National Sea Grant American Lobster Initiative
Regional Research and Outreach Summit
February 6-7, 2023
Holiday Inn by the Bay
Portland, Maine

Monday, February 6, 2023
Plenary: Welcome and opening remarks – 9:00-9:30 am

Welcoming remarks were briefly made by Amalia Harrington of Maine Sea Grant. She shared the overarching goal of the American Lobster Initiative's (ALI) first Regional Research and Outreach Summit: to share updates on the science, make connections and get feedback, and to broadly think about merging the research program with extension. Alison Krepp of the National Sea Grant Office then provided an overview of the ALI and its component parts. She was enthusiastic and eager to hear more about the progress of the ALI and to have conversations about how to move the program forward to advance the research-to-extension model that is admired by others in the National Office and within NOAA. The Director of Maine Sea Grant, Gayle Zydlewski, introduced two members of the Maine Congressional Delegation, Senator Susan Collins and Congresswoman Chellie Pingree. Senator Collins provided pre-recorded remarks while Congresswoman Pingree addressed attendees in person. Both remarked on the importance of the ALI to the people of Maine who rely on the lobster industry, as well as advancing sound science to address the impacts of environmental change to promote resilience in the fishery. There was a brief overview of the agenda and logistics for the Summit before attendees were dismissed for the breakout sessions.

Session title: Larval lobsters and early life history stages
Part 1: Influence of environmental change on early development of lobsters & maternal effects – 9:30-10:45 am
Moderators: Dr. Brittany Jellison (University of New Hampshire, brittany.jellison@unh.edu) and Dr. Jason Goldstein (Wells National Estuarine Research Reserve, NERR, jsgoldstein2@gmail.com)

Dr. Benjamin Gutzler (Wells NERR, bgutzler@gmail.com) – *Investigating egg clutch size across the Gulf of Maine*

In this project, the researchers aim to understand the factors that influence lobster reproductive success and/or recruitment. They combined field surveys to determine what kinds of clutches occur in the natural environment, including partial clutches, as well as lab experiments to explore diet and temperature. They employed non-destructive egg sampling and a suite of metrics indicative of nutritional condition and health. The non-destructive egg sampling was validated using 10 females (maximum size 82 mm carapace length), and they are still working to improve methods to estimate volume. The team sampled early-stage egg-bearing females in August through October 2022 from New Hampshire and three sites in Maine (Wells, Casco Bay, and Downeast). Preliminary data suggests that bigger lobsters have bigger clutches, and that lobsters from Downeast had a higher mean blood refractive index compared to other locations. The refractive index appeared to correlate with clutch volume such that higher blood protein indices may correlate to bigger clutch sizes. They also observed potential hints of a geographic gradient in clutch sizes and nutrition, but require additional animals from southern

New England in 2023. When asked, the authors clarified that they have not yet explored nutritional status of egg samples, but may be able to with the approaches they have planned.

Dr. Brittany Jellison (University of New Hampshire, brittany.jellison@unh.edu) – *The effect of multiple stressors on reproductive success, embryogenesis, and emerging larvae of the American lobster*

This project explored early development in lobster eggs in the context of multiple stressors that are common in the Gulf of Maine, including ocean acidification (OA) and warming. The research team was interested in looking at both impacts to egg-bearing females and the brooded embryos. The team set up tanks with two egg-bearing females – one from Maine and one from Massachusetts – and exposed them to one of four possible stressor treatments. They had three females for each treatment combination from each state. They performed monthly sampling of eggs and measured growth and development from photographs, and investigated metabolic cost of stress responses via respirometry. They also flash froze some samples for additional analyses. They used a replicate sample size of three eggs for each metric. Based on preliminary analysis, the team observed larger differences in Maine-sourced lobsters in early development periods relative to Massachusetts-sourced lobsters, as well as a potential interaction between treatments of warming and OA. They found that warmer water treatments resulted in greater oxygen consumption, and produced smaller larvae at hatch. During the questions and answer period, they clarified that they did not notice early hatching with warming conditions, but that there was a lot of variability in the starting conditions for the eggs that may have affected hatching time. Their main conclusion at this point is that early development is influenced by environmental conditions and can alter size at later life history stages, but the interaction of stressors is complex and dependent on ovigerous female source location.

Sarah Koshak* (Virginia Institute of Marine Science, jskoshak@vims.edu) – *The shifting bacterial community of the American lobster (*Homarus americanus*) during early life history stages*

This project is a component of the larger project described by Dr. Jellison. Here, the objectives were to describe the bacterial composition of the lobster embryo and larvae to evaluate the potential effects of temperature and acidification. Samples were taken in December and March, two months after acclimation to the treatments described in the previous presentation. They found that warming and acidification do not appear to impact microbial community associated with embryos or larvae, though the sample size was small. They also found that embryogenesis stage drove the microbial diversity of the embryos sampled in this study. Larval microbiomes were unique from that of water sampled from the tanks, and late-stage embryo microbiomes were distinct from recently hatched larvae. Finally, they determined that lobster eggs were a highly selective microhabitat for bacterial microbiomes. They have not yet compared these results to the microbiome of parent lobsters (maternal and/or paternal).

Alex Ascher* (University of Maine, ascher.alex@gmail.com) – *Maternal size-effects on embryonic and larval lobster*

Work by Maine's Department of Marine Resources indicates that as the Gulf of Maine warms, female lobsters are reaching sexual maturity sooner and at smaller sizes. This work aimed to understand if warming models could predict maternal size effects on embryos. That is, the goals were to determine maternal size effects on embryonic and larval lobsters, and to

understand whether regional effects exist that could indicate future conditions in the Gulf of Maine under continued warming. They sampled females from Downeast and Midcoast, Maine, as well as Rhode Island and found a significant maternal size effect on the number and volume of embryos. Rhode Island and Midcoast females produced significantly more embryos than those from Downeast, and Rhode Island females produced significantly larger embryos than those from the Midcoast region. When the researchers focused just on the Midcoast females, they observed lager larvae from larger females. That is, larger females produced more and larger eggs compared to smaller females, which then hatched into more and larger larvae. They also found that females in the warmest areas (Rhode Island) were capable of out-producing females in colder regions. These larger larvae produced from larger females were also more likely to survive during forced starvation trials compared to those from smaller females. Overall, this works suggests that maternal size significantly effects both quantity and quality of embryos. Great maternal size may also result in benefits to larvae, implying that larvae from smaller females may be less capable of surviving in the pelagic realm. Finally, this work might suggest the potential for counter-gradient adaptation in that females in warmer regimes showed some ability to outperform females from cooler/northern populations. When asked during the question and answer period if they found an effect of first vs. successive reproduction in individual females, the speaker stated that data show potential, but the sample size is too low to say with certainty.

