Gulf of Maine uniquely situated in the context of coastal acidification, as well as what we are learning about the region through ongoing research efforts.

Installation of carbonate chemistry sensors in National Estuary Program waters

Liebman, M., Bohlen, C., Salisbury, J., Hunt, C., Valle, P., Santoni, A.

Presented by: Matthew Liebman, liebman.matt@epa.gov

Coastal acidification is the modulation of ocean acidity by coastal processes, including microbial respiration of nutrient enriched phytoplankton blooms and (potentially acidic) riverine discharge.

Combined with stratification, respiration results in localized increases in CO2 and reductions in pH and calcium carbonate saturation state. These depressions are of concern to aquatic resources, including both wild and cultured shellfish. In 2015 EPA began to fund carbonate chemistry sensors at locations within eight EPA funded National Estuary Programs, including three in New England: Casco Bay, Massachusetts Bays and Long Island Sound to better characterize carbonate conditions and variability throughout the year at a "continuous" time scale. In Casco Bay, University of New Hampshire installed a CO2, pH and oxygen sensor suite at a pier near a station with a long-term nutrient record. Combined with measures of salinity and temperature, UNH has calculated calcium carbonate saturation state for almost three years. The sensors in 2015 and 2016 recorded high variability of pCO2 and pH conditions; pCO2 ranged from about 300 to almost 1400 uatm and pH ranged from 7.4 to 8.3. In both years, saturation state declined periodically or for several weeks, in association with respiration of phytoplankton bloom biomass (in 2015) or riverine inputs (in 2016). The Massachusetts Bays Program is working with UMass Boston to install a pumped system at a pier in Duxbury Bay and are continuously recording CO2, and pH in real time following the protocol used in Casco Bay. The system was deployed in September 2017. The EPA has funded economic modeling to project future impacts to the commercial shellfish industry in the Gulf of Maine and Puget Sound. Preliminary results indicate potential impacts to clam, oyster, scallop and crab industries. Continuous monitoring demonstrates the importance of observing key ocean and coastal acidification parameters throughout the growing season for shellfish.

NECAN—The Northeast Coastal Acidification Network—in Action

Morrison, R., Turner, E., Ball, J.

Presented by: J. Ru Morrison, ru@neracoos.org

NECAN, the Northeast Coastal Acidification Network, is a nexus of scientists, federal and state resource managers, and marine industry partners dedicated to coordinating and guiding regional observing, research, and modeling endeavors focused on ocean and coastal acidification (OCA). NECAN strives to better identify critical vulnerabilities to OCA, particularly with respect to regionally important and economically significant marine resources. Additionally, NECAN helps to make available OCA information, resources and data products tailored to and informed by the interests of regional stakeholders and decision-makers. Since NECAN's inception the group's efforts have continued to diversify and expand, and we currently have four working groups for Science, Policy, Communication and Outreach, and Industry. We also host a webinar series to highlight new results relevant to the region, and convene topical workshops on OCA issues in collaboration with other partners. We will provide a brief history of NECAN and the current and future activities of this regional collaboration. We welcome discussion and input from RARGOM participants on desired

NECAN activities and how to align efforts within the broader regional and national OCA communities. In doing so, the region can better address the impacts of OCA in the Northeast.

Interactive effects of sediment buffering and predator exclusion on recruitment of two commercial intertidal bivalves in northern Casco Bay: Results from field experiments (2014-2016)

Beal, B., Randall, S., Coffin, C., Goodenow, C.

Presented by: Sara Randall, sara.randall1@maine.edu

Soft-shell clam (*Mya arenaria*) landings in Casco Bay communities have declined dramatically over the past decade by nearly 70%, and this has coincided with unprecedented increases in Gulf of Maine sea surface temperatures. Declining clam stocks could be due to over-fishing, pollution, ocean/coastal acidification, predation, disease, loss of intertidal habitat, recruitment limitation, or a combination of these and other factors. In 2014, we initiated a three-year field study at four intertidal flats in Freeport to investigate simultaneously two of the purported causes. Sites chosen had low sediment pH (< 7.4), and we attempted to buffer those sediments by adding crushed clam shells to large (100 ft2) or small (0.20 ft^2) plots. Success was measured as the density of wild recruits of Mya and northern quahogs, Mercenaria mercenaria, after 4-5 months (April/May - October/November). In 2014 and 2015, we observed no significant difference in mean recruit density for both species between controls (without crushed shells) and plots with crushed shell (13 or 26 lbs. of shell/plot). Small-scale studies demonstrated similar findings – that is, the presence of crushed shell material did not result in a significant enhancement of clam recruits. However, when we applied predator netting (aperture = 4.2 mm) to plots with or without crushed shell, we found significantly more clams compared to the unprotected plots. In 2016, we carried out a small-scale study at two intertidal sites to examine effects of different sizes of crushed clam shell as well as crushed oyster shell on clam recruits. Neither the presence nor size of shell material had a significant effect on clam recruitment at either site, but plots that were protected from predators with netting contained significantly more clams. We conclude that buffering sediments to combat low sediment pH is not effective compared with applying netting to deter predators.

