2018 RARGOM Annual Science Meeting

PROGRAM

RARGOM Annual Science Meeting

Drivers of Change in Gulf of Maine Ecosystems

Date: October 26, 2018
Location: Hannaford Hall, University of Southern Maine, Portland, ME

Featured keynote speakers:
***Kevin Friedland**, NOAA Northeast Fisheries Science Center*
***Lisa Kerr**, Gulf of Maine Research Institute*

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Meeting Schedule and Oral Presentations

Start Time	Dur.	Presenter	Title
8:15 AM	0:45		**REGISTRATION and poster set up**
9:00 AM	0:05		**WELCOME**
9:05 AM	0:10		**Opening musical performance: *Whale Dive*, written by Zachary Friedland and performed by tuba soloist Gary Buttery (Connecticut College)**
9:15 AM	0:15	James Manning	Real-time telemetry of bottom temperature from fixed and mobile fishing gear
9:30 AM	0:15	Andy Thomas	Thirty-five year patterns of North American east coast shelf SST and SST phenology
9:45 AM	0:15	Andy Pershing	Causes and consequences of marine heatwaves in the Gulf of Maine
10:00 AM	0:15	Hsiao-Yun Chang	Estimating spatiotemporal variation in distribution of northern shrimp, *Pandalus borealis*, using environmental variables in a changing Gulf of Maine
10:15 AM	0:15	Sara Randall	Drivers of change: warming water temperatures and green crabs
10:30 AM	0:30		**BREAK & POSTERS**
11:00 AM	0:30	Kevin Friedland	**Keynote:** Disjunctive regime shifts in surface and bottom thermal environments of a continental shelf ecosystem
11:30 AM	0:15	Dan Codiga	Inter-annual variability and long-term trends in water column ecology of the Massachusetts Bay system
11:45 AM	0:15	Justin Suca	The relationship between *Calanus* and sand lance on Stellwagen Bank and the northeast US shelf
12:00 PM	0:15	Paul Caiger	Monitoring long term trends of Atlantic cod (*Gadus morhua*) in Massachusetts Bay using passive acoustics
12:15 PM	1:45		**LUNCH & POSTERS**
2:00 PM	0:30	Lisa Kerr	**Keynote:** Managing fisheries in a changing Gulf of Maine
2:30 PM	0:15	Joe Langan	Characterizing changing ecosystem phenology in response to climate in a large temperate estuary
2:45 PM	0:15	Nick Record	Climate-driven circulation changes threaten conservation of endangered North Atlantic right whales
3:00 PM	0:15	Kristina Cammen	Genomic approaches to historical ecology and shifting baselines for pinniped populations in the Gulf of Maine
3:15 PM	0:30		**BREAK & POSTERS**
3:45 PM	0:15	Tony Diamond	Beyond ocean warming: bottom-up effects of climate change on the Gulf of Maine food-web inferred from diet and demographic changes in seabirds of Machias Seal Island
4:00 PM	0:15	Don Lyons	Differential response of Gulf of Maine seabirds to the 2018 ocean heat wave
4:15 PM	0:15	Brad Franklin	The impacts of warmer ocean temperatures: from species distribution shifts to community economics
4:30 PM	0:15	Beth Turner	Responding to ocean and coastal acidification through a regional network: the role of NECAN
4:45 PM	0:15	Jeff Runge	Implementation of the Integrated Sentinel Monitoring Network (ISMN)
5:00 PM			**Adjourn**

Poster Session: Presenters and Titles

Juliana Berube	Dietary trends of stranded harbor seals (*Phoca vitulina*) and local fisheries in the Gulf of Maine
Andre F. Bucci	A hyperspectral, cross-basin view of Gulf of Maine surface waters and the variability of their optical constituents
Bradford Butman	Near-bottom observations of sediment resuspension in the western Gulf of Maine 2014-2017
Aliya Caldwell	The Impact of Plastic Pollution on Four Species of Seabird Nesting on the Isles of Shoals, ME/NH
Grace Callahan and Callum Backstrom	The relationship between intertidal mercury pollution and gull nesting density: a case study of the Isles of Shoals
Quinn Carey	Ocean climate change in four east coast North American LMEs: 21st century SST changes from CMIP5 projections
Gemma Clucas	Monitoring tern diets using DNA metabarcoding of fecal samples
Brenna Friday	Replacement of a foundation species in the lower intertidal
Parker Gassett	M.A.P.—Monitoring Acidification Project
Julianna Berube and Jessica Veo	Long term population assessment of harbor seals (*Phoca vitulina concolor*) and grey seals (*Halichoerus grypus*) at the Isles of Shoals
Jessica Veo	Characterizing the diet of stranded harbor seals (*Phoca vitulina concolor*) in the Gulf of Maine
Connor Jones	A histopathological health and condition assessment of farmed blue mussels (*Mytilus edulis*) in a changing Gulf of Maine
Brianna King	Multispectral classification of Gulf of Maine surface waters: seasonal and interannual variability
Karl J. Kreutz	A role for Pacific climate variability on extreme events in the Gulf of Maine
Joan LeBlanc and Andy Pershing	Gulf of Maine 2050: A Symposium and Workshop about the Future of the Gulf of Maine
Sarah Neitzel	Raising the BAR on breakpoint detection in biological data with a new Bayesian procedure
An T Nguyen	Data management to reveal potential in Shoals Marine Laboratory's long-term intertidal monitoring dataset
Daniel E. Pendleton	Tracking phenological changes for North Atlantic right whales and fin whales in Cape Cod Bay over twenty years using multi-season occupancy models
Emily Ray	A freshwater lake on a maritime island: The first limnological assessment of Crystal Lake
Hyejoo Ro	Impacts of a trematode parasite on the behavior of an invasive shore crab in the Northwest Atlantic
Louise Roberts	Finding a home in the noise: cross-modal disruption of search behaviour due to seabed vibration
Maya Roe	Population Biology of Rockweed (*Ascophyllum nodosum*) in Frenchman Bay: Assessment of a commercially targeted and ecologically important species
Heidi M. Sosik	NES-LTER: A new Long Term Ecological Research site on the Northeast U.S. Shelf
Mary Stack	Investigating potential impacts of climate change on the Gulf of Maine through water quality monitoring and *Mytilus edulis* as bio-indicators
Page C. Valentine	Mapping seabed substrates in the Stellwagen Bank region – providing a framework for ecological research
Peter G. Wells	The science-policy interface for evolving ecosystems: scientific information use in coastal and ocean decision-making

Abstracts: Oral presentations

Monitoring long term trends of Atlantic cod (*Gadus morhua*) in Massachusetts Bay using passive acoustics

Caiger, P., DeAngelis, A., Dean, M., Hatch, L., Rice, A., Stanley, J., Zemekis, D., van Parijs, S.

Presented by: Paul Caiger, paul.caiger@noaa.gov

Atlantic cod (*Gadus morhua*) populations in Massachusetts Bay have failed to recover since major declines. In order to rebuild these stocks, reliable information on their spawning dynamics is critical for designing and implementing management measures. Atlantic cod form dense, site-fidelic spawning aggregations, during which they vocalize, permitting acoustic detection of their presence at such times. This study utilized passive acoustic monitoring to follow trends over 10 consecutive seasons, the longest such timeline of any passive acoustic monitoring of spawning activities in a fish species. The acoustic presence of winter spawning Atlantic cod was principally confined to two areas within Massachusetts Bay; a site within the Winter Cod Conservation Zone, and two closely situated sites inside the northwestern edge of the Stellwagen Bank National Marine Sanctuary. Moreover, the presence of Atlantic cod at these locations was not consistent temporally, with the disappearance of large spawning components after just one or two seasons, and an eastward shift throughout the study. This project demonstrates that passive acoustics monitoring can be a very effective and cost-effective means of assessing the presence of an acoustically active fish species, and is an alternative means of substantiating traditional fisheries-related stock assessment methods.

Genomic approaches to historical ecology and shifting baselines for pinniped populations in the Gulf of Maine

Cammen, K., Vincze, S., Heller, A. S., McLeod, B., Wood, S. A., Bowen, W. D., Hammill, M. O., Puryear, W. B., Runstadler, J., Wenzel, F. W., Kinnison, M., Frasier, T.