Dr. Carolyn Tepolt (Woods Hole Oceanographic Institution, ctepolt@whoi.edu) – *Variability in heat tolerance in Stage I lobster larvae among families and regions*

This work has its foundation in the presenter's interest in the variability and diversity within green crabs, as well as prior evidence for genetic variation associated with environmental temperature in lobsters (see Benestan et al 2016). This work was partially funded by Maine Sea Grant Program Development funding. The primary focus of this work was to understand if thermal tolerance differed among larvae from different regions. The study design included three regions, four to six families per region, three hatches per family, and 20-30 larvae per hatch. Upon hatch, stage I larvae were kept either at 16 °C or rapidly ramped to either 26.5, 26, 29.5, or 31 °C for a total of 18 hours (including the ramp). Mortality was assessed and live larvae were saved in RNALater. Results indicated no regional difference in thermal tolerance, but that different lobster families have different early stage larval thermal tolerance. The next steps will include exploring why different families have different thermal tolerances and whether there is standing genetic variation in thermal tolerance. Future work will also test the potential for rapid adaptation from standing genetic variation, and determine the architecture of this variation and how its distributed along the coast.

Discussion

There was some discussion on if the results of these studies indicate that climate change will make things worse or better for lobster. The evidence right now seems to suggest that OA is not affecting lobsters as much as temperature. Other audience members questioned this as we haven't yet been able to test over the whole life history of an individual lobster. Early-stage larvae seem to have greater thermal tolerance than later-stage larvae, and then once they settle, they regain more thermal tolerance. Early maturation likely means decreasing recruitment; however, if we have more, smaller egg-bearing females with lower quality eggs, how successful will larvae be? There may be some adaptation going on, but don't have enough data to say for

sure. There was some discussion on the challenges of working with multiple variables and attributing cause/effect, as well as challenges rearing larvae and accounting for variation in larval hatch times. There was a brief discussion on potentially applying this work to management, with a particular focus on the physiological floor of L50, which seems to be about 75 mm carapace length (comment from Jes Waller, ME DMR). Some lingering questions from the audience include: How do dynamic environmental parameters influence our capacity to answer these kinds of questions? How much does movement of ovigerous females into different conditions affect their larval outcomes? When thinking about lab vs. field comparisons, how close can the rate of change in the lab mimic rate of change in the field?

Part 2: Trophic interactions in the pelagic food web – 11:00-12:15 pm
Moderator: Dr. Rick Wahle (Lobster Institute, University of Maine, richard.wahle@maine.edu)

Dr. Rick Wahle (University of Maine, richard.wahle@maine.edu) – *Bridging the great disconnect: linking lobster recruitment dynamics to the Gulf of Maine's pelagic food web*

The impetus for this project (and many in this session) was an increase in the abundance of stage I larvae and egg-bearing females that coincided with a decline in abundance of the postlarval and young-of-year stages. The initial analysis (Carloni et al. 2018) determined that the disconnect in abundance occurs sometime between stage I and the postlarval stage. The downward trend in postlarval abundance strongly correlated with a decline in the abundance of a major prey item, *Calanus finmarchicus*. The group of studies in this session represent an effort to understand this correlation.

Dr. Burton Shank (Northeast Fisheries Science Center, burton.shank@noaa.gov)– *Lobster larval and settlement dynamics: correlations and connections to basin-scale oceanographic processes*

Following on the introduction, this presentation started by restating what Carloni et al. (2018) observed: correlations between the time series for *Calanus finmarchicus*, lobster larvae, and larval settlement dynamics. Here, this work explored if the pattern holds for basin-scale processes. First, the presenter explained the seasonality of the Gulf of Maine EcoMon sampling regime, as well as the decision to combine the summer and fall seasonal samples to build indices. A principle components analysis was used to look for temporal trends and shifts in the major plankton classes. Surprisingly, there were no strong spatial components to the species composition; however, the first three components had different trajectories but breakpoints at similar times. When comparing the EcoMon sampling correlations with the individual American Lobster Settlement Index (ALIS) raw study area indices, it was evident that there were better correlations in southwest than Downeast, Maine, and even better with a one-year time lag. This work was the basis for building "north" and "south" ALSI indices, and both track very well with EcoMon sampling after 2005. In looking at what might be driving these patterns, it seems like it is closely tied to water coming into the Gulf of Maine (note: there are a mix of sources, but the presenter was using Labrador Slope Water supply into the Gulf of Maine as a proxy). When asked about what happened in around 2005, the first year ALSI suction sampling showed a spike in settlement east of Penobscot Bay, the presenter did not have a clear answer at this time.

Joshua Carloni (New Hampshire Fish and Game, Joshua.T.Carloni@wildlife.nh.gov) – *Diverging phenology of larvae and their potential zooplankton prey in a warming ocean*

This presentation focused on the following questions: How has phenology of lobster larvae and *Calanus finmarchicus* changed over time (1988 to present)? Is there evidence of a match-mismatch in the phenology of these two species? In American lobster, there is a high resistance to starvation among late-stage larvae (i.e., they are more vulnerable in earlier stages) and survival at early stages is linked to food quality and quantity. The presenter explained the trend in earlier timing of both egg hatch and the first appearance of stage I larvae, and that both correlate well with increasing spring water temperature. When exploring the season of *C. finmarchicus*, the beginning of season has shown no trend over time. The end of the season is trending earlier in the season over time and the duration of season is getting shorter. Based on the correlation statistics between monthly abundance of *C. finmarchicus* and postlarval abundance, it appears that July and August are the most important months for larval development. In the most recent decade, there has been a difference in timing between the end of the *C. finmarchicus* season and peak stage I larval abundance. There has been a significant downward trend toward 0 and negative, suggesting an increase in the disconnect between these two metrics. The peak in stage I larval abundance is now happening well after the *C. finmarchicus* peak, resulting in a 70% decline in *C. finmarchicus* availability during the peak of the stage I season. There has also been an overall decrease in abundance of *C. finmarchicus* since 2010 that has likely exacerbated the mismatch between these two species. The presenter noted that while there are other prey items available for larval lobsters, this has been considered a major food source given that it is lipid-rich and abundant.

Maura Niemisto (Bigelow Laboratory for Ocean Sciences, BLOS, mniemisto@bigelow.org) and **Brendan Kellogg*** (BLOS and Southern Maine Community College, brenkellogg97@gmail.com) – *Depth wise associations of zooplankton with lobster larvae*

This work was done primarily by members of the Fields Lab at Bigelow Laboratory for Ocean Sciences. The research team worked aboard the *R/V Ira C* from the Darling Marine Center to sample 8 sites on 18 sampling days across three years. They towed a neuston net at 10, 20, and 30 m depth, filtering ~1000 m^3 with each tow. They also employed a CTD and took vertical plankton samples at depths of 0-10, 10-20, and 20-40 m. The team took water samples for chlorophyll and eDNA analyses and collected ~700 wild larvae for analysis of nutritional status, stomach content and diet analysis, and to pair with eDNA samples. In late June, the team collected nearly all stage I larvae, but by the end of the season were collecting nearly all postlarvae. The majority of larvae collected were in the neuston, but they observed a 5.5x increase in stage I larvae at greater depth (30 m). The zooplankton biomass was highest in the two uppermost depth strata with the most observed in the intermediate layer (20 m), a finding that did not correlate with the distribution and abundance of larval lobsters. The presenters showed a depthwise community structure of the zooplankton they sampled, noting that copepods dominated at all three depth strata. The next steps of this work include integrating the field analyses with the eDNA and diet analyses. There was some discussion during the question and answer period as to where the stage II larvae might be, and if they could be deeper than where they sampled. The presenter mentioned that the maximum depth over which they conducted tows was about 40 m. All tows were conducted during the day, and the presenter noted that the community structure could be different during the night.