Where does ocean acidification (OA) hide in the Gulf of Maine? Time scales and drivers of variability of the carbonate system

Joe Salisbury, Bror Jonsson and the UNH Coastal Carbon Group

Presented by: Joe Salisbury, joe.salisbury@unh.edu

The Gulf of Maine is one of the world's most valuable ecosystems in terms of fisheries landings, yielding over $1billion/year, primarily from landings of lobsters and scallops. These organisms and others are subjected to OA, but also to wide environmental ranges in temperature, salinity, nutrients and carbonate system parameters. Annual variability alone alters each of these with temperatures ranging from <2°C to 20°C, order of magnitude changes in limiting nutrient concentrations and aragonite saturation states ranging from ~0.8 – 3.0. However, we find that subdecadal variability caused by heat flux and circulation also play important synergistic and antagonistic roles in driving environmental conditions. For example, the recent warming and salt flux into the Gulf of Maine over the last decade had a considerable impact on the carbonate system, assuaging the impact of OA. While this event is unprecedented in over 100 years of observation, we find significant variability in temperature, and carbonate parameters occurring at subdecadal time scales. Depending on the source waters, local productivity, river discharge and heat flux, such events could be either stressful or helpful to calcifying ecosystems. This variability also tends to mask the expression of global OA in the Gulf of Maine and it may be another decade before we witness the emergence of OA.

Acid Justice: Adaptive capacity and social vulnerability to ocean and coastal acidification in the Gulf of Maine

A. Strong

Presented by: Aaron L. Strong, aaron.strong@maine.edu

Several states in the Northeast – Maine, New Hampshire, Rhode Island, New York and Massachusetts – have completed, are undergoing, are initiating, or are exploring formal governmental processes for assessing the threat of ocean and coastal acidification to our coastal ecosystems and economies. One emergent tool in the toolbox to combat ocean acidification is the use of formal risk assessments which seek to identify hotspots of physical, chemical, biological and ecological exposure to acidification that are also areas of high social vulnerability and limited adaptive capacity to the impacts of acidification. As the use of risk assessments spreads, determining what key indicators are relevant, measurable, and meaningful in the coupled social-ecological systems of the Gulf of Maine is emerging as a key focal point of research. In this study, I first assess the adaptive capacity around the Gulf of Maine to address ocean and coastal acidification in our region, using standard and widely-accepted social vulnerability indicators. I subsequently assess what regional and local concerns remain unaddressed by the use of standard risk assessment procedures, using the case study of Maine's wild-harvest fisheries and aquaculture industry. I conclude by assessing opportunities for the development of regionally-specific, bottom-up vulnerability indicators that may be tailored directly to the outcomes of recent and on-going state-level acidification management processes in our region that could enable state managers to

more effectively prioritize the allocation of resources for acidification monitoring and better identify key hotspots of high acidification risk.

The shallow, mobile sand ecosystem of Stellwagen Bank and the fish species it supports, based on long line, gill net, and otter trawl catch data

P.C. Valentine

Presented by: Page C. Valentine, pvalentine@usgs.gov

Mapping of the southcentral part of Stellwagen Bank has revealed the presence of 19 geologic substrates in an area of 211 km^2, extending from the bank crest (25 m water depth) westward into Stellwagen Basin (100 m). Catch results from NOAA Fisheries observers on commercial longline (20 sets), gill net (135 sets), and otter trawl (51 tows) vessels from 2010 to early 2017 were examined to determine the distribution of fish species on substrate types. Fishing effort is separated geographically by gear type. Otter trawls fished north-south (30-45 m) along the bank crest and western flank on substrate A1, a rippled, coarse-grained sand. Gill nets and longlines were set together north-south (30-35 m) along the bank crest and the eastern flank on substrate B, a rippled, coarse-grained sand that partially covers pebble-cobble gravel and boulder ridges. The rippled, coarse-grained sands of substrates A1 and B are texturally identical. The other 17 mapped substrates experienced little fishing effort. On A1, otter trawls caught 30 fish species. On B, gill nets caught 25 fish species (23 in common with otter trawls), but longlines caught only 12 species. A combined total of 33 fish species was observed. Otter trawls caught 7 flounder species, gill nets 5, but longlines only 1. All gear types caught 4 to 5 species of skate. On B, gill nets caught cod at half of the sites, but longlines caught it at all sites; gill nets caught monkfish and lobster at most sites, while longlines caught neither. The combined observer data for three gear types document that the shallow, rippled sand substrate of the bank supports 26 benthic, 5 bentho-pelagic, and 2 pelagic fish species. The apparent under sampling by longlines, and the non-observance of sand lance and herring (known to inhabit this part of the bank), suggest that gear type and species behavior influence the numbers and kinds of species caught.