Presented by: Kristina Cammen, kristina.cammen@maine.edu

Molecular approaches that characterize the diversity of contemporary and historical specimens can provide windows into the historical ecology of a system. In recent decades, the Gulf of Maine has experienced rapid and dramatic change in pinniped population and abundance, particularly for the gray seal (*Halichoerus grypus atlantica*) and harbor seal (*Phoca vitulina vitulina*). To investigate the historical ecology of both species throughout the Northwest Atlantic, we compared genetic diversity at the mitochondrial control region today to diversity in archaeological specimens. The latter represent the populations approximately 300-1000 years ago, prior to regional hunts and bounties that drastically reduced population sizes in the late 1800s to mid-1900s. We further investigated the genomic diversity present in contemporary samples using restriction site-associated DNA sequencing. Our findings are consistent with the historical presence of large, genetically diverse populations of pinnipeds prior to human exploitation, and suggest that gray seals may have been more dramatically impacted by historical bottlenecks than harbor seals in the Northwest Atlantic. These results will be discussed within

the context of shifting baselines for pinniped populations today and related challenges to protected species management and ecosystem health in the Gulf of Maine.

Estimating spatiotemporal variation in distribution of northern shrimp, *Pandalus borealis*, using environmental variables in a changing Gulf of Maine

Chang, H-Y., Tanaka, K.R., Chen, Y.

Presented by: Hsiao-Yun Chang, hsiaoyun.chang@maine.edu

The northern shrimp (*Pandalus borealis*) is a key demersal species once supporting a significant commercial fishery in the Gulf of Maine. The spatial variation in shrimp distribution has been postulated to be influenced by environmental drivers although the effects of environmental drivers on the shrimp distribution have not been quantified. P. borealis in the Gulf of Maine is considered to be at the southern limit of the species' distribution, which makes them sensitive to the bottom-up forcing such as climate-driven temperature change. The objectives of this study are to identify the effects of environmental drivers on the shrimp distribution and estimate spatial variation in the shrimp distribution in the Gulf of Maine. Using bottom trawl survey data collected from 1984-2016, we developed a season- and sex-specific generalized additive modeling approach (GAM) to quantify associations of shrimp abundance with environmental (e.g., bottom temperature) and spatial factors (e.g., latitude). The quantified shrimp-environment associations were coupled with a regional circulation model to provide a spatially-varying shrimp density probability map in the Gulf of Maine. Bottom water temperature and salinity were found significant in influencing the P. borealis distribution. Furthermore, the GAM predicted high P. borealis abundance in the western Gulf of Maine, which could be indicative of spatially-dependent processes. This study provides a modeling framework that can quantify the environmental impacts on the P. borealis biogeography for the use to enhance the monitoring and management of this species in a changing Gulf of Maine.

Inter-annual variability and long-term trends in water column ecology of the Massachusetts Bay system

Codiga, D.L., Keay, K.E., Taylor, D.I.

Presented by: Daniel L. Codiga, dan.codiga@mwra.com

Water column ecology in Massachusetts Bay, Cape Cod Bay, and Boston Harbor (collectively the Massachusetts Bay system) has been monitored extensively since the 1990s in association with the September 2000 relocation of a treated wastewater outfall from Boston Harbor to 15 km offshore in Massachusetts Bay. Observations of physical, nutrient, phytoplankton, and zooplankton conditions span 26 years. Most aspects of seasonal cycles are understood. This analysis explores inter-annual variability and long-term trends. Mass Bay vertical-mean ammonium concentrations are up to 3-6 uM higher within about 10-20 km of the outfall since operations began. Outfall impacts have not been detected farther away, nor in other nutrients, chlorophyll, phytoplankton abundance, or dissolved oxygen. Bays-

wide, inter-annual variability includes inversely-related temperature and dissolved oxygen (DO) anomalies on timescales of 3 years and longer. Positive/negative 0.5-1 C temperature anomalies are associated with opposite-sign 0.25-0.5 mg l-1 DO anomalies. Inter-annual plankton variations appear influenced by predator-prey dynamics, based on inversely-related phytoplankton and zooplankton abundance anomalies at timescales of 6 years and longer (Libby et al., 2017). For many parameters, long-term trends are not statistically robust relative to inter-annual variability. Temperature and DO, however, show significant long-term trends: about 0.48 C decade-1 warming and about 0.15 mg l-1 decade-1 DO reduction. The influence of temperature on solubility can account for about 2/3 of the DO decline. The rate of warming is consistent with other regional estimates. Warming is occurring throughout the water column, thus not affecting stratification. Ongoing analysis of other aspects of inter-annual variability and long-term trends, including relationships to drivers such as river runoff and other climatic variations, will be presented.

Beyond ocean warming: bottom-up effects of climate change on the Gulf of Maine food-web inferred from diet and demographic changes in seabirds of Machias Seal Island

Diamond, A.W., Scopel, L.C.

Presented by: Tony Diamond, diamond@unb.ca

Changes in the prey field of planktivorous fish and birds have been predicted as a result of reduced nutrient status and phytoplankton abundance in the eastern Gulf of Maine since 2008, resulting from warming throughout the water column and increased stratification in summer and fall. Seabirds are near the top of this food-web, and their breeding success and diet are vulnerable to changes in the prey field. The largest community of seabirds in the Gulf of Maine is Machias Seal Island, a Canadian Migratory Bird Sanctuary at the junction between the Bay of Fundy and the Gulf. We describe declines in occupancy, breeding success, and chick growth rates in razorbills and Atlantic puffins (apex predators dependent on marine resources) breeding there, and associated population trends, in relation to changes in diet particularly after 2010, when low-fat species not previously recorded in the diet began to appear. Lipids, and particularly fatty acids, are essential for a range of important physiological properties of fish, including adaptation to temperature. Temperature rise affects the balance of fatty acids by favoring saturated acids (characteristic of warmer-water fish) over unsaturated acids (HUFA and PUFA) which characterise colder waters because they have a lower melting point, allowing cell membranes to maintain the fluidity which is an essential component of adaptation to temperature. The main sources in the marine food-web of the unsaturated ("essential") fatty acids that hetrotrophs cannot produce are diatoms, which have declined in the phytoplankton. We suggest that changes in diet and demography of razorbills and puffins in the eastern Gulf of Maine are best interpreted through consideration of system changes at scales ranging from cell membranes to ocean water masses, and that effects of warming temperatures operate on all components of the system in sometimes surprising ways.

The impacts of warmer ocean temperatures: from species distribution shifts to community economics

Franklin, B., Kennedy, B., Mills, K., Allyn, A., Pershing, A.

Presented by: Bradley Franklin, bfranklin@gmri.org

Climate projections indicate that ocean temperatures will continue increasing, potentially shifting the distribution of marine fish species and affecting the economics of the fishing industry and fishing communities. In this study, an integrated ecological-economic framework is used to evaluate how commercially important species will change, quantify the economic impact of these species shifts, and assess the value of specific adaptation strategies available to fishermen. A quantitative species distribution model coupled with qualitative expert vulnerability assessment ratings is used to project relative changes in the presence of over 50 commercially important fish species out to 2050 based on ocean temperatures projected by the CMIP5 ensemble of climate models (RCP 8.5 scenario). The results are used to estimate changes in species catchability, which are used as inputs to a port-specific economic optimization model. The optimization model assumes profit-maximizing behavior by the commercial fishing fleet at each port and adjusts the effort level of fishing activities— defined by the combination of gear used, species targeted, and fishing area — to changes in catchability. Future adaptation scenarios are elucidated through interviews and focus groups with fishermen and municipal leaders in New England ports. The economic model is then used to assess how adaptation scenarios can buffer climate-related impacts and to evaluate the relative value of different adaptation options, such as switching gear types, species targeted, and fishing location. We also consider specific policy changes that may be required to facilitate adaptation and measure the potential benefits of such changes.

Disjunctive Regime Shifts in Surface and Bottom Thermal Environments of a Continental Shelf Ecosystem

Friedland, K.D., R. E. Morse, J.P. Manning, D.C. Melrose, T. Miles, A. Goode, D.C. Brady, J. Kohut, A.C. Thomas

Presented by: Kevin D. Friedland, kevin.friedland@noaa.gov

Habitats within continental shelf ecosystems can be defined by their thermal properties, which considered with other aspects of their ecology are often divided into surface and bottom domains. Though satellites measure surface temperature nearly continuously, we are dependent on in situ measurements to characterize benthic thermal regimes. Ship based temperature measurements were used to develop a time series of gridded spring and fall surface and bottom temperature fields for the US Northeast Shelf. Gridded estimates were made using an adaptation of optimal interpolation. Surface and bottom temperature have increased over the study period of 1968-2017 in both spring and fall, albeit, spring temperatures increased at a slower rate. Surface and bottom temperature were highly correlated during spring, whereas in fall, this correlation broke down in the southern portion of the ecosystem and along the margins of Georges Bank associated with tidal front formation. A change-point analysis suggests a warming regime change occurred in the surface waters beginning in 2011 and progressed from the middle of the ecosystem outwards. A regime change in bottom temperature began in 2008 in the eastern Gulf of Maine and progressed westward each year, penetrating to the Middle

Atlantic Bight by 2010. The varying spatial and temporal progression of warming in the two layers suggest they were actuated by different forcing factors related to atmospheric warming in the surface, advective warming in the bottom, and variations in salinity potentially affecting both layers. These change points in temperature are reflected in the response of other aspects of the ecosystem including the production and distribution of lower and higher trophic levels.