Alex Ascher* (University of Maine, ascher.alex@gmail.com) – *Lobster larval diet study: utilizing mixed methodologies*

This project aims to understand what lobster larvae eat and if they rely on *Calanus finmarchicus* for nutrition. The presenter shared three methods that were used to address these questions: traditional microscopy to estimate gut fullness visually, which relies on expertise and is subject to bias; metabarcoding to broadly identify taxa present in many guts simultaneously but may miss key taxa and includes PCR bias; and targeted qPCR assays, which target and identify a single target species with high fidelity but may be unable to identify the total breadth of diet. When examining the gut contents of postlarval lobsters, microscopy resulted in identification of a lot of copepods but very few *C. finmarchicus.* The top prey items identified using metabarcoding were green crabs, dinoflagellates, bivalves, Anomalocera, and green algae; importantly, this methodology did not identify *C. finmarchicus*. Finally, the targeted qPCR assay of 48 larval guts (tested in triplicate) determined that slightly more than 20% contained *C. finmarchicus*, including several in which metabarcoding did not detect *C. finmarchicus*. Overall, this work demonstrated that larval lobster diet is broad, but consists largely of copepods, decapod larvae, other crustacea, annelids, bivalves, and *C. finmarchicus*. It also demonstrated the utility of mixed methodologies and acknowledged that while each approach had its own pros and cons, they helped fill in a piece of the puzzle. When asked during the question and answer period, the presenter mentioned that he was unsure how long it takes for a larval lobster to digest *C. finmarchicus*, but that residence time appears to increase from stage I to stage IV (based on other studies). It was also shared by a member in the audience that *C. finmarchicus* is ~300 times more dense than other prey items in terms of calories. Finally, the presenter addressed a question about the potential for secondary consumption, particularly in reference to the dinoflagellates and algae, and noted that secondary consumption would still provide some level of nutrition.

Evie Layland* (University of Maine, evelyn.layland@maine.edu) – *Ontogeny of prey preference and functional response of larval lobster (*Homarus americanus*)*

Larval development changes the ability to capture and handle prey, resulting in variable risk of food limitation. This study had four main questions: Are early stage larvae able to eat *Calanus finmarchicus*? Are early stage larvae less competent than late stage to eat *C. finmarchicus* (and thus more likely to be prey limited)? Do lobster larvae selectively feed on *C. finmarchicus* when given a choice of two other prey items at once? Does larval functional response to prey density vary by larval stage and prey type? The presenter concluded that early stage lobster larvae can eat *C. finmarchicus*, but they are less competent than later stages. Stage IV are capable of eating at least twice as many *C. finmarchicus* per hour than early stage larvae, indicating better handling capacity in later stages. When given a choice, lobsters sometimes preferentially prey on *C. finmarchicus*, but this is dependent on stage and prey species. All stages preferred *C. finmarchicus* over *Acartia* and *Temora* spp., but no preference was detected when given the choice of crab zoea or *Centropages* spp. along with *C. finmarchicus*. When exploring functional response curves, early stage larvae exhibited higher ingestion rates on smaller, slower prey items that can be captured and consumed quickly. Stage IV fed more on *C. finmarchicus* but preferentially fed on Artemia, which are smaller and slower swimming. In an additional prey density study with postlarval lobsters, the presenter found that postlarvae do not appear prey limited even at low prey densities. When asked if some stages appear more/less opportunistic, the presenter shared that it would be difficult to comment given their data; however, larvae seem happy to eat anything they are presented with so long as they can catch the prey item. When asked about stage III lobsters, the presenter mentioned that other work suggests that this stage

might be using all of its energy stores to prepare for postlarval development rather than chasing and finding food.

Discussion

Many in the audience agreed that the "disconnect" in larval development seems to be somewhere between stage I and stage IV. There was some discussion about the potential for onshore/nearshore transport of *Calanus* that could also transport late-stage larvae. It does not seem like postlarvae would be transported nearshore given their ability to swim, and the potential for storms to transport them nearshore also seemed unlikely. Postlarvae seem to have an understanding of supply as well as competency for swimming. There was a discussion on the importance of nutrient limitation in addition to food limitation, particularly regarding the nutritional value of Labrador Slope water. Secondary feeding may be an important contribution to larval diet, and that mode of eating is not the first order of business for postlarvae (especially when compared to spiny lobster larval counterparts that do not even have mouth parts). People were interested in whether or not there have been studies examining the relative abundance of other, more easily captured but lower-nutritional-quality species (e.g., green crab), but no one seemed to have a clear description of any work on the topic. There was also a brief discussion on whether or not selectivity of prey depends on temperature (or other factors). None of the presenters have explored temperature within their feeding trials, but one participant suggested the potential for seasonality to be a large driver of the presence/absence and abundance of plankton. There was one final question regarding the potential danger of dooming all larval lobster to starvation in light of the discussion of increasing the gauge size for harvest. That would be a question of biomass in the water, but it would involve a perfect storm of factors to doom all (i.e., limited food, temperature…etc.).

Part 3: Environmental drivers of behavior and distribution
Moderators: Dr. Jason Goldstein (Wells NERR, jsgoldstein2@gmail.com) and Dr. Benjamin Gutzler (Wells NERR, bgutzler@gmail.com)

Dr. Steve Jury (Saint Joseph's College of Maine, sjury@sjcme.edu) – *Behavioral thermoregulation of ovigerous American lobsters (*Homarus americanus*)*

This study explored thermoregulatory behavior in ovigerous lobsters across the various stages of egg development. Researchers paired 154 ovigerous females with 145 control (i.e., non-ovigerous) lobsters and placed them in thermal gradient tanks (8-20 °C, 10 ft x 3 ft dimensions) to observe behavior over a 48-hour trial period. Each female was fitted with a HOBO temperature logger and an accelerometer that collected data every five minutes. These data were used to calculate mean thermal preference and relative activity for each lobster. The team found that early-stage egg-bearing females preferred warmer water temperatures relative to control lobsters, but that late-stage egg-bearing females preferred cooler water temperatures relative to control lobsters. They also observed differences in behavioral thermoregulation based on season. They reasoned that spring and fall are critical times of changing temperatures and thermal preferences going into (and out of) winter, which influences rate of egg development. Newly extruded eggs can develop quickly from summer into fall prior to overwintering by females remaining in warmer temperatures. In the spring, egg development can be delayed by remaining in colder temperatures until it is time for larvae to hatch. They determined that females with developed eggs are very active and likely move to different thermal habitat before,

during, and/or just after hatching. Changing water temperature will likely affect the time and location of hatching that is critical to larval release, survivorship, and recruitment.

