RARGOM Annual Science Meeting
December 2nd, 2022
Virtual Conference

Welcome 9:30am
Dr. Damian Brady

Dr. Andrew Pershing of Climate Central is returning to the Gulf of Maine to discuss "Ten years after 2012, should we still be surprised by heatwaves?" December 2nd, 9:30am

Dr. Lisa Colburn of NOAA will be discussing, "Social Change in Gulf of Maine Fishing Communities" December 2nd, 10:00am

Dr. Darren Ranco, Associate Professor of Anthropology and Coordinator of Native American Research at UMaine will be giving a keynote entitled, "Indigenous Environmental Management: Critical for the Future of the Planet" December 2nd, 10:30am

Dr. Kimberly Davies of the University of New Brunswick will be discussing, "North Atlantic right whales in uncharted waters: How a changing ocean environment disrupted the recovery of a critically endangered species." December 2nd, 11:00am

Dr. Jeremy Collie, Professor of Oceanography at the University of Rhode Island GSO will be delivering a keynote on, "Changing productivity of Gulf of Maine fish stocks" December 2nd, 11:30am

Lunch break, 12 - 1pm

Student Presentations

Group 1

1:00, Bailey Tausen, College of the Atlantic, Bar Harbor, ME 04609, “A Longitudinal Survey of Copepod Quantity and Quality as Foraging Potential for Gulf of Maine Whales”

The waters surrounding Mount Desert Rock, a remote island 25 miles off the coast of Maine, is a prominent location of nutrient upwelling, making it a known area of phytoplankton productivity. Consequently, the area is also a hotspot for highly caloric zooplankton such as the

copepod *Calanus finmarchicus* and its predators, including species of endangered whales such as the North Atlantic right whale *Eubalaena glacialis*. Today, their total population size is under 350 individuals, and vessel strikes and entanglement are among the leading causes of their decline. Still, reports of both live and deceased animals exhibiting emaciation indicate that inadequate nutrition may be escalating mortality. Have right whale sightings around Mount Desert Rock significantly decreased because of their rapid decline in numbers? Or because the area cannot provide adequate nutrition that would justify migration there? To answer this, we studied zooplankton productivity at three traditional whale feeding grounds around the island. Between the summers of 2019, 2021, and 2022, we collected weekly plankton tows and CTD scans from each site. We concentrated on seasonal and annual changes in water column temperatures, copepod population density, and the prevalence of *C. finmarchicus*. We also analyzed individual copepods and their lipid sizes using the imaging software ImageJ, primarily focusing on the lipid size of *C. finmarchicus*. Preliminary results suggest an incline in water column temperature by an average of 1.2°C and surface temperature increase of 2.3°C. The average number of *C. finmarchicus* collected per sample and their lipid size declined annually. Population densities stayed relatively constant over the years but not to the degree observed in other studies conducted in proximity to actively feeding right whales. These data provide insight into how zooplankton productivity, as an indicator of nutritional input for *E. glacialis*, is declining in a rapidly warming environment.

1:10, Camille Ross, Tandy Center for Ocean Forecasting, Bigelow Laboratory for Ocean Sciences, East Boothbay, ME 04544, USA, " Incorporating prey information into North Atlantic right whale density surface models used in decision support"

Predictions of North Atlantic right whale distributions form an increasingly important tool used in policy and management decisions for this endangered species. Incorporating plausible prey fields into right whale models has the potential to improve predicted whale distributions, and by implication the decisions based on them. We statistically modeled distributions of *Calanus finmarchicus, Centropages typicus*, and *Pseudocalanus* spp. using a Random Forest model with the goal of incorporating these prey fields into a right whale density surface model that is part of the National Oceanic and Atmospheric Administration's (NOAA's) North Atlantic right whale decision support tool. Initial runs indicated that the right whale model's skill metrics (e.g., REML score, AIC, etc.) were improved by incorporating the modeled prey distributions. Differences between the right whale models with and without zooplankton layers highlighted ecologically important regions for this critically endangered species (e.g., Bay of Fundy, Nantucket Shoals).