Managing Fisheries in a Changing Gulf of Maine

Kerr, L.

Presented by: Lisa Kerr, lkerr@gmri.org

The Gulf of Maine is warming rapidly, with a long-term warming trend that is four times the global average rate and recent decadal warming that is faster than 99 % of the global ocean. Climate change is reshaping the ecosystem in ways that impact our fishery resources, including impacts on the productivity, distribution, and interaction of species. Key aspects of our fisheries management system, including: 1) observations of the resource, 2) stock assessment, 3) catch advice, and 4) allocation are being challenged by a changing climate. However, there are opportunities to account for the effects of a changing environment on these aspects of fisheries management system. Advancing fisheries management systems to recognize and respond to the impact of climate change on marine resources is a global challenge which will have both ecological and economic repercussions.

Characterizing Changing Ecosystem Phenology in Response to Climate in a Large Temperate Estuary

Langan, J.A., Puggioni, G., Oviatt, C.A., Henderson, M.E., Collie, J.S.

Presented by: Joseph A. Langan, joseph_langan@uri.edu

Recent work has demonstrated that interannual variation, multidecadal oscillation, and long-term change in climate can impact the distribution, trophic interactions, and productivity of marine organisms. However, the respective impacts of these environmental drivers on seasonal patterns of habitat use remain unclear due in part to the extensive data required for such an investigation. Conducted in Narragansett Bay, a large temperate estuary near the thermal extreme of many species' ranges, the University of Rhode Island weekly fish trawl survey (1959-present) offers a unique opportunity to understand how climate impacts the seasonality and function of the coastal marine ecosystem. This dataset indicates that composition of this community is in flux and species' residence times have changed by as much 3 months, likely resulting in significant disruption of the trophic relationships that previously defined the local food web. Regression analyses of the annual days of first and last observation for each candidate species revealed that climate change, the North Atlantic Oscillation, seasonal temperature variation and precipitation patterns appear to impact fish and invertebrate phenology. These results suggest that the residence time of seasonal resident species in inshore habitats has non-linear relationships with climate processes that will be critical considerations

for understanding the seasonal dynamics of coastal ecosystems and the fisheries they support throughout the Northwest Atlantic.

Differential Response of Gulf of Maine Seabirds to the 2018 Ocean Heat Wave

Lyons, D., Kress, S., Shannon, P.

Presented by: Don Lyons, dlyons@audubon.org

Seabirds nesting in the Gulf of Maine (GOM) are dependent on abundant and accessible forage fish during summer months to feed and fledge young. Previously, anomalously warm years (e.g., 2012 and 2013) have been associated with reduced productivity for seabird species in the GOM. During the summer of 2018, GOM sea surface temperatures (SST) varied dynamically between long term average levels and daily maximums not seen in the last two decades. In particular, in early August daily mean SST exceeded the long term average by >4°C and previous daily maximums by >2°C. This thermal event (ocean heat wave) apparently had significant impacts on the distribution and potentially the abundance of forage fish in the Gulf. We saw a variable response among different seabird species, with impacts related to breeding biology and foraging mode. Razorbill nesting success was least impacted, presumably due to their early fledging (mid-July) and capacity for deep diving where they can find herring and other forage fish seeking cooler temperatures . Tern nesting was heavily impacted, consistent with their surface foraging mode and need to finish raising chicks during late July and early August. Puffin chick growth slowed considerably during the thermal event and many chicks died, but those that survived received ample feedings during a return to more moderate conditions in later August and many ultimately fledged at normal mass. The puffin's capacity to defer migration and extend their chick-rearing season proved advantageous. These observations suggest that the timing of even short-term thermal events, and the capacity of individual species for adaptive behavioral compensation, will play large roles in determining which seabird species persist in a warming Gulf of Maine.

Real-time telemetry of bottom temperature from fixed and mobile fishing gear

Manning,J., Pelletier, E., and Stymiest, C.

Presented by: James Manning, james.manning@noaa.gov

Approximately one hundred commercial fishing vessels out of New England ports now have temperature sensors installed on their fixed or mobile gear. Most have hourly time series at fixed locations for well over a decade. Their bottom temperature data is served on-line according to IOOS standards, is being used to evaluate numerical ocean models, and has been assimilated into hindcast simulations. Some have also experimented with salinity monitors, cameras, pressure sensors, acoustic listening devices, and current meters. The primary focus of the talk will be on the transition to real-time telemetry. At the time of this writing, twenty vessels (mostly mobile gear trawlers from the Northeast Cooperative Research Program's "Study Fleet") are fitted with satellite transmitters and have automatically reported close to 5000 haul-averaged bottom temperatures in the last few years. With

funding available for well over 50 vessels, it is hoped that the ocean modelers will start assimilating this data so that the industry will someday be able to target regions based on improved bottom temperature forecasts in an effort to reduce by-catch. A variety of processes are affecting the bottom temperatures at different time scales. The dominant processes at a particular site differ depending on water depth and proximity to geographic features. In some areas, the wind, for example, drives the largest variation while areas near the shelf-edge are affected by intrusions of the deep ocean. In general however, the Environmental Monitors on Lobster Traps (eMOLT) time series document the upward trend in water temperatures throughout the region with 2002, 2006, 2012, 2016, and 2018 being relatively warm.

Causes and consequences of marine heatwaves in the Gulf of Maine

Pershing, A. J., Mills, K. E., Dayton, A. M., Franklin, B. S., Kennedy, B. T.

Presented by: Andrew J. Pershing, apershing@gmri.org

The extreme temperatures in the Gulf of Maine in 2012 and their impact on the ecosystem helped motivate an international effort to study marine heatwaves. Every year since then has had at least 80 days that reached heatwave levels, challenging the very definition of a marine heatwave. While heatwave conditions have become common, notable events occurred in 2016 and again in 2018. Based on this experience, we propose a conceptual model of heatwaves in the Gulf of Maine. In this model, circulation changes associated with the long-term warming trend precondition the ecosystem. Then, anomalously warm weather pushes temperatures to very high levels. Extreme events like heatwaves reveal sensitivities to the environment but they can also motivate change. For example, the 2012 event exposed the limited capacity in Maine to process and store large quantities of soft-shell lobster that are caught during warm years. Lobster processing capacity in Maine increased after 2012 and new markets were developed. These adaptive changes meant that when temperatures and landing patterns similar to 2012 occurred in the 2016, the price of lobster remained high. While we see evidence in the Gulf of Maine and beyond that people act in response to heatwaves, it remains to be seen whether people will take actions that anticipate future, more extreme conditions.

Drivers of Change: Warming Water Temperatures and Green Crabs

Beal, B., Randall, S., Coffin, C., Goodenow, C., Pepperman, K.,Ellis, B., Jourdet, C., Protopopescu, G., Lewis, J.

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

Commercial soft-shell clam (*Mya arenaria*) landings have declined dramatically over the past 40 years along the entire coast of Maine, with landings in southern Maine particularly hard hit, by nearly 70%, over the past decade. During the same time, populations of a clam predator, the invasive green crab, Carcinus maenas, have increased, especially along the warmer southern Maine coast (McClenachan et al. 2015). The decrease in clams and increase in green crabs coincides with recent mild winters in this region (Fernandez et al. 2015), and warming seawater temperatures in the Gulf of Maine (Pershing et al.

2015). To disentangle the factors driving the loss of clams in the southern Gulf of Maine the Downeast Institute conducted a series of field experiments in southern Maine from 2013- 2017 in partnership with the Maine Clammers Association. Green crab trapping studies occurred from 2013-2015. Findings show crab densities increased with temperature, and crabs were, on average, larger after warmer vs. colder winters. Clam recruitment dynamics also were investigated in three tidal estuaries (Wells, Portland, Freeport) during 2014 and 2015 with experiments using several types of deterrent netting to exclude predators on post-settled, 0-y class individuals of Mya. In Wells and Portland, clam recruits were up to 118X more abundant when predators were deterred versus controls. And in Freeport, recruits were 899x more abundant. Collectively, results suggest that post-settlement mortality rates of 0-y class individuals of Mya due to predation exceed 99%, and that this is the primary cause of significant declines in clam populations. Predators, therefore, are jeopardizing one of Maine's most important fisheries, and severely limiting ecosystem services that these bivalves otherwise would provide. Invasive green crabs are one of the most important drivers of ecosystem change in the Gulf of Maine, and with seawater temperatures predicted to continue to rise, the impetus to take action to adapt to their impacts heightens.