Dr. Jason Goldstein (Wells NERR, jsgoldstein2@gmail.com) – *Warming GoM waters and their impact on postlarval swimming activity*

We know that the Gulf of Maine is changing and temperatures are increasing. Lobster populations appear to be moving into deeper and cooler waters, which means larvae may be hatching farther from shore into different currents. This project was interested in understanding how increasing water temperature impact the swimming behavior and physiology of postlarval lobsters. The research team conducted 72-hour, video-recorded swimming trials with over 700 lab-reared postlarvae. Postlarvae were placed into tanks held at either 15 or 22 °C with either moving (i.e., "swimming") or static water. After 72 hours, postlarvae were dehydrated and weighed, and then preserved for biochemical tests (i.e., lipids and proteins) to examine energy reserves. The research team found that postlarvae exposed to 22 °C exhibited a drop off in swimming activity sooner and maintained a lower proportion of individuals continuing to swim than those exposed to 15 °C. Although researchers observed behavioral changes with temperatures, they did not observe consistent and significant changes in nutritional condition. There was no significant difference in mean dry weight or protein content across treatments, but they did observe a significant effect of treatment on lipid content. They speculated that this may constitute behavioral conservation of energy reserves, which could have potential implications for swimming and foraging activities.

Dr. Jesús Pineda (Woods Hole Oceanographic Institution, jpineda@whoi.edu) – *Concentration and condition of American lobster postlarvae in convergences*

Since flotsam and plankton accumulate at some hydrographic convergences, this team wanted to explore if postlarval lobsters are more abundance inside relative to outside of convergence zones. To do this, the team sampled 15 convergences from Massachusetts to Maine over the course of 9 cruises from July-August 2021. During the cruises, they took cross-convergence oceanographic measurements and conducted net tows. The presenter shared examples of temperature and salinity profiles for active vs. inconsistent convergences, noting that 11 of the 15 convergences they sampled were considered active. They found that postlarvae were more abundant and had a higher density inside relative to outside of convergence zones, but they did not aggregate equally across convergences (i.e., large variability). The researchers also found that postlarvae in convergences were not in better condition than those outside of convergences, but they did vary in color (e.g., more green coloration inside of convergences, more yellow coloration outside of convergences). They also conducted some post-collection starvation experiments with postlarvae but observed no significant differences in survivorship.

Dr. Eric Annis (Hood College, annis@hood.edu) – *Larval thermal tolerance and implications for distribution and settlement*

Research suggests that temperature plays a role in where lobster larvae settle. Settlement has historically been restricted to shallow waters (< 20 m depth), but deepening of the 12 °C isotherm has allowed settlement to expand into deeper water (> 50 m). Larvae do not often settle below 12 °C because lower temperatures result in slower development and growth rate and increase mortality. With this project, the research team wanted to better understand the range of thermal tolerance for stage IV lobsters and to explore how results generated in the lab translated

to the field. They used "scope for activity" as a general metabolic indicator of temperature stress. This was determined via microrespirometry, which measured oxygen consumption of individual larvae in five developmental stages that were all reared in lab at 18 °C. Scope was defined as the difference between oxygen consumption when swimming actively and oxygen consumption at rest. A positive difference in these values suggests a larva still has the metabolic scope to engage in active swimming. As the scope reaches zero, a larva essentially has nothing left metabolically and is approaching a critical temperature. The researchers also subjected each developmental stage to a chronic temperature exposure (i.e., until they molted or died). They found that scope for activity was a function of temperature in stage IV larvae. After an acute exposure (~30 minutes), scope was zero in lab-reared larvae at both 8 and 27 °C. In contrast, scope was zero in wild-caught larvae at 4 and 32 °C, indicating that wild larvae were much more tolerant of temperature stress than lab-reared larvae. Researchers also found that mortality was a function of temperature, and that wild-caught larvae persisted at 3 °C for five months. The presenter suggested that the differences between lab-reared and wild-caught larvae are likely due to different rearing conditions and that sublethal effects may be selective drivers. They observed no difference in scope between the two groups of larvae at a non-stressful temperature (18 °C), and found that wild-caught larvae had a much higher scope at both stress temperatures. They also found that both acclimation temperature and diet improved the response to cold stress. The presenter suggested that settlement depth might be driven by a behavioral response in addition to the 12 °C limit for settlement. Future work needs to reconcile the 12 °C limit for settlement, and should consider critical vs. pejus temperatures as well as wild-caught vs. lab-reared larvae.

Caroline Benfer* (Hood College, ceb16@hood.edu) – *Broad-scale distribution of lobster larvae and potential prey in the Gulf of Maine and Georges Bank*

In this project, the research team examined the distribution and abundance of lobster larvae and their zooplankton prey across the Gulf of Maine and Georges Bank stock area to better inform management efforts. They hoped to identify potential relationships between zooplankton and environmental indicators, such as temperature or wind advection, with larval lobster recruitment. This project's sampling design had an extremely broad spatiotemporal scale. Sites for sampling included Rye, New Hampshire; sites in Boothbay, Penobscot Bay, and Milbridge, Maine; and Georges Bank. They observed both east-to-west and inshore vs. offshore differences in the abundance of stage I and stage IV larvae. In New Hampshire, they found that both stage I and stage IV were distributed across the entire transect and possibly higher offshore than nearshore, supporting the hypothesis that females may be moving farther offshore to release eggs. In Boothbay, they found that stage IV were distributed across the entire transect but stage I were only found closest to shore, demonstrating a distinct difference in the stage I distribution and hatching patterns between the two western-most sites. They observed low abundance of both stage I and stage IV larvae at all stations within Penobscot Bay. The Milbridge site was very different from both Rye and Boothbay sites in that stage I arrived very late (approximately one month after the western sites) and at the same time as the other larval stages. They also observed a high abundance in stage IV at the offshore station in Milbridge late in the season, but the researchers were unable to determine their source given the scope of this project. Finally, they observed a modest abundance of stage IV larvae at Georges Bank, but they likely missed the stage I season in their sampling efforts. The presenter compared this work to historical data before providing an overview of some data on the zooplankton abundance.

Part 4: Monitoring, modeling, and forecasting – 3:00-4:15 pm
Moderator: Dr. Damian Brady (University of Maine, damian.brady@maine.edu)

Dr. Andrew Goode (University of Maine, andrew.goode@maine.edu) – *Climate effects on reproduction and larval distributions of the American lobster*

This presentation began with a background on changes in the Gulf of Maine (GoM) ecosystem conditions, and links to a peak in landings and subsequent decline after 2016. The presenter has focused on lobster life history for the last six years, with the last three primarily working on ALI-funded research. One major project is understanding the climate-driven egg hatch phenology for American lobsters. This work involves partnering with ME DMR, MA DMF, and RI DEM to use the data collected through the sea sampling and ventless trap sampling surveys, which also record the developmental stage of lobster eggs. The goal was to determine what proportion of gravid females have either recently hatched or extruded eggs to identify when spawning is slowing down the fastest and when hatching proportion is highest. They found regional differences in spawning and hatching, which was observed by examining the accumulation of thermal degree days to start of spawning and start of hatching. There is some degree of plasticity that allows lobsters to regulate start times that is based on thermal conditions and depends on accumulation of higher degree-days. Southern New England and GoM populations seem to have differences in phenology in that warmer temperatures translate to faster spawn and hatch, and shorter overall duration. There is some capacity for regulation, but some intrinsic relationships that keep lobsters from adapting beyond thresholds. The center of female biomass has shifted deeper and farther offshore. In the GoM, this is attributed to increased habitat suitability farther offshore. They are using a particle tracking model to pilot test the potential impacts of changes by tracking a one-month trajectory of larvae. Preliminary runs indicate that shallower locations of release show larvae tracking along coastal regions. However, if released just 20 m deeper, larvae can get swept much farther offshore, and even out of the GoM as they get pulled into a stronger current (note: the presenter also showed tracks for 40 m and 80 m depth release). They are getting close to developing an early life history model that incorporates climate data. When asked if the particle model can include behavior influences (e.g., what strength of swimming would allow a larvae to stay closer to the coast), the presenter mentioned that they have ideas, but nothing concrete at the moment. The tentative nature of these relationships has kept them from including them but they hope to include them in the future at some point.