Lessons for artisanal fisheries from Penobscot Bay: 1800 - 1960

Willis, TV; Alexander, K; Leavenworth, W; Schmitt, C; Wilson, K; Wilson, J

Presented by: Theodore V. Willis, theodore.willis@maine.edu

Traditional Artisanal fisheries supply around 70% of fish protein consumed worldwide. These fisheries are local, near-shore, often use rudimentary fishing gear and focus on a broad catch, in terms of species and target size. Fisheries in the Gulf of Maine once fit these criteria as well. In 1800, Penobscot Bay was the frontier: lightly populated and minimally exploited. The fishing centers focused on local markets, supplying a diversity of marine vertebrates and invertebrates for everything from fertilizer to table delicacies. We documented the progressive specialization of Penobscot Bay fisheries over 160 years using historical catch records and contemporary press articles. We focus on six species, and their fisheries, demonstrating how outside influence and economic drivers "from-away" repeatedly focused and refined effort until sustainable harvest was achieved through collapse, bankruptcy and, ultimately, restructuring markets. We documented three stages of exploitation: harvest focused on local consumption (slow-burn), focus on distant markets for consumption or commodity (fast-burn), and less destructive harvest with relatively more local control (medium-burn). In this context we used multivariate analysis and quantitative data from the turn of the 19th century to explore relationships between gear, catch and effort. Catches were significantly larger and more diverse early on. Landings progressed from a focus on diadromous riverine species to an offshore species focus. There was a North to South spatial pattern in the exploitation. The fisheries that reached the medium-burn, "sustainable" stage were those where the fish autecology limited harvest during some portion of the year. Once initial declines resulted in commercial extinction, the refuge period and local management helped maintain populations. Our lessons for artisanal fisheries are that local populations are nearly impossible to maintain under strong pressure from distant markets, and local management that recognizes the vulnerability of certain life stages is critical to maintaining a sustained fishery.

Microplastic fiber uptake, ingestion, and egestion rates in the blue mussel (*Mytilus edulis*)

Woods, M.N., Stack, M., Fields, D.M., Matrai, P.

Presented by: Madelyn Woods, mwoods@meriresearch.org

Microplastics are a ubiquitous contaminant in the marine environment. Their small size and high availability qualify them as additional stressors to filter-feeding organisms already faced with increasing seawater temperature and ocean acidification in the Gulf of Maine and beyond. Here we present the effects of polyethylene terephthalate microplastic fibers (MPF) on blue mussel (*Mytilus edulis*) feeding rates, quantified using imaging flow cytometry. This study represents the first step

in a three-part assessment of multi-stressor effects of microplastics, elevated seawater temperature, and ocean acidification. Mussels were fed a diet of *Rhodomonas salina* and experimental treatments ranged from 3,000 to 30,000 MPF/L. Experimental microalgal uptake rates were greatly reduced in mussels exposed to levels of 15,000 MPF/L or higher. Although pseudofeces production showed a positive correlation with MPF uptake rates at 30,000 MPF/L, further examination revealed up to 70 MPF in a single fecal pellet and an average of approximately 100 to 1000 MPF accumulating in the digestive track. Based on our results, it is possible that mussels act as microplastic sinks in Gulf of Maine coastal waters. Depuration times of exposed mussels were also examined to assess MPF egestion rates and may be an important processing step for commercial farmers. Ecological implications of MPF intake and egestion by Gulf of Maine bivalves already exposed to warmer and potentially acidified waters will be discussed.

Abstracts: Poster presentations

Long-term Data Identifies Declines in Cover and Differences in Interannual Variability of Foundation Species on Appledore Island, ME

Kinsman, N., Lindsay, T., Rhodes, E., Wilcox, R.