1:20, Alexandra Ouimet, School of Marine Sciences, University of Maine, Orono, ME 04469, "Environmental Drivers on the Abundance and Reproductive Rate of Marine Cladocera in the Damariscotta Estuary"

Marine cladocera are an abundant crustacean that can be the numerically dominant zooplankter during early and late summer coastal systems. Cladocera reproduce

parthenogenetically which can fuel an exponential rise in population abundance under favorable environmental conditions. As a result of their abundance and rapid reproduction, cladocera occupy an important link in marine food webs between primary producers and higher trophic levels. Despite their importance, little is known about population dynamics of cladocera or the environmental conditions that support the high reproduction. In this study we sampled populations of 2 marine cladocera, *Evadne normandii* and *Podon leukarti*, in the Damariscotta Estuary. Vertical net tows were collected every 3 days over an 8-week period paired with YSI measurements of temperature, salinity and chlorophyll (CHL) concentration. Samples were processed to assess total biomass of all particles over >150um, and cladocerans were identified and enumerated via microscopy. In addition, a minimum of 50 individual cladocerans from each species were photographed for size, number of eggs and egg type (clonal or resting egg). The data shows rapid increase in population size in early June with a peak abundance reaching up to 2109 individuals/m^3 for *Evadne sp.* and 397 individuals/m^3 for *Podon sp*. The highest proportion of females with eggs was 25% for *Evadne sp.* and 12% for *Podon sp.* Peak fecundity occurred ~16 days after peak CHL levels for *Evadne sp.*, indicating a possible link between growth and food availability. *Podon sp.* saw rapid increase of resting eggs starting early July following a trend of increasing temperature and salinity. This suggests that environmental conditions may become suboptimal around 14˚C for this species. This study provides the framework for understanding of the environmental conditions necessary for cladocera growth both in natural and lab environments.

1:30, Sarah Weisberg, School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY, USA, “An uncertainty-based approach to analyzing the resilience attributes of the Gulf of Maine food web”

An ecosystem’s resilience constrains its responses to disturbance. As climate change places systems under intensifying stress, robust, complementary indicators of resilience are needed. Certain properties of trophic networks, or food webs, can confer resilience – for example, the diversity and redundancy amongst trophic flow pathways. These network properties can be quantified via ecological network analysis (ENA). ENA metrics have existed for decades, and have many qualities of useful indicators: they are relevant, objective, and communicable. Yet for various reasons, ENA has rarely been integrated into fisheries management. To address this disconnect, we created a novel workflow for analyzing the resilience attributes of the Gulf of Maine (GoM) food web. Our approach combines well-established tools and has the dual aim of better understanding the GoM’s food web dynamics and advancing efforts to operationalize resilience management. First, we built a mass-balanced GoM food web model in the open-source R package Rpath. We integrated Rpath with an existing R package for Ecological Network Analysis (ENA), enaR, thereby allowing for the transparent, reproducible calculation of ENA-based indicators. With this integration, we calculated dozens of system indicators, including the ENA metrics of relative efficiency, resilience and robustness. Using Ecosense, a simplified Bayesian synthesis routine, we generated hundreds of plausible, unique versions of our GoM food web; we then calculated indicator values for each plausible model. This ensemble of models was further analyzed to give insight into the combinations of species-level

parameters that tend pull the system towards an overly brittle or overly stagnant state. Finally, we explored the practical implications of our work – specifically, how it can advance the integration of system-level resilience indicators into risk analyses and, ultimately, management decisions.

1:40, Isabel A. Honda, Woods Hole Oceanographic Institute, Woods Hole, MA, USA and MIT/WHOI Joint Program in Oceanography/Applied Ocean Science & Engineering, Cambridge and Woods Hole, MA, USA, "Synchrony Patterns Detected from Sparse and Unevenly Distributed Plankton Survey Data"

Spatial population synchrony is the study of correlating population fluctuations through time. Understanding whether spatially separated populations of organisms are synchronized can help researchers infer potential environmental drivers of population variability. Although statistical techniques have been developed to detect synchrony, many require input data to be uniformly distributed across time and space, which is not easily accomplished in dynamic ocean systems. Here, we present two approaches to detect synchrony in irregularly distributed spatiotemporal data sets. We apply our methods to analyze the spatial synchrony patterns of Calanus finmarchicus, and further extend our analysis to investigate the seasonal and interannual variability of chlorophyll-a, temperature, and potential C. finmarchicus invertebrate predators within and across various strata of the Northeast U.S. Shelf. Our findings indicate that synchrony changes depending on the timescale of analysis and that predation may play a significant role in influencing C. finmarchicus population dynamics.