Climate-driven circulation changes threaten conservation of endangered North Atlantic right whales

Record, N.R., J.A. Runge, D.E. Pendleton, W.A. Balch, K.T.A. Davies, A.J. Pershing, C. Johnson, K. Stamieszkin, R. Ji, Z. Feng, S.D. Kraus, R.D. Kenney, C.R.S. Thompson, C. Hudak, C.A. Mayo, C. Chen

Presented by: Nicholas R. Record, nrecord@bigelow.org

Conservation strategies rely on mean environmental conditions, or in some cases future scenarios. As variance around mean conditions and trends increases, ecosystems will be pushed rapidly into new states, where such conservation strategies are no longer effective. In the Gulf of Maine, climate-driven changes have restructured the ecosystem rapidly over the past decade. Changes in the Atlantic meridional overturning circulation (AMOC) have altered the deep-water, late-summer abundance of the copepod Calanus finmarchicus, which is a critical food supply for the endangered North Atlantic right whale (*Eubalaena glacialis*). The oceanographic changes have driven a deviation in the seasonal foraging patterns of E. glacialis upon which conservation strategies depend, making the whales vulnerable to ship strikes and gear entanglements. The links between the AMOC shift and a species of high conservation concern undermine assumptions about how species will respond to changing climate and highlight the need for a management paradigm that is robust to rapid environmental changes.

Implementation of the Integrated Sentinel Monitoring Network (ISMN)

Runge, J. A.

Presented by: Jeffrey A. Runge, jeffrey.runge@maine.edu

There is a broad consensus that monitoring activities in the Gulf of Maine and Northeast Region are fragmented and moreover leave important gaps in coverage of responses of key ecosystem properties

to drivers of change. To address the need for an integrated observing system, the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS) and the Northeast Region Ocean Council (NROC) sponsored a series of regional workshops, culminating in the publication of a Science and Implementation (S&I) Plan for an Integrated Sentinel Monitoring Network (ISMN) for the Northeast U.S. The Plan represents the collective efforts of over 60 experts from 45 state and federal agencies, universities, and non-governmental organizations, as well as from Fisheries and Oceans Canada. It outlines a regional infrastructure to provide coordination support for maintaining data collections, data access and integrated interpretation and synthesis of data from multiple sources. NERACOOS has now obtained seed funding to implement the ISMN. As a first step, it is establishing an Oversight Committee that will serve the ISMN in the following roles: (1) advise the ISMN Director on the implementation, integration and sustainability of ISMN activities, (2) identify priorities and opportunities for enhancement of present observing activities, (3) establish and recruit participants in technical science committees to integrate and facilitate effectiveness of data collection, management, and analysis across ISMN activities and (4) guide the ISMN Director in acquiring funding and awarding grants for data synthesis and interpretation through the Center for Analysis, Prediction and Evaluation (CAPE). Nominations for candidates to serve on the Oversight Committee are now being solicited. Here I will discuss the purpose and function of the ISMN, and lay out a vision for its implementation in the coming decade.

The relationship between *Calanus* and sand lance on Stellwagen Bank and the northeast US shelf

Suca, J.J., Wiley, D.N. Giandonato, T., Glancy, S., Thompson M.A., Hong, P., Silva T.L., Richardson, D.E., Baumann, H., Kaufman, L.S., Llopiz, J.K.

Presented by: Justin Suca, jsuca@whoi.edu

Sand lance are an important forage fish throughout the sub-polar regions of the Atlantic and Pacific Oceans. On the northeast US shelf, northern sand lance (*Ammodytes dubius*) are critical prey for numerous top predators, including humpback whales, bluefin tuna, and several seabird species. However, the distribution, abundance, and feeding of northern sand lance has been understudied owing to a lack of a directed fishery for the species. Our work aims to understand what drives the extreme spatio-temporal variability in the distribution of adult sand lance (*A. dubius*) and their quality as a prey source through habitat modeling, stomach content analysis, and lipid content analysis. Presence/absence generalized additive models using in situ CTD casts coupled with adult sand lance collections on Stellwagen Bank indicate that sand lance are most often caught in shallow depths (<40 m) with low bottom fluorescence and moderate salinities (32-32.5). Stomach content analysis suggests that sand lance feed from February through October, after which they appear to reduce feeding prior to spawning in November. Diet varies seasonally, with *Calanus finmarchicus* constituting a large portion of their diet by biomass during the spring and Centropages spp. representing the majority of their diet by number and biomass in the fall. Total lipid content (whole fish) exhibits significant intra-annual variability, peaking around May—likely a result of spring consumption of *Calanus finmarchicus*. Total lipid content subsequently decreases in early fall through early winter during the spawning period. Further, the spatial distribution of sand lance correlates to the spring abundance of *Calanus finmarchicus* on Stellwagen Bank, corroborating the likely importance of *Calanus* to sand lance. Further

analyses of sand lance distribution throughout the region will determine if these patterns are consistent on broader spatial and temporal scales.

Thirty-five year patterns of North American east coast shelf SST and SST phenology

Thomas, A.C., Record, N.R., Stamieszkin, K., Mills, K.E., Kerr, L.A., Friedland, K.D.

Presented by: Andrew Thomas, thomas@maine.edu

Thirty-five years (1982 – 2016) of OISST data, subset over the 3 NOAA Large Marine Ecosystems (LMEs) that encompass the North American east coast shelf north of Cape Hatteras are used to quantify decadal trends in both SST and 3 metrics of summer SST phenology. Monthly OISST data provide maps of the 35-year trends in SST, characterized by warming over most of the study region, strongest in the Gulf of Maine / Scotia Shelf. Cooling (weak) is restricted to a very small region immediately north of Cape Hatteras. Self-organizing maps (SOMs) allow visualization of the dominant interannual structure behind these trends, presented as a 1) map of similarly behaving regions and 2) the temporal structure within each grouped region. The dominant temporal feature of all regions is increased warming in the latter portion of the time series. Daily OISST data are then used to extract 3 metrics of summer phenology (summer start, end and duration) within each year. Thirty-five year trends in these three metrics are mapped over the study region, showing earlier trending start dates, strongly trending later end dates and increasing summer duration, especially over the Gulf of Maine and Scotia Shelf. SOMs are used to group the interannual structure behind the phenology trends, presented as maps and time series. For a national perspective, these SST and phenology trends are compared to North American west coast LME trends.

Responding to ocean and coastal acidification through a regional network: the role of NECAN

Turner, E., NECAN Steering Committee

Presented by: Beth Turner, elizabeth.turner@noaa.gov

The Northeast Coastal Acidification Network (NECAN) was formed in 2013 to review, assess and communicate relevant ocean and coastal acidification (OCA) information to interested communities in the U.S. Northeast. NECAN has worked to identify and communicate knowledge gaps and regional priorities for monitoring, research and modeling to state and federal agencies while serving to educate the public and stakeholders on regional OCA issues and respond to regional user needs. Since the formation of NECAN, OCA conditions in the Gulf of Maine have continued to be assessed and a range of monitoring coordination activities have been engaged. New research targeting key NECAN priority areas has illuminated potential impacts to commercially important species. State commissions have been formed to address impacts to local resources, and a wider swath of people in the region have become informed and involved through a series of workshops and a highly successful webinar series. NECAN has also served as a model for regional OCA networks in other geographic areas. This presentation will address how NECAN has evolved over the past 5 years to better address regional issues related to OCA,

and highlight some future activities (e.g. development of a conceptual model, citizen science activities, symposia). We welcome feedback on how NECAN can continue to respond to regional needs and issues surrounding coastal acidification.

Abstracts: Poster presentations

Dietary trends of stranded harbor seals (*Phoca vitulina*) and local fisheries in the Gulf of Maine

Berube, J., Bogomolni, A.,Lysiak, N., Sette, L., Pugliares, K.

Seals are important ecosystem indicators for ocean and public health. Passage of the Marine Mammal Protection Act of 1972 has resulted in rapidly expanding populations of harbor and gray seals; increases that necessitate more study in order to both understand their role in the ecosystem and conflicts with humans. Conflicts have occurred with fisheries through competition for the same resources, damage to fishing gear, and depredation in nets. To more fully understand the relationships between seals and fisheries, we examined the diet of harbor seals in Gulf of Maine and trends of local fisheries over the past 30 years. Stomach contents of 38 seals stranded along the Maine, Massachusetts, and New Hampshire coast from 1984 to 2012 were analyzed and fisheries landings data were examined to determine if there are similar trends between harbor seal diet and fisheries catch. Our data does not yield a strong correlation, however, it does exemplify local diet. The stomach content of harbor seals also reflects a broader prey base beyond many of the most important commercial species in the Gulf of Maine.