Presented by: Kylla Benes, kbenes@uci.edu

The rocky intertidal ecosystem is highly dynamic, yielding well-documented organismal zonation patterns. The algal foundation species representative of these zones compete for space and resources and are subject to stochastic disturbances. These processes lead to changes in species densities and zone boundaries across seasons, years, and even longer time scales. Long-term data are critical to discern seasonal or otherwise cyclic noise from alterations due to human-induced climate change. Shoals Marine Laboratory has maintained a student-driven species survey at five permanent intertidal transects since 1976. Presently the survey includes permanent photo quadrats, point-intercept transects, and more exhaustive censuses to observe and quantify trends in species abundance and distribution at these sites. Analysis of data from 1995 to present shows high variability in all four of the foundation species of algae: *Ascophyllum nodosum*, *Fucus* sp., *Mastocarpus stellatus*, and *Chondrus crispus*. Of the four species, *Fucus* and *Chondrus* showed the highest interannual variability in percent cover. *Chondrus*, a once conspicuous member of the low intertidal zone, has diminished to near zero percent cover. *Nucella lapillis*, a small whelk associated with each algal zone, also shows high variability with a positive correlation to *Mastocarpus* percent cover. Calculations and patterns, such as the ones presented here, can be used to select indicator species to track changes in the intertidal community due to climate change. Further, high variability of the foundation species is likely to have a notable impact on the invertebrates like *N. lapillis*. To determine the implications and persistence of these findings, future research should examine the sensitivity of algal species to climate change and the relationship between the dominant canopy formers and the associated community.

Population Assessment of Harbor (*Phoca vitulina concolor*) and Gray Seals (*Halichoerus grypus*) at Duck Island Ledges, ME

Breslow, I., Tommasi, K., Bogomolni, A., Lysiak, N., Sette, L.

Presented by: Ian Breslow, irb4@cornell.edu

Duck Island and its surrounding ledges are a part of the Isles of Shoals in the Gulf of Maine (GoM). This area acts as a central resting point along the seasonal migratory route of harbor and gray seals, making it a highly relevant study site for population assessment. The abundance of pinnipeds in the GoM has increased since the Marine Mammal Protection Act (MMPA) went into effect in 1972. Prior to the MMPA, two species of phocids, *Halichoerus grypus* (gray seal) and *Phoca vitulina concolor* (harbor seal), were hunted for bounty and experienced a significant population decline in the Northwest Atlantic. Annual counts of seal populations in the GoM will track the degree of recovery. Accordingly, 20-30 shipboard photographic surveys were conducted each summer from 2011-2017 during low tides off Duck Island and adjacent ledges. During this period, gray seals increased every year, whereas harbor seals numbers fluctuated and declined after 2016. During summer 2017, 13 gray seals and one harbor seal were entangled in fishing gear and marine debris; protruding and bulging eyes were documented in harbor seals on eight different occasions; and 53 seals were re-sighted, several on an annual basis since 2011. Correlation of seal counts and time of low tide showed that counts conducted between 0500 and 1000 were least variable, possibly because of minimal disturbance by recreational and lobster boats.

Environmental and Anthropogenic Factors Contributing to Harbor (*Phoca vitulina concolor*) Seal and Gray (*Halichoerus grypus*) Seal Counts on Duck Island Ledges, ME

Breslow, I., Bogomolni, A., Lysiak, N., Sette, L.

Presented by: Ian Breslow, irb4@cornell.edu

Duck Island and its surrounding ledges are a part of the Isles of Shoals in the Gulf of Maine and serve as a central resting point along the seasonal migratory route of *Phoca viulina concolor* (harbor seal) and *Halichoerus grypus* (gray seal). Both species haul out for a variety of reasons, both biotic (rest and molting) and abiotic. To determine the relative influence of several abiotic factors, we conducted and analyzed 20-30 shipboard photographic surveys each summer during low tides from 2011-2017 off Duck Island and adjacent ledges. Air temperature, water temperature, wind speed, and disturbance by recreational and lobster fishing vessels appear to have no association with numbers of either seal species. Type of vessel may have different influences on seal haul out behavior. However, seal counts did vary with time of day; gray seals numbers greatly declined as the day progressed, whereas harbor seal counts fluctuated throughout the day. Based on minimum

counts, the optimal time to conduct a survey was during low tides occurring between 0500-1000 hrs. Therefore, estimates of seal abundances throughout their range should be standardized with respect to time of low tide.

Remote sensing data linkages to interannual variability of toxic *Alexandrium fundyense* blooms in the Bay of Fundy (Canada)

Bucci, A. F.; Thomas, A. C.; Martin, J. L.