1:50, Brandyn M. Lucca, Stony Brook University, 239 Montauk Highway, Southampton, NY 11968, "Variability in zooplankton and fish abundance in the Wilkinson Basin from Feb 2021 to Jan 2022 as measured by a multi-frequency bottom-mounted echosounder."

The Gulf of Maine contains a diverse assemblage of both commercially and ecologically important zooplankton, fish, and marine mammals that all exhibit different spatiotemporal distributions. We deployed an upward-facing multi-frequency (38, 120, 200 kHz) echosounder in the Wilkinson Basin that measured backscatter 2 minutes every hour for 11 months between 15 February 2021 and 08 January 2022. A classification algorithm used frequency-specific backscatter to determine what proportion of integrated backscatter was due to the presence of swimbladdered and swimbladderless fish, zooplankton, and other organisms. In addition to monitoring lower trophic levels, targets consistent with backscatter from higher trophic level predators such as dolphins were also detected. Near-surface (0 – 25 m) backscatter at 120 and 200 kHz rapidly increased between March and April 2021 which is consistent with increases in organisms expected with the spring bloom. Low-frequency backscatter (38 kHz) was consistently greater at deeper depths (> 100 m) during late-spring and summer months which could be tracking demersal fish abundance. We were able to track vertical migrations that spanned the entire water column (~ 140 m) across all frequencies, which enables us to make inferences on sub-week to sub-monthly mesoscale patterns. For instance, a seasonal trend in the average

backscatter of vertically migrating scattering layers increased five-fold from May to November 2021. Variability in diel vertical migration peaked during the winter and spring months, likely due to factors such as limited near-surface prey availability. Reverse vertical migration was also sporadically observed throughout the time series that may be attributed to predator-prey interactions. This time series presents a unique view into both short- and long-term variability in distributions of biological backscatter attributed to fish and zooplankton.

Group 2

2:00, Willow Dalehite, Princeton University, Princeton NJ, USA, "Parental investment in Black Guillemots (*Cepphus grylle*) on the Isles of Shoals"

Studying black guillemots (*Cepphus grylle*) on the Isles of Shoals affords a unique opportunity to understand how a cold climate-adapted species could respond to changing environmental conditions. As ocean temperatures rise, climate change has the potential to affect both parental fitness and reproductive success. To better understand how black guillemots respond to these changes, we researched how parents balance investment in current and future reproductive efforts. We established a monitoring program and collected nest footage using trail cameras to analyze how frequently parents return to the nest and how much time they spend there, as opposed to foraging at sea. Preliminary results suggest that nest visits often are made without prey but involve other behaviors such as vocal communication, and that nest visit rate does not necessarily predict nest success. We also present a non-invasive method for identifying individuals within pairs using plumage rather than capturing and banding them. Future monitoring of this study population will shed light on long-term trends

2:10, Rowan Cirivello, URI Graduate School of Oceanography, Narragansett, 02882, USA, "Environmental Drivers of Phytoplankton Abundance and Community Size Composition During Warming Events and Marine Heatwaves in the U.S. Northeast Shelf Ecosystem"

Phytoplankton are a diverse group of microorganisms and are critical components of global biogeochemical processes. Rapid changes in the Gulf of Maine, a region where multiple marine heatwaves have occurred and is warming faster than the global ocean, have far reaching effects on ecosystems and biogeochemical processes; this study seeks to describe how these changes impact the drivers of phytoplankton abundance, size class composition, and distribution. Given the potential consequences to the global carbon cycle resulting from a change in phytoplankton abundance and/or size composition, this study will provide insight into these areas by focusing on the environmental drivers acting on the base of marine ecosystems. Here the relative importance of environmental drivers on abundance and size class composition were analyzed across thermal regimes using satellite and derived data. Additionally, time series of abundance, size class, and environmental variables were constructed to describe the dynamic parameters of this region. Across both size and temporal scales relative driver importance varies, though euphotic depth is universally most impactful. Differing importance of environmental drives

between size classes and temporal periods may lead to decreased trophic and carbon cycling efficiency, trends that are projected to continue.