Kristyn Kleman (University of Maine and the Darling Marine Center, kristyn.kleman@maine.edu) – *The American Lobster Settlement Index (ALSI): cross border collaboration and forecasting*

This presentation provided an overview of the American Lobster Settlement Index (ALSI). The ALSI program includes both diver-based suction sampling and deepwater passive cobble larval collectors to assess larval lobster and young-of-year abundances. The presenter shared the list of collaborators from the US and Canada and mentioned that the deepwater collector project was originally funded by Maine Sea Grant but is now continued with support from Ready Seafood. The deepwater collector project samples three different depth strata in two study areas (Western GoM and Eastern GoM). The results show a spread of settlement into deeper waters in the west with values slowly creeping up at all depths in the east. It was important to note that sampling in 2022 indicated high settlement across the board. Optimal

thermal conditions for settlement is dependent on water temperatures from the previous summer. When looking at the forecasting work that has used the ALSI data, predictions for the Northeastern GoM are consistent with surveys. The data are still limited on depth distributions for settlers, but the ALSI program has given rise to new collaborations and projects. It has encouraged industry involvement, and the forecasts are useful to the fishery. The ALSI database is also a useful tool to rapidly generate reports to investigate current and past trends. The presenter also mentioned a new publication in Frontiers of Marine Science, and shared that there will be an annual ALSI meeting in mid-April.

Declan McCormick* (University of Rhode Island, djmccormick@uri.edu) – *Early life history of American lobsters in coastal southern New England waters*

The southern New England lobster stock was robust until the 1990s, crashing around 1997-1998. The stock has never recovered. The project presented here was part of the ALSI network. It used benthic collectors and nets for larval tows at sites throughout the southern New England region. The benthic collectors included the traditional larger cobble design, and some with both large and smaller cobble (25% of collectors included gravel). The analyses are ongoing, but the presenter shared preliminary results from the 2021 sampling season and noted there was also a sampling season in 2022. They identified all four larval stages in their surveys, including an even abundance of stage III and stage IV. All of the collection locations had surface temperatures at or above the 20% stress threshold for lobsters. They caught low numbers overall of young-of-year lobsters, but the new traps with gravel seemed to catch more than the larger cobble (traditional) collectors. Interestingly, they have been finding a good number of two- to four-year-old lobsters, but it is unclear where they are coming from. The presenter mentioned that the benthic collectors are good at catching lobsters and even better at catching crabs – Jonah, rock, and mud crabs. They have also caught fish, including 47 black sea bass in one collector. They did not do the stomach content analysis on bass or crabs but would like to in the future. When asked about predation within the collectors, the presenter acknowledged that yes, it is a dance between waiting long enough to catch settlers, and waiting too long so they settle and then get eaten. There was a questions about if they might have missed the peak of stage I and II in 2021 given their break in sampling, and the presenter acknowledged that could have happened because their boat motor broke and they lost three weeks in June; they had better sampling consistency in 2022. There was also a question about how using the different substrates within the collectors might have changed the overall trajectory of postlarvae in the collectors. The presenter acknowledged the potential for tradeoffs, and that they likely did not have enough data to say if the smaller cobbles were better. The potential tradeoffs are that they are heavier, take longer to process, can catch more fine substrate, but they need more data.

Everett Rzeszowski* (University of Maine, everett.rzeszowski@maine.edu) – *Tracking exchange between offshore GOM regions via tagging*

The objective of this study was to address the 2015 ASMFC Stock Assessment research priorities to examine stock connectivity between the Gulf of Maine (GoM) and Georges Bank (GBK) regions. They conducted a tag-recapture study that involved four organizations in the initial tagging: MRAG Americas, ME DMR (fishery dependent), ME DMR (fishery independent), CFF (fishery independent, dredge sampling). The presenter noted that they had to exclude the data from CFF because 1/3 of their sampled lobsters died. They completed pilot study in 2015-2016 and the full tagging study in 2017-2020. From the recapture data (10%

recapture rate for all but CFF, which was 2%), they concluded that lobsters initially tagged in LMA 1 and LMA3 GBK traveled a shorter distance compared to those initially tagged in LMA3 GoM. The LMA 3 GoM lobsters had variable directional patterns. A high proportion (90%) of lobsters tagged in the GBK area were recaptured there. In contrast, lobsters tagged in the other study areas were more likely to be recaptured in other areas (as high as 25-30%). The key findings were that there seemed to be a low exchange between LMA 1 and LMA 3 GBK lobsters; that the LMA3 GoM area acts as a transitional region, interacting with both LMA 1 and LMA 3 GBK lobsters via exchange; and that fishery dependent and independent protocols observed similar exchange rates. There was a question on the potential for genetic sampling to understand dispersal pattern of larvae vs. adults, but that work was outside of the scope of this project. There was some discussion on whether or not the industry collaborators were concerned about tagging. Those involved in the field work of this project (the presenter did not participate in tagging but performed the analyses) shared that those already collaborating in the study were science proponents. The concerns came from those picking up tagged lobsters who were not aware of the studies and do not understand the use of tags. Several people from the audience shared that fishermen finding tags are often happy to share the data they have collected. Another person mentioned that they conducted a small-scale tag retention study in the lab and showed very low mortality. There was some discussion on linking tagging studies with temperature data, as well as presence of shell disease. There was a brief discussion on how this work might impact how the 2025 stock assessment will be handled as LMA 1 and LMA 3 were previously combined due to the potential for connectivity, but that this work might create doubt about that. People from the audience suggested that they would be doing a workshop with current research prior to conducting the next stock assessment.

Tuesday, February 7, 2023

Plenary session: Lobster research in support of management objectives – 8:30-9:40 am

The session was kicked off with comments by Carl Wilson, the Director of the Bureau of Marine Science at the Maine Department of Marine Resources (DMR). The opening remarks provided a review of the Lobster Research Collaborative (LRC), a precursor and inspiration for the ALI. In Maine, the lobster industry is the single highest value species with lots of people and communities that depend on it. In 2016, the industry panelists of the Maine Lobster Research, Education, and Development (RED) Board indicated a need for applied research. Using the funds from the sales of Lobster Specialty License Plates, DMR put out a request for proposals seeking to support research projects that would take a collaborative approach toward improved science for the lobster fishery. The LRC supported six projects and concluded in 2018, but the collaborative nature of the work produced several new projects that ultimately received funding from the ALI's research program.

Mr. Wilson stressed that patience is necessary when working on lobsters. The regulations guiding the fishery have been in place for over 100 years, but the double gauge law took 20 years to be accepted back in the 1930s; good ideas will eventually land. He also highlighted the myriad externalities that influence this work. We can get mired in the details of the research, but economics and social change, as well as issues like whales, influence the fishery. We need to understand the impacts on the lobster resource, especially since we are in a time of change. It will take time for recovery, but those involved in this collaborative work through the ALI are well-positioned to make contributions to understanding change.