Presented by: Andre F. Bucci, andre.bucci@maine.edu

The Bay of Fundy experiences annually recurring harmful algae blooms of the dinoflagellate *Alexandrium fundyense*, presenting risks to human health due to paralytic shellfish poisoning. The area is regularly surveyed for *A. fundyense* abundance, resulting in a time series of roughly weekly data of almost 30 years. A subset (1998-2014) of these historical data were used to quantify interannual variability in 3 metrics of *A. fundyense* blooms: magnitude, duration and timing of occurrence. Gaussian curves were fitted to the abundance data in each year to obtain the parameters. In most years, a one mode Gaussian curve best fit the data, however in 2001 and 2008 a two mode Gaussian was necessary and the parameters were averaged for comparison to other years. The magnitude of the blooms was highly variable between years, with maximum values in 2004. Since 2002, the timing of the blooms has trended to be earlier in the year, advancing from day 240 (late August) to the minimum of day 160 (mid June). The duration of the blooms was maximum in the period 2003 - 2007 (maximum of 21 days) and lower outside that period (<10 days duration). The 3 metrics of bloom interannual variability were then compared to time series of high resolution (1km) concurrent ocean color (SeaWiFS and MODIS) and sea surface temperature (AVHRR) data. Linkages between the bloom metrics and the ocean color data are highly variable, likely due to the optically complex coastal waters in this region. A trend was observed of blooms occurring in warmer waters (10-16˚C) prior to 2007, while after that period, the blooms developed in colder waters (4-10˚C). This shift in water temperature is the result of the timing of the bloom shifting sooner in the year, when the temperature of the water is still low.

Biological and physical drivers of pH change in the Damariscotta River and implications for shellfish aquaculture

Coupland, K., Brady, D.

Presented by: Kate Coupland, Catherine.coupland@maine.edu

The Damariscotta River supports over 80% of all of the oyster aquaculture in the state of Maine as well as some mussel aquaculture. The primary growing area is in the upper third of the estuary where residence time is increased due to a geological constriction leading to reduced tidal flushing. This area has markedly different oceanographic conditions (temperature, chlorophyll a, turbidity, nutrients, etc) than the lower portions of the estuary. Our research uses hourly buoy data from the past three years collected in the growing area to better understand the interactions between pH and salinity, as well as between pH, nitrate, chlorophyll a, and dissolved oxygen. pH can be a first indicator of low aragonite saturation, leading to poor oyster growth, or death of larval organisms. The growing area is heavily impacted by freshwater run off, with salinities dropping 8-10psu and taking over a month to return to pre-existing salinities. The growing area pH is also impacted via photosynthesis and respiration on diel cycles, as well as responding to pulses of nitrate entering the river from the Gulf of Maine on weekly and monthly scales. There is some indication that photosynthesis may be able to buffer against acidity during low salinity events within the growing area.

Deployment of a continuous water quality and coastal acidification monitoring station in Casco Bay, ME

Doan, R. M.

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A major knowledge gap in the understanding of acidification and water quality in near-shore coastal systems is the lack of high frequency data. We address that need through the deployment of a continuous monitoring station that collects hourly measurements of water temperature, salinity, dissolved oxygen, pH, chlorophyll fluorescence, and the partial pressure of carbon dioxide. Additionally, dissolved inorganic carbon, total alkalinity and the saturation state (omega) of aragonite are calculated from measured data. This station is deployed year round and undergoes rigorous bi-weekly maintenance and calibration. Data from the first year of operation reveal predominately seasonal variability, with occasional weather-related influences. Carbonate chemistry generally improves throughout the late summer and early fall. A strong negative correlation between dissolved oxygen and pCO_2 suggests that a dominant driver is the balance between productivity and respiration. In addition, the saturation state of aragonite showed episodic

dips below 1.6, a threshold critical in the development of bivalve shells. Generally, these dips occurred in the spring and during rain events, and higher values prevailed under dryer conditions.

Ocean Genome Legacy: Preserving marine biodiversity through DNA biobanking

Evankow, A., Distel, D.