Long term population assessment of harbor seals (*Phoca vitulina concolor*) and grey seals (*Halichoerus grypus*) at the Isles of Shoals

Berube, J., J. Veo, A. Bogomolni, N. Lysiak, L. Sette

Pinnipeds play a vital role in the Gulf of Maine ecosystem. As sentinels for ocean health, understanding pinniped population dynamics can give a broader insight into the dynamics of the entire ecosystem. In the eighth year of this long term population assessment, a haul out of harbor (*Phoca vitulina concolor*) and grey seals (*Halichoerus grypus*) on Duck Island in the Isles of Shoals were monitored between the months of June and August. Twenty-six boat based photographic surveys were conducted with a DSLR camera and a 400 mm lens. Data collected from each survey included: minimum count estimates, number of entangled individuals, number of injured individuals, number of diseased individuals, and number of harbor seal pups. Additionally, photographic mark recapture was utilized to identify individuals based on unique pelage, scars, tags, or brands. For the first time since the study began in 2011, the average number of grey seals exceeded the average number of harbor seals, with an average of 188 grey seals and 184 harbor seals. Thirty-eight injuries were observed, including three cases of shark interactions and two cases of bulging eye. Twenty-eight entangled individuals were observed. Forty individuals were resighted in 2018, including some that were resighted multiple times. Among the resights was Mr. T, a male grey seal first sighted on Duck Island in 2011, and a female grey seal with a Canadian brand “06”, believed to be “06Z”, who was spotted on Duck Island in 2017.

A hyperspectral, cross-basin view of Gulf of Maine surface waters and the variability of their optical constituents

Bucci, A. F.; Thomas, A. C.; Balch, W. M.

Previous biogeochemical surveys in the Gulf of Maine (GoM), provide an understanding of the water properties in the area. However, a hyperspectral optical characterization of the GoM waters has yet to be undertaken. Here we present a preliminary view of the hyperspectral characteristics of surface waters in the GoM, focused on relevant oceanographic regions and the variability of their optical constituents. We conducted 5 surveys in 2017 from July to October along a transect from Yarmouth (NS, Canada) to Portland (ME, U.S.A.). Above water radiometry was measured underway using a Hyperspectral Surface Acquisition Sensor (HyperSAS). Remote Sensing Reflectance (Rrs) was calculated from these measurements and decomposed in the optical constituents of the water (phytoplankton, non-algal particles and colored dissolved organic matter). The Scotian Shelf displayed the highest variability in Rrs, reflecting a rapid change in ocean color as the transect progressed towards Portland (ME). This variability was associated mostly with chances in concentrations of non-algal particles and dissolved organic matter, rather than phytoplankton. Phytoplankton, however, was responsible for most of the changes in ocean color observed off Penobscot Bay, increasing from 30% relative contribution to 80% from July to October. This likely represents the highly productive Eastern Maine Coastal Current turning off-shore in that region. These findings highlight the increased information content of hyperspectral data compared to multispectral data and provide new insights into the optical complexity of surface waters in the Gulf of Maine.

Near-bottom observations of sediment resuspension in the western Gulf of Maine 2014-2017

Butman, B., Wallinga, J., Pettigrew, N. R.

Cysts of the dinoflagellate Alexandrium fundyense that cause harmful algal blooms along the Maine coast in the spring overwinter in the bottom sediments. It has been hypothesized that fall and winter resuspension events may redistribute cysts on the seafloor while spring events could release large numbers of cysts into the water column affecting bloom timing and intensity. Temperature, salinity, and light transmission observations have been made approximately 12 m above bottom (mab) at five locations in the western Gulf of Maine to monitor fine-grained sediment resuspension. Instruments were deployed on UMOOS/NERACOOS/IOS moorings at sites A (Massachusetts Bay; 65 m water depth), B (western Gulf of Maine shelf; 62 m), E (central Gulf of Maine shelf; 100 m), I (eastern Gulf of Maine shelf; 100 m), and at 35 mab at M (Jordan Basin; 285 m) (http://www.neracoos.org/realtime_map). The goal was to obtain observations continuously for three years. Fouling of the transmissometer optics and power failures resulted in gaps in the data records. Typically beam attentuation (-4ln(percent light transmission over 0.25 m)) was about 1 m-1, with increases of a few days duration during resuspension events. Between June 2014 and December 2017, there were 15 events (associated with nine northeasters, four tropical storms, and two Alberta clippers) that caused resuspension of varying magnitude and duration at several sites. One of the largest and longest resuspension events was associated with a sequence of northeasters on January 28-29 and February 3, 2015; these storms resuspended sediments at A and E (instruments operational during that period). The observations at E from July 2016 to December 2017 (the transmissometer was outfitted with a mechanical wiper to

control fouling) show higher (~1 m-1) and variable beam attention in summer and lower (<0.5 m-1), less variable beam attenuation in winter, except during resuspension events.

The Impact of Plastic Pollution on Four Species of Seabird Nesting on the Isles of Shoals, ME/NH

Caldwell, A., Craig, E., Seavey, J.

Plastic debris is a widespread and critical environmental challenge with potentially harmful impacts on marine life. Seabirds are of critical conservation concern and are considered excellent bioindicators of overall marine ecosystem health. Information about the prevalence of plastics exposure in the seabirds can serve as an indicator of plastic exposure across multiple trophic levels in the world's oceans. Our study aims to understand the prevalence of -and differences in- plastic ingestion in four species of seabird (Great Black-backed Gulls Larus marinus, Herring Gulls *Larus smithsonianus*, Common Terns *Sterna hirundo*, and Roseate Terns *Sterna dougallii*) nesting on the Isles of Shoals in the Gulf of Maine. Plastics were found primarily in pellet samples, with significantly higher levels in Herring Gulls than the other three species of seabird. The data show that 61.5% of Herring Gull individuals and 18.5% of Great Black-backed Gull individuals have ingested plastics pieces, while only 1.3% of Tern individuals (across both species) have interacted with the pollutant. Common plastic types ingested across all species are user fragments (hard plastic pieces) and sheets (thin plastic bags and wrapping).

The relationship between intertidal mercury pollution and gull nesting density: a case study of the Isles of Shoals

Callahan, G., Backstrom, C.

Methylmercury (MeHg) is a neurotoxic pollutant that bioaccumulates and biomagnifies in food webs throughout aquatic systems, impacting the health of piscivorous wildlife and human consumers of predatory fish. While biotic and abiotic factors may influence the methylation and bioaccumulation of mercury in organisms on a local scale, it is important to consider the capacity for biota to transport mercury contaminants between trophic levels and ecosystems. Stable isotope signatures demonstrate that nutrients deposited from seabird guano can be integrated into coastal tide pool organisms. However, the link between avian guano input and the availability of mercury in a given ecosystem is not well understood. To characterize the relationship between bird guano deposition and mercury concentrations across comparable ecosystems, we collected organisms of a variety of taxa, as well as gull feather and guano samples, throughout the Isles of Shoals in the Gulf of Maine. We sought to determine whether the coastal nesting density of great black-back and herring gulls (*Larus marinus* and *Larus smithsonianus*, respectively) is positively correlated with the mercury levels in local marine biota.

Ocean climate change in four east coast North American LMEs: 21st century SST changes from CMIP5 projections

Carey, Q., Thomas, A.C.

The climate projections from 26 individual global climate models within the Community Model Intercomparison Project Phase 5 (CMIP5) are used to observe SST change from 1976 to 2099 over the four large marine ecosystems (LMEs) of the eastern seaboard of North America [the southeast US shelf (6), northeast US shelf (7), the Scotian shelf - Gulf of St. Lawrence (8), and the Newfoundland - Labrador shelf (9)]. The CMIP5 ensemble mean shows increasing SST trends in each LME, strongest (0.46 oC / decade) in LME 8 and weakest (0.06 oC / decade) in LME 6. Separated by months, the warming has a strong seasonal bias with strongest SST trends evident in summer (0.18-0.59 oC decade) and weakest in winter (-0.03 – 0.27 oC decade) in each LME. SST from each of the 26 CMIP models are then compared to Optimally Interpolated Sea Surface Temperature (OISST) data, averaged over the same LME regions, over a thirty-five year period of overlap (1982 -2016) to assess which models track SST trends best. Best performing models varied between LME regions, but in LMEs 7, 8 and 9, most of the models under-projected observed OISST trends in the overlap period. We then reform ensemble means for each LME using only the best performing CMIP5 SST projections in each region and recast 21st century LME SST projections.