Panel facilitators:

- **Jesica Waller**, Director, Division of Biological Monitoring & Assessment (Maine Department of Marine Resources, jesica.d.waller@maine.gov)
- **Dr. Heather Glon**, Marine Resource Scientist III, Lobster Research Biologist (Maine Department of Marine Resources, heather.glon@maine.gov)

Panelists:

- **Kathleen Reardon**, Marine Resources Scientist III, Lobster Fishery Biologist (Maine Department of Marine Resources, kathleen.reardon@maine.gov)
- **Jeff Kipp**, Senior Stock Assessment Scientist (Atlantic States Marine Fisheries Commission, jkipp@asmfc.org)
- **Joshua Carloni**, Biologist, Lobster Research and Monitoring (New Hampshire Fish and Game, Joshua.T.Carloni@wildlife.nh.gov)
- **Dr. Burton Shank**, Research Fishery Biologist (Northeast Fisheries Science Center, burton.shank@noaa.gov)
- **Kim McKown** (New York State Department of Environmental Conservation, retired, kamckown@yahoo.com)
- **Colleen Bouffard** (Connecticut Department of Energy & Environmental Protection, Colleen.Bouffard@ct.gov)

How do empirical data get into the stock assessment? What makes these data informative?

There is a well-developed process for the Atlantic States Marine Fisheries Commission (ASMFC). Milestones are laid out and the technical committee puts out a request for datasets to inform assessment. These data are reviewed by the technical committee to determine what might

help inform assessment. The next assessment is in 2025, so the call will come out at the end of 2023. In order to make sure your research is informative, we encourage you to take a look at the research recommendations, and to talk to ASMFC to learn more about what will be useful. Finally, it is important to not underestimate the kinds of data you have that could be helpful. Other things go into the assessment in addition to the model, and current research could potentially inform changes to the model.

Regarding the preferred channel of communication, panelists mentioned that the technical committee brought researcher together to present their work ahead of the last assessment. This allowed for a discussion about the work and data collected, and they will be doing something similar this round. If researchers would like to be a part of that process, please reach out through our provided contact information. This will also allow the committee to connect you with a specialist in the field to figure out a conduit for getting data in. The panel encouraged researchers to engage early and often with the technical committee to talk about how they use data from monitoring programs. This allows the committee to point toward research questions that it is interested in, and they can serve in an advisory capacity when researchers are putting proposals together. Small modifications to research are easier early, so communicate early to learn what could be changed easily before beginning research. There was some discussion of examples of successful interactions with the committee, and the facilitators referred the audience to the existing assessment as a valuable resource for those new to lobster work, particularly the list of high, medium, and low research priorities.

How have you seen early involvement in the project planning stage yield good, informative results for your work?

The stock assessment feeds data into the UMaine model, which is then interpreted. The technical committee also looks at what did not make it into the model – if there is enough information to be included, they will try to work it into the model. They have generally refrained from modeling early life stages (i.e., the youngest age they have included is four or five years old), and it will be a major expansion to include them. The research projects funded through ALI are an acknowledgement of the need for data on early life stages. The panel also noted that temperature is affecting the life history of lobsters and updating the parameters is important and may modify the model (which spans from 1982). Having those kinds of data is essential to moving in that direction. The panel also noted that a lot of thought went into developing the research recommendations in the current assessment to ensure they help frame future research.

What tips do you have for those interested in leading a project that uses federal and/or state agency fisheries data?

They stated that when working with or seeking confidential data, the Atlantic Coastal Cooperative Statistics Program (ACCSP) is a central warehouse for commercial data throughout the Atlantic coast. Researchers have to work with the state and federal agencies where those data originated to gain access, and there is an official request form to complete. They noted that it always helps to point to a stock assessment to say why you want to work with those data. It is also important to understand how the data are collected. For example, Connecticut DEEP gets a lot of requests for their trawl survey data and the survey employs a stratified random sampling design. It is important to communicate with the staff collecting those data so errors are not made in spatial or temporal analyses, or in parsing or joining the data with other data. The panel explained that it can be hard to get commercial catch data, and researchers should not assume

they will get access. There are times staff can collapse data to preserve confidentiality requirements but still provide information that can be helpful. On the other hand, fishery independent data is very available. For example, DMR has portals for requesting access to data online and there is a wealth of data there.

What specific directions is the group headed in for the 2025 assessment?

The panel stated that they are really trying to get a handle on early life history processes and what is happening with young lobsters. We know things are changing a lot in the environment and with these stages, but the models assume things are staying the same. In cases where we have some understanding of how things are changing and what we can expect, this will be really useful for management. It can also help us tell managers what we do not know, and where we cannot comment on what to expect. One of the panelists mentioned the potential for scholarship and/or fellowship opportunities for doing research – if someone is looking for a good project, NOAA/NEFSC has a lot of interesting data to explore that would inform the assessment.

The technical committee will also look at stock structure as it is currently set as its default but is evolving with new information. They plan to explore this early in the process, and anything to do with movement (e.g., tagging, genetics, larval dispersal) would be useful for the stock structure. They also acknowledged that growth is a major uncertainty that relies on a lot of old information, so thinking about how to better handle growth will be a priority. Social science and economic implications are important to look at, but we need input on what indicators to consider. Finally, they mentioned the need for more information on sublethal exposure, especially in southern New England. Given the experience with southern New England, more information on survival and the effects of sublethal exposure to stressful conditions is needed. Not all lobsters in southern New England succumb to these stressors, and it would be valuable to know what gives those that persist the ability to survive and presumably go on to reproduce, and how they respond to successive periods of exposure to those stressors.

How do you share or communicate the results of the assessment and engage with industry members?

The panelists acknowledged that sharing the results can be challenging. Maine DMR (and other state agencies) provides the industry with the data every year from our monitoring programs. The trends from those programs will appear in the assessment, so it should not be a surprise to the industry. We are expecting the upward trend will not continue, so we are always communicating about it so folks are not surprised. The assessment also includes a section on stock indicators that compare the time series data with the bigger picture trends in the population. The process of the assessment is open to the public, but it can be dense as the committee gets into the weeds. That said, interested parties are welcome and can engage through that process.

Several panelists also mentioned that both field researchers and fishermen can help the technical committee explain what it is seeing in the data that we cannot totally explain. Many have had good experiences working with fishermen on field research projects. This gets them thinking about early life history stages and other research questions that they might not have been thinking about.

Final thoughts

The panel reminded the audience to review the updated research recommendations in the 2020 stock assessment (specifically on pages 134-143). There is a place where there is an update

to the 5 year research recommendations, so researchers are aware of what problems are being tackled. All panelists agreed that communication with the technical committee is key. Committee members can be important conduits of information, and there could be things that would be informative to future stock assessments. Feel free to share your ideas and talk to the committee about your work. They also suggested researchers not limit their work to what is in the model alone. There is a wealth of other information that helps with the assessment. Finally, they reminded the audience that no question is too small. If anybody has an idea for a research project, please reach out.