2:20, Kyle Shehata Oliveira, School of Marine Sciences, University of Maine/Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, "Review and comparison of data sources on *C. carcharias* in the northwest North Atlantic"

The white shark, *Carcharodon carcharias*, is a species of growing interest in the Gulf of Maine, with many stakeholders interested in the impacts the predator can have on a coastal ecosystem. Historically, systematic surveys for white sharks have not been conducted in the Gulf of Maine beyond the Cape Cod region, which leaves current researchers with a gap in their occurrence data impacting range maps or response curves for this species. This gap can be partially filled using data aggregated from online repositories, like the Ocean Biodiversity Information System (OBIS) and iNaturalist, historical data, or species reporting apps, like Sharktivity. The challenge is then to consider how the varying data quality associated with the compilation of multiple datasets, with multiple forms of data collection and effort biases, will impact subsequent analyses. To address these issues, we reviewed the datasets on *C. carcharias* in and around the Gulf of Maine to characterize historical observations. We then developed freely available software that compares occurrence data from different sources under a common framework: the thermal niche. By pulling data for a species from multiple sources, subsetting the dataset by the basis of record, creating a thermal niche response curve for the species utilizing various modeling methods, and assessing variance associated with these response curves, we tested how the basis of record influenced the mean, range, and variance of the thermal niche. Sequential random sampling of data and data types allows us to create a distance metric between response curves built from different bases of record. Users of this software will have the ability to visualize uncertainty and interpret the differences between response curves built from different datasets. In addition to highlighting patterns in the *C. carcharias* historical data, the software can be used generally to assess species observation data before being incorporated into ecological models.

2:30, Clayton Nyiri, School of Marine & Environmental Programs, University of New England, 11 Hills Beach RD, Biddeford Maine, 04005, "Using groundfish rods and field trials to determine if electronic bycatch reduction devices (BRDs) will deter spiny dogfish, *Squalus acanthias*"

Bycatch reduction devices (BRDs) are designed to let out voltages in a series of pulses to disturb sharks' electroreceptors, Ampullae of Lorenzini, and deter them from longline hooks. Overall, to reduce bycatch in longline fisheries. The spiny dogfish (*Squalus acanthias*) was selected as a model species to determine how effective BRDs work on groundfish rods. Pooled and unpooled data indicated that rods with active BRDs caught less spiny dogfish than those with non-active BRDs.

2:40, Mary Margaret Basilious, Department of Biological Sciences, Dartmouth College, Hanover, NH, USA, “Aging architecture in the sea versus on land: quantifying structural integrity of shell homes across five years”

Animals build and create a diversity of structures, which span sea and land. Shells, in particular, represent essential homes for many secondary occupants, including hermit crabs. However, the impacts of abiotic and biotic wear and tear on the structural integrity of these homes over time has rarely been tested, particularly in the sea versus on land. Interestingly, after snails die their remnant shells may persist for years in the sea or may wash onto land, sometimes remaining in one or the other of these environments for extended periods before eventually entering the housing market of shells occupied by populations of marine hermit crabs (*Pagurus acadianus*). Here, we conducted a systematic and controlled longitudinal experiment on shells, spanning 5 years across both sea and land. On Appledore Island in the Gulf of Maine, we emptied the shells of living gastropods (*Littorina littorea*)—generating brand new homes that had never before been inhabited by hermit crabs—and then randomly allocated these empty homes to cages, which we positioned in the subtidal and on land, equidistantly from the shore, starting in 2018. Every subsequent year (2019, 2020, 2021, and 2022) we collected one of these cages (each with N = 30 shells) from both sea and land. All recollected shells were measured, and in 2022 all shells were subject to a controlled crush test in an Instron engineering machine, quantifying each shell’s maximum compressive load, based on the force it could tolerate before fracturing. Here we report how homes stood the test of time (0, 1, 2, 3, and 4 years) and the differential environmental impacts of being in the sea versus on land. Broadly, our study reveals how aging and environment ultimately determine the protectiveness and longevity of animal architecture, with important implications for the fitness of occupants of shell homes.