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The process of ocean acidification is a potential threat to global marine biodiversity. The goal of the Ocean Genome Legacy Center at Northeastern University (OGL) is to document and preserve the ocean's vast biodiversity for research and conservation efforts. OGL is a non-profit biorepository dedicated to archiving marine genomes and making them widely available to the global scientific community. Currently, the OGL collection contains 25,000+ genomic DNA samples representing 1,500+ marine species. Of these, there are currently 17 phyla, 33 classes, 190 families, and over 260 species represented from the Gulf of Maine. In collaboration with researchers and citizen scientists around the world, including local organizations such as the Massachusetts Division of Marine Fisheries and National Oceanic and Atmospheric Administration, OGL provides secure storage and broad public access to genomic materials; creates a forum for sharing samples, data, and ideas; and supports research that can improve human health, improve the sustainability of global food and energy supplies, and protect marine ecosystems. An example of a current collaboration is the use genetic resources to identify seafood with DNA barcoding. We invite you to explore our online DNA catalog and contribute tissue samples to the OGL biorepository at www.northeastern.edu/ogl/.

Disseminating OCA Citizen Science Monitoring Guidelines and Resources

Gassett, P. R., Strong, A., Stancioff, E., Turner, E.

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As ocean and coastal acidification (OCA) presents unique challenges to the human-ecological interface, it is a salient issue that strategies for research and management support a plurality of organizational engagement. There is a tremendous opportunity in the Northeast to build upon existing networks of water quality monitoring groups to develop robust opportunities for citizen scientists and stewardship organizations to engage with OCA. In moving from regional vulnerability assessments for OCA, to actionable steps towards statewide mitigation and adaptation, it will be important to delineate local and open ocean drivers of acidification along the Northeast's

heterogeneous coast. Coordination and data sharing among monitoring groups can help to fill critical gaps in current coastal acidification research. This work aims to help cross-calibrate citizen science OCA monitoring protocols by providing workshop trainings, webinars and resources specifically for volunteer and citizen scientist audiences. Ultimately, the objective of this effort is to make possible multi-level institutional collaboration for OCA monitoring by supporting foundational improvements in data usability.

Multispectral classification of Gulf of Maine water mass types and their seasonal and interannual variability

King, B., Thomas, A.C.

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Bio-optically, the Gulf of Maine (GOM) is a strongly heterogeneous system, exhibiting a highly variable distribution in both time and space of suspended sediment, colored dissolved organic matter, and phytoplankton community composition and biomass. The concentration of these components alters the optical properties of the water and renders the standard NASA chlorophyll algorithm strongly suspect. However, the spectral signature of the water is well quantified by satellite-based multispectral remote sensing reflectance measurements. A high-resolution, multi-year systematic analysis of the spatial and temporal variability in these spectral signatures within the GOM has not yet been conducted. Here, we aim to identify the dominant spectral signatures of water types present in the GOM based on monthly composite SeaWiFS and MODIS 1 km resolution data. We use a combination of multivariate clustering techniques, including k-means and hierarchical clustering, to distinguish different groups of water mass spectral signatures. Results are remapped to develop a climatological view of dominant water mass types and their seasonal variability. Preliminary results indicate a small number of spectral water types dominate the GOM interannually, especially over the deeper basins, augmented by several smaller groups. Many of these smaller groups are present only during specific months or seasons and are absent during the remainder of the year. Future work will include the development of a time series from 1998-present to examine interannual variability and quantify trends. These results will provide new views of GOM surface water mass variability over seasonal and interannual time scales.

Altered Behavior of Parasitized Carcinus maenas Decreases Susceptibility to Predation by Definitive Bird Hosts

Love, C., Blakeslee, A.

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Traditional food web analyses often overlook the interactions between parasites and their hosts, yet some food webs have more parasite-host links than predator-prey links. Parasite-induced behavioral modifications are a known strategy that increases the susceptibility of infected hosts to predation, thereby increasing transmission rates. Several studies have supported this hypothesis; however, others have not. This study utilized laboratory and field-based experiments to test how the trematode, Microphallus similis, alters the predation rates of its second- intermediate host, Carcinus maenas. Infected crabs were characterized by lethargic behavior, which decreased in severity >48 hrs after infection. Tethering experiments in the intertidal revealed infected were crabs preyed upon by gulls (definitive host) more than uninfected crabs.

Incidental catch of Atlantic halibut in Cape Cod commercial fisheries

Marshall, R., McGuire, C., Zemeckis, D., McBride, R., Bank, C.