Replacement of a Foundation Species in the Lower Intertidal

Carter, H., Friday, B., Hoyer, P., Owens, S.

Since 1982, students at Shoals Marine Laboratory (SML) on Appledore Island, ME have conducted annual surveys to determine species composition of local intertidal communities. Using this survey data, we investigated temporal changes in three algal species: *Chondrus crispus*, *Mastocarpus stellatus* and *Fucus* spp. Historically, the low intertidal zone (0-4.5 feet above MLLW) has been referred to as the "Red Zone" because of the abundance of red algae. However, recent qualitative observations around Appledore Island suggest a large change in abundance of *C. crispus*. We used the long-term, student-generated SML dataset to obtain annual percent-cover estimates for the three species to uncover potential changes in species composition in the Red Zone. Additionally, we utilized data obtained from a second survey method (National Park Service) to further assess species composition trends in permanent photoplots in the Red Zone since 2011. We found that *C. crispus* declined in abundance on the wave-protected side of the island at an average rate of 1% cover annually since 1982. Concurrently, *M. stellatus* increased at an average rate of 1.1%. *Fucus* spp. abundance surpassed *C. crispus* in 2012 and has since been steadily increasing. Similar trends were not observed on the wave-exposed side of the island. *C. crispus* has been shown to be less tolerant than *M. stellatus* to environmental stressors, and increasingly frequent extreme weather events in the Gulf of Maine could be instrumental to the species' recent decline. Alternatively, *Fucus* spp. and M. stellatus could be outcompeting *C. crispus* for space in the Red Zone, or they could be taking advantage of space previously occupied by *C. crispus*. Future research on climate trends around the Gulf of Maine and *C. crispus'* physiological response to extreme temperatures, desiccation, etc. is necessary to ascertain the reasons behind the species' disappearance and the ensuing ecological consequences.

Monitoring tern diets using DNA metabarcoding of fecal samples

Clucas, G. V., Seavey, J. R., Kovach, A. I., and Craig, E. C.

The Gulf of Maine is one of the fastest warming marine habitats on earth, causing shifts in the abundance and distribution of many marine species in the region. Breeding seabirds sample the marine environment surrounding their colonies and, therefore, shifts in their diets can provide information about changes occurring in the ecosystem. However, seabird diets can be difficult to monitor. Here, we trialed a fecal metabarcoding method to monitor Common (Sterna hirundo) and Roseate Tern (Sterna dougallii) diets at a mixed breeding colony on the Isles of Shoals in the Gulf of Maine. We collected fresh fecal samples from adults and chicks of both species. We then used metabarcoding to identify fish prey items from the DNA contained in the fecal samples. We compared these diet results with chick-provisioning observations to assess the suitability of the technique for long-term monitoring of tern colonies. We show that fecal DNA monitoring can identify more prey items, with greater resolution, and less bias than chick-provisioning observations, and can provide a cost-effective alternative for monitoring seabird diets in the future.

M.A.P.—Monitoring Acidification Project

Gassett, P., Corso, J., O'Brien-Clayton, K., Cataldi, C.,Stancioff, E., Bastidas, C., Morrison, R., Liebman, M.

Nearshore environments and the communities that rely on them are uniquely vulnerable to ocean and coastal acidification, yet we lack comprehensive monitoring at spatial and temporal scales requisite to providing actionable information. While there are a small number of existing long-term, decadal and climate-scale coastal acidification monitoring sites, crowdsourcing monitoring through broad collaborations of water quality stakeholders offers an opportunity to vastly expand monitoring of nearshore conditions of acidification. Existing networks of volunteer and citizen science water quality monitors in the Northeast United States are well positioned to expand monitoring from their traditional focus on marine habitat protection, nutrient pollution and watershed management to include carbonate chemistry parameters. To help meet this goal, the "Monitoring Acidification Project" M.A.P. provides an online GIS Story Map showing the first ever Northeast US archive of monitoring sites that measure ocean acidification parameters. Distinct water monitoring groups can more easily connect and collaborate by seeing the comprehensive coverage and gaps in monitoring through info-rich GIS layers showing the location of monitoring sites, which parameters are being measured for each location, and links for organizations' websites and contact information. As sharing data is easier than collecting data, collaborating with partner organizations can offer novel insights into local patterns for water quality and ocean acidification. Additionally, developing organizational relationships among water quality monitoring groups can better serve individual organizations' missions by facilitating broader impacts, securing team grants, and improving existing monitoring coverage. M.A.P. is important because solutions and management for ocean acidification will require connectivity and participation from water quality stakeholders and local decision-makers throughout the Northeast and among other coastal regions more broadly.

A Histopathological Health and Condition Assessment of Farmed Blue Mussels (*Mytilus edulis*) in a Changing Gulf of Maine

Jones, C., St. Gelais, A., Condon, M., Jane A., Parker, K., Byron, C., Costa-Pierce, B.

Aquaculture of Blue mussels, *Mytilus edulis*, is increasing in the Gulf of Maine at a time when naturally occurring mussels are disappearing and environmental conditions are rapidly changing. Through the use of histopathological techniques, an 18-month long health and condition baseline was created for a population of farmed blue mussels. Farmed mussels were collected twice a month in Casco Bay, Maine to determine gonad area fraction, storage tissue fraction, reproductive stages, and the intensity of pathological agents and environmental stress responses using light microscopy and ImageJ analysis. In both years, mantle tissue showed a strong inverse relationship between levels of gonad tissue and storage tissue. During critical reproductive time periods, 2018 and 2017 differed significantly in the levels of energy allocated towards reproduction and storage. In 2018 the mussels invested significantly more energy in reproduction. Although parasite levels were low throughout this time period, there was a high prevalence of stress-induced conditions. The most common of these was oocyte atresia, present in over 90% of female mussels. This suggests that there is some type of environmental stressor present. This baseline health assessment is designed to monitor the effect changing local environmental conditions are having on a species that is important to Maine's coastal ecology and economy.

Multispectral classification of Gulf of Maine surface waters: seasonal and interannual variability

King, B., Thomas, A.

Bio-optically, Gulf of Maine (GOM) surface waters are strongly heterogeneous, exhibiting highly variable distributions in both time and space of suspended sediment, colored dissolved organic matter (CDOM), and phytoplankton. The concentration of non-algal components strongly impacts water optical properties in the GOM, rendering the standard NASA chlorophyll algorithm suspect. However, spectral signatures of the water are well quantified by 19 years of satellite-based multispectral reflectance measurements. Here, we identify the spectral signatures of dominant water types present in the GOM using monthly composite SeaWiFS and MODIS data from 1998-2016. A merged multivariate clustering approach, including Self-Organizing Maps and hierarchical clustering, is used to group dominant spectral signatures across time and space. Remapped results provide a climatological view of bio-optical water types and the interannual variability of their distribution. Results indicate the same 2-3 spectral water types dominate the central GOM interannually. Several less spatially dominant water types are present mainly along the coast and over George's Bank, varying in location seasonally. Spectral signatures of the water types suggest they range from relatively clear waters, mixed waters dominated by suspended sediments, and waters dominated by CDOM and phytoplankton. The dominant features of interannual variability and quantified trends are in May over the duration of the 19-year time series and in September-November in recent years. These shifts appear to be from clearer waters to a water type characteristic of the spring and fall phytoplankton blooms and are suggestive of an expansion of bloom conditions in space and/or time. These results provide new satellite ocean color views of GOM variability over seasonal and interannual time scales.

A Role for Pacific Climate Variability on Extreme Events in the Gulf of Maine

Kreutz, Karl J., Wanamaker Jr., Alan D, Griffin, Shelly M., Ummenhofer, Caroline C., Whitney, Nina M., Black, Bryan, Parfitt, Rhys, Lower-Spies, Erin E., Introne, Douglas

While the Gulf of Maine has seen rapid ecological and oceanographic changes recently, putting these changes into historical context and determining primary climatic drivers is hindered by the relatively short instrumental records in the region. Population-level shell growth of the long-lived bivalve *Arctica islandica* (ocean quahog) varies based on environmental conditions and therefore can be used as a record of past oceanographic changes. We will present a 254-year, annually resolved record of shell growth from a master shell growth chronology developed from shells collected at 38 meters water depth near Seguin Island in the western Gulf of Maine. Shell growth is inversely related to spring seawater temperature. Extreme shell growth years during the instrumental record were identified based on composite analysis. These events appear to be driven by seawater temperature stratification, which controls the nutrient flux to the clams. Stratification varies with freshwater runoff into the Gulf of Maine, which is in turn influenced by precipitation patterns. Both seawater temperature and precipitation appear to be driven in part by atmospheric circulation patterns and the location of the eddy-driven jet, which are themselves influenced by Pacific sea surface temperature patterns. Therefore, extreme shell growth events recorded in Gulf of Maine clams appear to be driven, in part, by variability in Pacific climate. Using cutoffs for extreme events determined during the instrumental period, we have also identified extreme growth events back before the instrumental record in an attempt to put recent climatic changes observed in the Gulf of Maine into context. Based on these analyses, it appears that the frequency of low shell growth years has been increasing in recent times, consistent with the recent warming observed in the Gulf of Maine.