Group 3

3:00, Emily Dombrowski, College of Charleston, Charleston, SC 29401, USA, “Using Hemolymph Chemistry to Predict and Assess Molting in Green Crabs, *Carcinus maenas”*

Invasive green crabs, *Carcinus maenas*, have resided in New England coastal waters for over 150 years, but their impact on local shellfish and ecosystems have not been fully realized in recent years as their numbers remain excessively high in some areas. As a consequence, local stakeholders, including harvesters and coastal resource managers, are exploring strategies for exploiting and mitigating the impacts of such large populations. One option is to establish and promote a soft-shelled product for this species, as seen in Italian fisheries. A primary challenge to implementing a soft-shell fishery in New England is the difficulty of readily and clearly identifying pre-molt crabs. This project aims to evaluate the use of visual (color) and biochemical (protein and calcium concentrations) cues in green crab hemolymph (blood) as a diagnostic tool to help predict molting. We captured green crabs at two locations (Wells, ME

and New Castle, NH), where we tagged, measured, and held animals in individual compartments in floating “crab condos”. Hemolymph samples were collected from each crab (n = 126) twice a week for up to 3 weeks and were evaluated for total protein concentration, color, and calcium. Preliminary data suggest a relationship between hemolymph protein and crab molting status, as well as a correlation between hemolymph color and calcium content. Our results are important in understanding the biological underpinnings of molting in this species and in creating an accessible and informative molt assay tool which can be employed by local fishers to simultaneously maximize economic benefits and reduce the impacts of green crab populations.

3:10, Phoebe Jekielek, University of Maine, Orono, ME 04473, “Developing eDNA as a tool for monitoring cultured and wild populations of sea scallops (*Placopecten magellanicus*) in Maine, USA”

The Maine eDNA program aims to use molecular tools to better understand and promote sustainable use of wild and cultured fisheries resources. Quantitative eDNA assays for sea scallops have been developed and calibrated for sperm and dockside conditions, but this assay has not been calibrated for other life stages, e.g., eggs or larvae, nor has it been tested in more dynamic field environments. Here we explore whether eDNA from adults vs gametes and larvae can be distinguished by sampling at different depths and points in time in a wild population of sea scallops. I hypothesize that the scallop DNA signal will be highest near the bottom outside of spawning and larval transport season and evenly distributed throughout the water column during those seasons. I collected water samples at 8 different depths above a well-characterized wild scallop bed off of Hurricane Island in Penobscot Bay over a 10-week period. Results show that scallop DNA signal is more stratified outside of spawning season, with deeper depths having highest gene copy numbers per liter. Signal stratification decreases in September with spawning and scallop DNA signal increases and becomes even across all depths. This pattern persists until late September when the signal begins to be stratified again. However, mid-October shows the highest gene copy numbers throughout the entire sampling timeframe and potentially indicating a signal from larval transport. Therefore, we do see spatial and temporal differences in scallop DNA signals using our stratified sampling design. Results from this work may inform the use of carefully constructed sampling designs to develop adult stock assessments or to estimate recruitment potential.

3:20, Caitlin Haley, University of Maine, Orono, ME 04473, “What do larval lobsters eat? Detecting various species of zooplankton in the guts of larval American lobster (*Homarus americanus*) using eDNA”

The Gulf of Maine’s American lobster fishery has undergone an unprecedented boom in recent decades and is now the nation’s most valuable single-species fishery. But current research shows a disconnect between the high number of adult lobsters and low rates of larval settlement. Understanding this disconnect is a key goal for researchers, industry, and stock

managers. A correlative analysis suggests that the decrease in settlement may be linked to the climate-related decline of the zooplankton species *Calanus finmarchicus*. Analysis of the lobster larval diet with eDNA tools can help test this hypothesis. In this study, we will determine the efficacy of a *C. finmarchicus* real-time PCR assay (rtPCR) by testing lab reared larvae fed only *C. finmarchicus*. We can then apply this methodology to field-caught larvae to determine if *C. finmarchicus* is present in their diet. These experiments will provide a better understanding of lobster recruitment and inform future application of eDNA tools.