Presented by: Rachel Marshall, rachel.carmen.marshall@gmail.com

The Atlantic halibut (*Hippoglossus hippoglossus*) resource off New England is presently depleted and classed as a Species of Concern. However, reports from Cape Cod commercial fishermen indicate increasing incidental catch rates of Atlantic halibut since 2010. This provided the opportunity to collect additional biological information to supplement sampling completed during fishery-independent surveys, and to improve our understanding of the life history of this data poor species. Cape Cod commercial fishermen collected biological samples (gonads, otoliths, heart, spleen, and fin clip) from up to two halibut caught incidentally per day trip using gillnet, trawl, or longline gear. Preliminary data analyses suggest a higher percentage of females caught than males, with five times more females than males. Also observed was a higher percentage of immature halibut caught than mature or developing. Additional biological samples are being collected through 2018, and further analyses, including gonad histology and otolith aging, will be performed. The improved understanding of halibut life history will be combined with concurrent studies employing electronic tagging and genetics in order to investigate stock structure off New England and inform fishery management.

Modeling and Measuring Change in the Gulf of Maine: The Legacy of the EcoSystem Indicators Partnership (ESIP)

Tilburg, C., Murdoch, P., Parlee, K., Latimer, J., Elskus, A., Liebman, M, Russell-Robinson, S.

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The EcoSystem Indicator Partnership (ESIP), a committee of the Gulf of Maine Council on the Marine Environment (GOMC), was formed to better understand and convey information on the status and trends in the Gulf of Maine ecosystem and the impacts of human use. The primary goals of ESIP have been to (a) provide consistent, scientifically-sound baseline data and information about ecosystem condition against which future changes can be compared; (b) ensure that information reaches decision-makers within the Gulf of Maine and Bay of Fundy region in a manner that is useful to them; and (c) provide easy access to the compiled data via a web-based Indicator Reporting Tool. Through collaboration with regional experts from local, state, provincial and federal governments, along with academia and members of non-government organizations, ESIP has selected twenty-one priority indicators under seven indicator themes. Recently ESIP 2.0 has begun focusing on indicators to track ecosystem services-- the benefits that people obtain from the ecosystem. This work is intended to go beyond providing information on how ecosystems function to providing information that we can use to better manage those ecosystems to meet societal needs. ESIP has also released an innovative tool, linking mobile Smartphone technology and citizen science to visually document changes in the Gulf of Maine – the ESIP ICUC (I See, You See) Smartphone App. The ICUC users can look up information about pre-selected monitoring locations, and can submit time-stamped photos from those sites to visually document changes over time. Efforts are underway to preserve some or all of these valuable ESIP contributions to the GOM community as the program shifts to accommodate funding constraints.

A preliminary study testing the effects of high CO2 on the early life stages of the northern sand lance *Ammodytes dubius*

Murray, C.S., Wiley, D., Baumann, H.

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Fish early life stages are potentially vulnerable to ocean acidification, yet divergent responses are well documented across similar species and even populations. This variation may reflect local adaptation to existing CO2 variability prevalent in many coastal systems. For example, populations that spawn in shallow and highly productive systems like saltmarshes likely produce offspring capable of tolerating large, biologically driven CO2 fluctuations typical during spring and summer.

Conversely, fish that spawn in the open-ocean or during winter generally experience more stable CO2 conditions during early life and may lack adaptations necessary for high CO2 tolerance. As a pilot study, we conducted a CO2 exposure experiment on offspring of the northern sand lance *Ammodytes dubius*, an ecologically important forage fish that spawns on the northwest Atlantic shelf in early winter. Spawning-ripe adults were collected from Stellwagen Bank National Marine Sanctuary. Fertilized embryos were reared at two temperatures (5° and 10°C) crossed with three CO2 levels (~400, 900, and 2,000 µatm). At 10°C, hatching success was near zero across CO2 treatments. At 5°C, moderate hatching success was observed at 400 (22%) and 900 (15%) µatm CO2. However, at 2,000 µatm less than 1% of embryos survived to hatch. Hatch length (treatment average ± SD) was similar at 400 (5.84 ± 0.32 mm) and 900 (5.78 ± 0.57 mm) µatm CO2. Insufficient samples prohibited hatch length measurements at 2,000 µatm. This preliminary study suggests high CO2 may influence hatching success of A. dubius, however further experiments are needed to produce more statistically robust results.

Networking across the Gulf of Maine

Seavey, J., Webber, H., Sewall, L., Cleaver, C.