Gulf of Maine 2050: A Symposium and Workshop about the Future of the Gulf of Maine

LeBlanc, J., A. Pershing

The Gulf of Maine 2050 symposium will take place in November of 2019. The symposium will integrate environmental, economic, social, and institutional perspectives on emerging climate challenges and opportunities. It will bring together multiple science disciplines, natural resource managers, municipal planners, representatives from key industries, a diverse mix of community leaders, NGO's, and the donor community to understand of how the Gulf of Maine is expected to change in the next 30 years. It will build a shared vision of regional resilience, identify steps necessary to achieve that vision, and activate new collaborations against specific prioritized initial work plans.

Raising the BAR on breakpoint detection in biological data with a new Bayesian procedure

Neitzel, S.; Haglich, K.; Liebner, J.; Pitts, A.

Bayesian Adaptive Regression (BAR) is a new approach for finding the quantity and location of breakpoints, or change points, in data series. In addition to breakpoints themselves often being areas of interest, identifying breakpoints allows for more appropriate and accurate modeling by accounting for

underlying structural changes. BAR locates breakpoints by proposing new breakpoint sets in a reversible-jump Markov Chain Monte Carlo (MCMC) and then evaluating those proposals using the Metropolis-Hastings algorithm. Currently, BAR has two variations and this talk will provide a case study for both. Bayesian Adaptive Linear Regression (BALR) will be demonstrated using global temperature anomaly data from NOAA. Bayesian Adaptive Auto-Regression (BAAR) will be demonstrated using brown pelican (Pelecanus occidentalis) population data from the Christmas Bird Count.

Data management to reveal potential in Shoals Marine Laboratory's long-term intertidal monitoring dataset

Nguyen, A. T.

The rocky intertidal zone on offshore Appledore Island, ME, is home to a wide array of biodiversity. A student-run program was established in the 70s at the Shoals Marine Lab to monitor the presence and abundance of key intertidal seaweeds and invertebrates. This program has since evolved into a 2 ½ week internship program at the lab. All combined, the dataset documents almost 40 years of intertidal biodiversity (approx. 150 unique taxa). There are few comparable monitoring projects in the Gulf of Maine; thus this dataset will prove valuable in determining patterns and changes in species composition and distribution in this unique and vulnerable habitat in a changing and ecologically important region. However, the program's diverse history and data management practices has hitherto impeded data discovery and utilization. During the summer of 2018, I used reproducible methods to 1) consolidate raw data, 2) evaluate inconsistencies, 3) document metadata, 4) archive a complete data package on the Environmental Data Initiative portal, and 5) create graphical and interactive visualization tools. Future researchers can now easily discover and make use of the dataset. The project furthermore can serve as a model for student-driven data collection and provide lessons in data practices to overcome associated challenges.

Tracking phenological changes for North Atlantic right whales and fin whales in Cape Cod Bay over twenty years using multi-season occupancy models

Pendleton, D.E., Tingley, M., Staudinger, M., Kenney, R.D., Mayo, C.A., Kraus, S.D.

The Gulf of Maine has experienced extremely rapid warming over the past decade due to climate change. This region serves as important seasonal feeding grounds for North Atlantic right whales (*Eubalaena glacialis*). Over the last eight years, multiple survey teams have recorded substantial changes in sighting rates of right whales, with lower sighting rates in some feeding habitats (e.g., Bay of Fundy) and higher rates in other habitats (e.g., Cape Cod Bay). The time of year during which right and other at-risk species occupy these key habitats will impact the effectiveness of conservation and management actions designed to protect them from human activities, such as fishing and shipping. The present work focuses on quantifying the magnitude of phenological changes and understanding their underlying causes. Toward this end, we built multi-season occupancy models for right and fin whales in Cape Cod Bay. Our models provide spatially-explicit estimates of the probability of occupancy, or habitat use, over time. Occupancy and other quantities derived from the models reflect the seasonality of habitat use. We found that the date of maximum occupancy has shifted later in the year for right whales, and has shifted

earlier in the year for fin whales. This approach and our results could aid long-term resource management planning efforts, and thus reduce anthropogenic causes of injury and death to marine mammals. Results are also intended to provide information on the vulnerability and adaptive capacity of right whales and other marine mammals to changing environmental conditions.

A Freshwater Lake on a Maritime Island: The First Limnological Assessment of Crystal Lake

Ray, E., Buck, D.G., Haney, J.

Crystal Lake, located on Appledore Island in the Gulf of Maine, is a small, shallow, freshwater lake. This study represents the first comprehensive limnological assessment of the physical, chemical and biological components of the lake. Changes in pH, dissolved oxygen, temperature, nutrient concentrations, plankton, and associated pigments were monitored for 14 weeks, from June to mid-September. The lake is considered eutrophic with elevated levels of nitrogen and phosphorus. The zooplankton community experienced a shift from one that was dominated by Asplanchna, a predatory rotifer, to one dominated primarily by grazers. The phytoplankton community shifted from one dominated by large green algae during the early summer to one that included colony-forming species of cyanobacteria. Increases in phycocyanin concentrations from 2.26 µg L-1 to 106.3 µg L-1 corresponded with the increase in cyanobacteria, including a late-season bloom of Microcystis. The cyanotoxin microcystin produced by these cyanobacteria was also found to be present with concentrations exceeding those found in other state-wide surveys in New Hampshire. Overall, results from this study highlight the importance of consistent, long-term monitoring of freshwater ecosystems. Within the Isles of Shoals, there is a clear need for more comprehensive study of the potential risks of exposure to wildlife that rely on Crystal Lake as an important freshwater resource.

Impacts of a trematode parasite on the behavior of an invasive shore crab in the Northwest Atlantic

Ro, H., Fowler, A.E., Blakeslee, A.M.H.

Numerous trophically-transmitting endoparasites can increase transmission likelihood in their definitive host by manipulating behaviors of their intermediate host(s). An example is the trematode *Microphallus similis* that infects non-native European green crabs (*Carcinus maenas*) in the northwest Atlantic. There is limited knowledge regarding how this parasite may alter crab behavior, which may ultimately influence life cycle transmission. Our project aimed to assess how infection by *M. similis* influenced behavioral shifts in green crabs across a temporal scale: prior to infection and at 4 other time points post-infection (72 hours, 1 week, 2 weeks, and 3 weeks). Behavior in infected and uninfected crabs was measured using righting response and an established ethogram that recorded numerous behavioral types, including those that may affect conspicuity to predators. We found that there was minimal influence of infection on behavior, and that individual crab behaviors remained resilient through time. An exception was a slight decline in conspicuity in the 72 hour post-infection time point, which may suggest that *M. similis* has the potential to decrease predation risk during parasite development in its

new host. Future work will include in-depth analyses for specific behaviors and investigations into infection burden.

Finding a home in the noise: cross-modal disruption of search behaviour due to seabed vibration

Roberts, L., Laidre, M.E.

The sensing of chemical information allows aquatic animals to interpret their surroundings over long distances. If the use and processing of chemosensory information is disrupted, the ability to find key resources such as food or shelter may be impaired. Anthropogenic activities directly contacting the seabed, such as pile-driving, drilling and dredging produce vibrations which have the potential to disrupt the use of not only the vibrational modality but also other modalities such as chemical. Here, in subtidal field conditions, we exposed unrestrained hermit crabs (*Pagurus acadianus*) to a repetitive noise source which produced vibrational energy in the seabed. We attracted crabs to the area using a specific chemical cue, indicative of the availability of a gastropod shell, i.e. a new home. Numbers of crabs arriving at the bait were monitored in noise versus control conditions. We found that significantly fewer crabs were attracted to the chemical cue during noise compared to the control. Furthermore, measurements of shell inadequacy indicated that compared to control crabs, crabs attracted during noise conditions had significantly poorer shells consistent with a higher motivation to find a new home. The results indicate that vibration disrupted a hard-wired shell searching behaviour, most likely by acting as a deterrent or a distractor. While the impacts of anthropogenic noise via seabed vibration are poorly studied, these results suggest that vibration can alter search behaviour even across modalities.

Population Biology of Rockweed (*Ascophyllum nodosum*) in Frenchman Bay: Assessment of a commercially targeted and ecologically important species

Roe, M., Oldach, E., Webber, H., and Petersen, C.