3:30, Bryson Torgovitsky, Department of Biological Sciences, University of New Hampshire, Durham, NH, "Impact of Ocean Acidification on the Physical Conditions of the Blue Mussel, *Mytilus edulis"*

Bivalve aquaculture generates benefits ecologically and economically, which makes the continued health of bivalve populations paramount. Ocean acidification is a global phenomenon and presents a growing danger to natural systems as well as aquaculture. Resilience of shells against crushing force is a key factor in the fitness of an individual, as juvenile mussels are predated by crustaceans including several crab species invasive to the Gulf of Maine. We exposed cohorts of the blue mussel *Mytilus edulis* to controlled levels of ocean acidification in a laboratory environment for three months and examined the degree of impact to shell strength. By the end of the study period, mussel shells greater than 30 millimeters in length which had been exposed to the highest level of acidification (0.5 pH below ambient levels) required statistically less force before breakage in comparison to mussel shells in control samples. There were no significant differences in mortality rates or growth rates between the treatments and the control. This short study showed that ocean acidification can negatively impact mussel shell integrity. Shellfish populations with weaker shells may be vulnerable to predation, disease, and low reproduction in the long run.

3:40, Abigail Lemmon, University of New Hampshire, Department of Biological Sciences, Durham, NH 03824, "Warmer waters reduce swimming activity in postlarval American lobsters (Homarus americanus)"

Recent declines in lobster settlement in the Gulf of Maine (GoM) have raised questions concerning the effects of climate change on lobster recruitment. Postlarval (PL) lobsters (*Homarus americanus*) metamorphose from planktonic larvae in offshore waters and must swim to inshore nursery grounds where they settle and grow, an energy-intensive process that may be a metabolic bottleneck. Using 72-hr. laboratory swimming challenges, we tested the performance of laboratory-reared PLs at historically favorable temperatures (15°C), as well as projected end-of-century GoM temperatures (22°C). Video observation and analysis of the trials showed that PLs in the 22°C temperature treatment spent a smaller proportion of time actively swimming compared with PLs at 15º. Metabolic rates for lobsters increase in warmer

temperatures, so it is possible that decreased swimming at warmer temperatures may be a behaviorally-mediated strategy for energy conservation. Ongoing analytical assays are also being used to determine the effects of warmer conditions on energy reserves (lipids, proteins). Overall, decreases in swimming activity in warmer waters may be a contributing factor in shifting patterns of lobster recruitment in the GoM.

3:50, Isabel Handal, University of St. Andrews, KY16 9AJ, United Kingdom, "Decreasing Barnacle Abundance in the Gulf of Maine"

Semibalanus balanoides (barnacles) is a key species essential to the ecology of intertidal communities. They serve as an important space occupier, food source, and filter water. Understanding what drives their abundance is important for predicting community and ecosystem processes in the intertidal zone. Since 1982, the Shoals Marine Lab (SML) has monitored intertidal transects on Appledore Island. We used SML survey data and environmental data from NOAA and NASA to examine if barnacle abundance changed over time and whether various abiotic and biotic factors influenced barnacle abundance. Abiotic factors included sea surface temperature, chlorophyll concentrations and wave height. Biotic factors included the abundance of competitors, such as *Mytilus edulis* (blue mussel), and *Fucus vesiculosus*. We found a significant decrease of *Semibalanus balanoides* abundance over time, with a steeper decline in percent cover on the exposed side compared to the sheltered side of the island. We also found a significant positive correlation between *Mytilus edulis* abundance and barnacle abundance on the sheltered side, and a significant negative correlation between sea surface temperatures and barnacle abundance on the exposed side. Because barnacles are an essential component of the ecology of the intertidal, there could be cascading effects on the rest of the intertidal ecosystem in the Gulf of Maine without them. Additionally, climate is changing rapidly, so it is important to continue surveys to monitor populations, and conduct experiments to identify mechanisms underlying change.