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The Northeastern Coastal Stations Alliance (NeCSA) is a network of small field stations spanning the Gulf of Maine—from the Maine/New Hampshire border to Nova Scotia. All stations are committed to using and leveraging existing resources (location, personnel, equipment) to contribute coupled abiotic and biotic data to each other and to the larger community to understand change in the Gulf of Maine. Member stations range in capacity, structure and mission. In 2015, field station directors and researchers participated in a year long strategic planning process to determine alliance priorities. Given the spatial extent of member station locations, a major priority that emerged was implementing standardized monitoring to track changes in the coastal zone. In 2016, we distributed autonomous temperature loggers (Onset® TidbiT® v2 Temp Data Loggers) and a simple, low cost deployment protocol to ten NeCSA field stations to explore standardized methodologies and best practices for data sharing, and to inform our growth as an alliance. In 2017, we piloted a protocol to monitor the intertidal biota. We will report on lessons learned about our collaborative efforts to date, which include the need to be adaptive in structure and function and to let initiatives emerge organically.

Interspecific Interactions and Habitat Preferences of Harbor Seals (*Phoca vitulina concolor*) and Gray Seals (*Halichoerus grypus*) on Duck Island and Ledges, ME

Tommasi, K., Bogomolni, A., Lysiak, N., Sette, L.

Presented by: Kadie Tommasi, kkt2001@wildcats.unh.edu

The number of pinnipeds in the Gulf of Maine has increased since the Marine Mammal Protection Act (MMPA) went into effect in 1972, making it illegal to harm or hunt all marine mammals in the United States. Gray and harbor seals inhabit the Northwest Atlantic and frequently utilize the same haul out areas, sometimes leading to aggressive interspecific interactions. Subtle differences in haul out areas, however, may minimize aggression. Previous studies showed that harbor seals preferred to haul out on large landing areas easily accessible at both high tide and low tide, while gray seals preferred rocky ledges only accessible at low tide. Between 20 and 30 shipboard photographic surveys were conducted for the haul out areas on Duck Island and adjacent ledges during summer low tides in 2011-2017. We counted the number of harbor seals and gray seals per ledge for all surveys. By 2017, one ledge once dominated by harbor seals shifted exclusively to gray seals and three ledges gray seals are becoming more abundant. Harbor seals haul out area have shifted, possibly in response to the steady increase of gray seals.

Infection dynamics of an Acanthocephalan parasite, *Profilicollis botulus*, in the green crab, *Carcinus maenas*, on the coast of Maine

Van Kirk, T., Bricknell, I., Joyce, O., Redcay, A., Westbrook, M., Spangenberg, C., Lopez-Anido, R., Gallandt, L.

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The European green crab *Carcinus maenas* is an invasive species to the coast of Maine that has been proposed as sustainable bait for the lobster industry. *C. maenas* is also the intermediate host of the Acanthocephalan parasite *Profilicollis botulus* which has been suspected to infect the American lobster *Homarus americanus*. Little is known about the infection dynamics of this parasite, therefore more information about parasite dynamics on the coast of Maine is needed. More information will allow ecologists to understand the parasite's impact on the coastal Maine ecology, and inform policy makers as to whether *C. maenas* can safely be used as bait. Crabs were collected from May 2017 through August 2017 from three alternating locations on the Maine coast and tested for parasite prevalence and intensity. Data collected were put through preliminary analysis to test the impact of a variety of factors on parasite infection dynamics. For each crab, five pieces of data were collected: sex, color morph, carapace width, parasite presence, and number of parasites. Fisher's Exact Tests and Kruskal-Wallis Tests were used to compare prevalence among different sub-samples. Overall

prevalence for the summer of 2017 was 17% for the entire coast, an insignificant increase from 14% in the summer of 2016. Prevalence was significantly higher in the southernmost bioregion of Maine at 32%, followed by the midcoast at 13% and the northernmost location at 10%. Prevalence was significantly higher than average amongst the following groups: female, red color morphs, and berried female crabs. Intensity was found to be highest in the southernmost location at an average of 5 cysts per instance of infection. These data support the hypothesis that a changing environment could significantly impact host-parasite dynamics of green crabs on the coast of Maine.

Monitoring marine sediment as an indicator of a changing ocean

Whiting, M., Steele, Z., Clift, A. & Gropp, R.

Presented by: Mark Whiting, mark.c.whiting@gmx.com

The purpose of this study is to monitor intertidal marine sediment pH and shellfish recruitment in Hancock and Washington Counties as indicators of ocean acidification. The monitoring protocol and quality assurance procedures are designed to engage NGOs, citizen scientists and academics in long-term monitoring of local resources. Data will be used to guide communities and other government agencies in resource management decisions. Preliminary data shows some patterns, namely (1) sediment pH is very low, (2) there are seasonal and intertidal variations, (3) eelgrass appears to provide an improved (higher) pH environment compared to bare mudflats, and (4) clam recruitment is poor at all sites investigated so far from Deer Isle, Blue Hill, Frenchman Bay and Great Wass Island.

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