Session topic: Food web dynamics/range expanding species – 10:00-11:15 am
Moderators: Dr. Marissa McMahan (Manomet, mmcmahan@manomet.org) and Helen Cheng* (Northeastern University, cheng.hel@northeastern.edu)

Helen Cheng* (Northeastern University, cheng.hel@northeastern.edu) – *Investigating the ecological impacts of range-expanding species to the American lobster fishery using collaborative surveys, fisher observations, and predator-prey experiments*

This project is focused on understanding the effect of two range expanding species, black sea bass (340 mm tail length) and blue crab (115-125 mm carapace width), on juvenile American lobster (35-40 mm carapace length). The team is exploring the interspecific interactions through a series of predator-prey experiments. Using rounded tanks with rock shelters, the team set up five replicates of each of four treatments: lobster, black sea bass, and blue crab; lobster and blue crab only; lobster and black sea bass only; or just lobster. In all treatments, mussels were also present as a potential prey item for both lobster and blue crabs, temperature was between 16-20 °C, and salinity was 30-31 ppt. Preliminary findings indicate sublethal and lethal direct effects of just blue crabs on juvenile American lobster, and the presenter shared video recordings of two different trials of this experiment with the audience. The researchers have not yet explored the potential differences in speed or pinch strength across these two species. There was a question from the audience about the potential for blue crab to become a prey item for lobster, and although the presenter did not have any data to answer the question it seems unlikely given how fast blue crabs move. The direct effects of just black sea bass on juvenile lobster are to be determined. When both species are present, the effects do not appear to be additive and the team noted indirect effects of the presence of both of these species on juvenile lobster. When all three species are present, black sea bass and blue crab interact with each other in an almost bullying manner, seemingly ignoring the lobster. It is possible that lobsters from the southern extent of the species range could adapt to range expanding species as they become more familiar with each other. This project is also exploring fisher observations to better understand their perceptions of risk that black sea bass present to other species, including lobster. This component was covered in more detail in the *Social-ecological coupling in the lobster industry* session, but the presenter did share that fishers from both southern New England and the Gulf of Maine regions cited lobster as the top species that black sea bass are eating. Some fishers also noted the different stages and size classes of lobsters that seem to be most common prey items for black sea bass.

Rebecca Peters (Maine Department of Marine Resources, rebecca.j.peters@maine.gov) – *"Who's eating juvenile lobsters?": An evaluation of lobster predation in the Gulf of Maine using stomach content analysis*

This project was developed after receiving photos and questions from lobster industry members asking what may be eating juvenile lobsters. To answer this question, the team performed stomach content analysis on stomachs collected from the Maine Department of Marine Resources (DMR) inshore trawl survey (spring and fall samples), as well as Maine Center for Coastal Fisheries (MCCF) sentinel survey (May-October). They collected 860 stomachs from: Atlantic cod (n = 65), red hake (n = 265), white hake (n = 268), Atlantic halibut (n = 53), Atlantic mackerel (n = 207), striped bass (n = 1), and black sea bass (n = 1). The presenter explained that they account for net feeding in the survey samples by noting any very fresh items in the stomach (i.e., undigested) or items still in the mouth. The team identified lobster in only four stomachs, two white hake and two red hake. The presenter also noted that they found one lobster in the stomach of a halibut. The size of lobsters identified were 24 mm, and two that were 10 mm in size. Based on abundance, shrimp species were the most common prey item found in the stomachs of cod, red hake, white hake, and halibut. For mackerel, copepod species were the most abundant prey item identified in stomachs. Diving more deeply into the results, the presenter shared the index of relative importance (IRI %) for the top five prey species in red hake: decapod shrimp (33.8%), crangonidae shrimp (18.7%), pandalid shrimp (17.2%), silver hake (10.1%), and bony fish (4.8%). In red hake, lobster IRI was 0.05%. For white hake, the top five prey species based on IRI % were: decapod shrimp (31.1%), pandalid shrimp (26.3%), crangonidae shrimp (17.8%), silver hake (12.2%), and decapods (3.3%). In white hake, the lobster IRI was 0.03%. During the question and answer period, the presenter explained that more samples were collected from the inshore trawl survey relative to the sentinel survey, but the sentinel survey provided a greater opportunity to sample cod. These data have not been analyzed but one of the project partners shared that they have never found lobster in any previous analyses of stomachs in cod. The presenter also stated that they do not encounter cunner in these surveys (precluding them from stomach content analysis), and that they infrequently encounter stripers, sea ravens, and sculpins in the survey but would like to analyze their stomachs if they were to catch them. Finally, when asked about collecting eDNA samples, the presenter explained that the team has had Bigelow run a few samples to confirm identification, but not on a regular or routine basis.

Panel discussion:
Additional panelists:

- **Dr. Conor McManus** (Rhode Island Department of Environmental Management, conor.mcmanus@dem.ri.gov)
- **Dr. Gabriela Bradt** (New Hampshire Sea Grant and University of New Hampshire Cooperative Extension, gabriela.bradt@unh.edu)
- **Dr. Jason Goldstein** (Wells National Estuarine Research Reserve, jsgoldstein2@gmail.com)
- **Dr. David Johnson** (Virginia Institute of Marine Science, dsjohnson@vims.edu)

What new range expanding species are the panelists seeing, and what changes are they seeing in their systems' food webs?

In Rhode Island, people are seeing black sea bass, scup, Asian shore crab, and mud crab. Some of the interactions with native species are less predatory and more competition for space. In Virginia, the panel shared that people are observing blue crab, lady crab, and fiddler crab more often in areas they traditionally have not been seen. Fiddler crabs were first observed in 2014 but

the abundance has doubled in the last decade. Fiddler crabs are parasite free in this expanded range, and are larger, carrying more eggs. They also lower the biomass of the plants, which affects the geomorphology of the marsh that serves as an important refuge for juvenile lobster and other species. Blue crabs have been in the Gulf of Maine before, back in the 1950s, but they have recently been observed in southern Maine (i.e., Wells NERR). They were first observed in 2019, and the Wells NERR staff quickly developed a monitoring initiative in surrounding marshes and tidal creeks. They caught 90 in 2020, and researchers are rethinking how this species will affect native flora and fauna. The team mentioned using resources from Maryland Sea Grant on blue crabs.

Some of the threats of range expanding species on lobsters include both predation and behavioral responses. However, they also present a new opportunity or potential. For example, there is a small number of commercial lobstermen in Massachusetts keeping black sea bass bycatch and selling it, and we need to think about management measures to help develop these opportunities. Some other examples to think about include Jonah crabs in southern New England.

What are some ways that extension can assist with issues related to range expanding species?

New Hampshire Sea Grant is doing some crowdsourcing of data. They sent a survey to various sectors, including commercial fishermen, aquaculturists, recreational fishermen, to try to capture sightings of blue crab. This approach can give researchers and extension associates a lot of useful information that cannot be captured in other ways. For example, they have received reports of sightings from Nova Scotia, Canada, and Matinicus Isle, Maine, in 2022. The team putting out the survey had not idea that blue crabs have already traveled that far, so this was a way to expand their dataset. It also provides an educational opportunity to increase awareness and understanding of range expanding species.