Rockweed or knotted wrack, *Ascophyllum nodosum*, is an important canopy-forming species in the mid-intertidal along rocky shores in New England. It also comprises 90% of Maine's 19 million dollar seaweed industry. Rockweed fishery limits in Maine include limiting the total rockweed biomass that can be removed in an area and requiring a minimum cutting height of 16 inches. In order to manage rockweed harvest, policymakers must carefully consider the alga's ecological and economic roles. To understand the rockweed resources of Frenchman Bay we collected data at sixteen sites around the bay, examining the extent of the rockweed bed; the size, weight, and age of plants; and the role that rockweed plays in influencing the temperature and light levels in the rocky intertidal. Preliminary data suggest that growth rates are largely consistent across sites, that larger alga are found in the mid and lower Bay, and that protected and exposed sites yield different biomass data. Rockweed has profound effects on the physical environment on the mid-intertidal, and the effects of harvest on these physical factors and the biological community are not well known. We have begun a set of experiments in Frenchman Bay, comparing areas of simulated harvest to control areas without harvest to try to understand how this species affects light and temperature intensity and community structure in the intertidal.

NES-LTER: A New Long Term Ecological Research Site on the Northeast U.S. Shelf

Sosik, H.M., Beaulieu, S., Chen, C., Fratantoni, P., Ji, R., Lentz, S., Llopiz, J., Menden-Deuer, S., Neubert, M., Richardson, D., Rynearson, T., Stanley, R.

The northwest Atlantic, renowned for its fisheries, is experiencing faster-than-average warming and other climate-related impacts. To date, the lack of systematic and detailed measurements over a sufficient length of time has hampered our ability to observe the responses of pelagic food webs to environmental perturbations and uncover the underlying causes and implications. To address this deficiency, NSF has established a new Long-Term Ecological Research site on the Northeast U.S. Shelf (NES-LTER). Its goals are to understand and predict how planktonic food webs change through space and time, and how those changes impact the productivity of higher trophic levels. Here we describe the NES-LTER strategy and report on activities and early results from our new observational plan. Our strategy combines observations that provide regional-scale context (NOAA survey cruises), process cruises along a cross-shelf transect, high-frequency time series at inner- and outer-shelf locations (Martha's Vineyard Coastal Observatory [MVCO] and OOI Pioneer Array, respectively), coupled biological-physical food web models, and targeted population models. Though this is the first year of a long-term plan, an existing archive of over a decade of high frequency physical oceanographic and plankton observations at the nearshore MVCO site allows us to put new spatial surveys into the context of known seasonal and interannual variability. Notable findings include synoptic spatial variability that is comparable to high levels of seasonal variability observed at MVCO for certain plankton taxa, novel information about the spatial extent of nearshore blooms, and documentation of unexpected taxa observed in mid- to outer-shelf zones despite having been detected only rarely or not at all during more than a decade of nearshore observations. The high levels of seasonal, interannual, and spatial variability in the NES will allow us to explore short-term responses to climate-related variables with the ultimate goal of gaining mechanistic knowledge that can be scaled up to understand and predict the impacts and feedbacks associated with decadal- to climate-scale forcing in the ecosystem.

Investigating Potential Impacts of Climate Change on the Gulf of Maine Through Water Quality Monitoring and *Mytilus edulis* as Bio-indicators

Stack, M., Woods, M., Shaw, S.

The Gulf of Maine is one of the fastest-warming bodies of water on Earth. Blue mussels, a keystone species in Gulf of Maine coastal ecosystems, have decreased by more than 60% over the last 40 years and their loss could cause cascading effects throughout the food web. This study investigated the potential link between declining mussel populations and changing ocean conditions in the Gulf of Maine. Two field sites, a thriving mussel bed and a declining mussel bed, were selected for this study. Mussel larvae collection boxes, both closed (n=3) and open to predators (n=3), were placed in random configuration within the intertidal zone at each site from June to October 2018. Water quality parameters such as temperature, pH, dissolved oxygen, turbidity, flow velocity, and chlorophyll a were collected twice weekly. Classification of sediment type and size as well as temperature and pH of the sediment were also investigated as potential factors. The major organisms collected and grown within the boxes were clams, mussels, and periwinkles. All organisms were analyzed for number settled,

average size, and evidence of predation. Preliminary analysis shows more mussels settled in closed versus open boxes, and the highest numbers were found at the thriving mussel bed site. However, initial examination of water quality parameters show slightly lower pH and DO levels at the thriving mussel site compared to the declining mussel bed site. Potential explanations and implications of this and other water quality and sediment parameters on blue mussel population declines across the Gulf of Maine will be discussed.

Mapping seabed substrates in the Stellwagen Bank region – providing a framework for ecological research

Valentine, P.C.

Geologic maps of Stellwagen Bank and adjacent basins show the distribution of 34 individual substrates in an area of 630 sq km ~30 miles offshore of Boston, Massachusetts in water depths of 20 to 180 m. The region is a complex glaciated terrain that has been reworked by several periods of sea level rise and fall since the Last Glacial Maximum. The maps are compiled at a scale of 1:25,000 from multibeam sonar bathymetric and backscatter imagery groundtruthed by sediment grain-size analyses and video imagery. A geologic substrate is a surface (or volume) of sediment or rock where physical, chemical, and biological processes occur, such as the movement and deposition of sediment, the formation of bedforms, and the attachment, burrowing, feeding, reproduction, and sheltering of organisms. A habitat is a geographic place where physical, chemical, and biological properties allow a particular species or group of species to live. A geologic substrate is one element of a habitat and is characterized by grain size composition, the grain diameter range of the sediment, sediment mobility, sediment layering, and seabed structures. Major hard and soft substrate types in the mapped region are mobile and immobile coarse-grained sand, fine-grained sand, muddy fine-grained sand, burrowed mud, sand veneer on gravel, and boulder ridges that are remnants of glacial moraines and eskers. In addition to the substrate maps, related thematic maps show the distribution of mobile and immobile sediment and the sand and mud content of the substrates. These maps, accompanied by the digital multibeam data used in their compilation, provide an unprecedented opportunity for ecological research on the seasonal distribution of benthic species and their use of substrates as habitats. For examples of substrate maps, see Valentine and Gallea, 2015 https://pubs.er.usgs.gov/publication/sim3341

Characterizing the diet of stranded harbor seals (*Phoca vitulina concolor*) in the Gulf of Maine

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For the past thirty years in the Gulf of Maine, stranded seals were collected by the New England Aquarium. The stomach contents of these stranded seals were cleaned and stored. This study analyzed the stomach contents of 38 stranded harbor seals from this dataset, from years 1984-2012. The goal of this study was to characterize harbor seal diet and to identify important prey items among these stranded seals. Among the hard parts analyzed were otoliths, bones, beaks, snail operculums, and crustacean carapace pieces. Gut content analysis revealed that silver hake was by far the most abundant prey item, while squid was the most frequently observed prey item. Previous studies had identified Acadian redfish as important prey items, however that was not found in this project.

The Science-Policy Interface for Evolving Ecosystems: Scientific Information Use in Coastal and Ocean Decision-Making

Wells, P. G., MacDonald, B. H., Soomai, S. S., Ross, J. D., Wilson, L., Cadman, R., Castillo, D., Eck, K., & Ryder-Burbidge, S.

Understanding how scientific information is communicated and used at the science-policy interface is fundamental for strengthening decision-making processes for ongoing changes in coastal and ocean ecosystems. For over a decade, the interdisciplinary Environmental Information: Use and Influence research program at Dalhousie University has been conducting research with national, regional, and international governmental and non-governmental organizations, including the Gulf of Maine Council on the Marine Environment. This poster describes major enablers and barriers that affect the update of scientific information in decision-making. Research on the use of state of the environment reports, technical assessments, and digital repositories; studies on communication in multi-sector networks; studies on decision-making processes within governmental and non-governmental organizations and in coastal communities identified the enablers and barriers. A suite of quantitative and qualitative methods (e.g., citation analysis; content and discourse analysis; interviews and surveys of researchers, decision makers and other stakeholders; observations of meetings at local, regional, and international levels; and network analysis) were used to build an understanding of the interactions at the science-policy interface. This research shows that multi-stakeholder partnerships involving government and non-governmental organizations, academic institutions, industry, and the public facilitate the production of credible, relevant, and legitimate information for decision-making. The uptake of such “useable” information is often influenced by organizational processes, bridging roles of particular actors, and the formats of information products. This understanding of the science-policy interface can guide individuals and groups to pursue appropriate roles in policy-making processes, thereby promoting good coastal and ocean governance.

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