Are there commercial opportunities for range expanding species, and can we prepare for this?

From a Maine perspective, one of the biggest hurdles is the fact that we do not have the ability to obtain quota for fishermen. This is also a challenge in terms of supporting diversification. There was a similar sentiment from a southern New England perspective in that a lot of the species managed by the southern councils and managed through quotas do not incorporate the ability to manage for emerging fisheries in northern regions, which are traditionally allocated by historical landings. Progress has been made, particularly for black sea bass, but so far it has been incremental. This is going to need to be a continuous discussion on how we "re-slice" the pie to balance current fisheries and new opportunities. In Rhode Island, the increase in blue crab abundance has launched a series of data-collection and monitoring efforts to help formulate some kind of population assessment to develop reference points to guide potential future management and harvest.

How can we better prepare for these changes?

One of the biggest issues from a management standpoint is that there is a lack of data. For example, there is not enough data to incorporate Gulf of Maine black sea bass into the black sea bass stock assessment. Forward-looking initiatives will help us get our heads around ways to address this and fill data gaps. Monitoring initiatives are critically important. For range expanding species that are directly affecting commercial species, such as lobster, we need to engage industry in the monitoring. We also need to look at both predation and predator-prey

interactions, as well as the potential for disease transmission. There is also a data gap around the sublethal effects of these species (e.g., Jonah crab claw removal research). We need to have a better understanding of the sustainability of the expanded range and whether it will be long-lasting and result in an established population, or if will it come and go. We also need better engagement and education efforts for anyone involved in collaborative research, so identifications of range expanding species are correct (e.g., blue crabs are often mistaken for color varieties of green crabs). It is also important to learn from other, previous range expansions in other states or areas to learn from those experiences and management shifts to develop plans at state and/or regional scales.

Additional discussion

There was a question about the potential knowledge surrounding planned migration (e.g., planting of southern species in Acadia National Park), but none of the panelists were familiar with this approach in a marine or estuarine environment. There was a comment from an audience member regarding tautog and a suggestion to check with dive shops and recreational fishermen to get a better understanding of their presence. There was a brief discussion of the collectors affiliated with the American Lobster Settlement Index sampling program, with a statement that they have not observed blue crabs but do see black sea bass in their deepwater collectors. Finally, there was a discussion around whether or not the shifts that we are seeing in the Gulf of Maine are a return to historical conditions but with a new assemblage of species (i.e., thinking about replacing groundfish with these novel species as lobster predators). One panelists remarked that in some instances, these new species are in different habitats. For example, black sea bass and blue crab in much more shallow water than what we might expect for groundfish, so they may be targeting different life history stages of lobsters). Another panelist noted that we are seeing different assemblages of species, but that some of these species expand and contract their range repeatedly over time. They may just play a different role, depending on what other species are there, but the key is trying to fill the gap between these observations and experiments and the stock assessments (e.g., we need to incorporate things like natural mortality).

Session topic: Alternative baits in the lobster fishery
Moderators: **Dr. Jynessa Dutka-Gianelli** (Gloucester Marine Station and UMass Amherst, jgianelli@umass.edu). and **Dr. Gabriela Bradt** (New Hampshire Sea Grant and University of New Hampshire Cooperative Extension, gabriela.bradt@unh.edu)

Dr. Jynessa Dutka-Gianelli (Gloucester Marine Station and UMass Amherst, jgianelli@umass.edu), **Bart DiFiore***, (University of California, Santa Barbara, bdifiore@ucsb.edu), and **Rachael Hamilton*** (University of Massachusetts Boston, rachael.hamilton001@umb.edu) – *Alternative bait development and future visioning in the New England lobster fishery*

In this presentation, researchers shared an overview of their collaborative research project exploring alternative bait sources for the American lobster industry. The project team is diverse and includes researchers from a range of departments in the University of Massachusetts system (e.g., environmental conservation, food science, and ecology/biology); lobstermen and other industry-related partners; and a range of graduate and undergraduate student researchers and interns. The goals of the project are to: develop an alternative, locally-sourced bait for use in the American lobster fishery; engage divers partners in finding feasible bait products that meet

industry needs; and to test the alternative baits in the laboratory and in the field. The presenters provided an overview of the components of their project, starting with the food science practicum and development of products to optimize and scale up in summer 2022. The team then conducted field trials to compare the alternative baits to the "gold standard" bait, herring. Preliminary analyses suggest that the team's gurry-based formulations fish effectively for only one night, and that herring outfished the alternative ~3:1. The presenters also discussed their work in the realm of community engagement and provided an overview of several projects, including interviews with industry partners to understand what kinds of alternative baits they already use and a bait cost analysis. The team will continue working to reformulate their bait and ensure its viability before conducting commercial field trials in 2023. To view a recording of a similar presentation given during a *Collaborative Chats* webinar, please click here.

Panel Discussion

Additional panelists:

- **Dr. Steve Jury** (Saint Joseph's College of Maine, sjury@sjcme.edu)
- **Ann Molloy** (Neptune's Harvest, ann@neptunesharvest.com)
- **Dr. Marissa McMahan** (Manomet, mmcmahan@manomet.org)

Is it possible to gather data on bait costs throughout the Gulf of Maine?

From bait dealers, that information is relatively available, but obtaining that information from lobstermen is more challenging. Lobstermen are generally more private and less willing to share information. However, collecting this kind of information, especially from year-to-year, would be a beneficial shared data source.

What about using "non-natural" baits (e.g., pig, cow hide) – are there tradeoffs?

There was some discussion about how common the use of hide is in the fishery in Maine. With other forms of bait, the panel mentioned the need to consider the potential for biosecurity risks. Maine's Department of Marine Resources has a set of standards they use to enforce what can and cannot be imported and/or used as bait, and New Hampshire Fish and Game follows those standards.

Who regulates bait use?

Bait is regulated on a state-by-state basis and with an ever-changing list of approved options. One audience member mentioned that the entity that regulates the fishery, the Atlantic States Marine Fisheries Commission (ASMFC), cannot oversee or streamline this process but that it has touched on the issue in the past without any management changes. The regulations are reviewed by the source and by the species as they are imported (e.g., Norwegian vs. Icelandic redfish). There is also some regulation of engineered vs. natural bonding agents. Those bonding agents that are approved for human consumption may be easier to pass regulations but might not be as cost-effective or effective.

Is there a bottleneck in the development of alternative baits?

The biggest hurdle in the development of alternative baits is the need for industry partners to scale up bait production. Although outside of the scope of the project presented, their primary industry partner, Neptune's Harvest, could be ready to scale up production if/when a formula is ready. Another topic discussed was the interest from fishermen to actually use an

alternative/manufactured bait. Even if they could produce their bait at a commercial scale, it does not seem like the market demand exists.

Can a reliance on one bait species, or a controlled farming of lobsters, impact lobster health or life history?

There has been some work looking at this, and there can be large implications for lobster growth or how healthy they are, such as impacts on shell strength or immunity. At this point, it seems unlikely that lobsters are eating enough of any one bait source to impact health. There was a comment from and industry partner in the audience that pig or cow hide is known to outlast herring, so maybe the alternative bait could serve as a supplemental component to avoid just one food source (e.g., a "seafood medley" to aid in lobster health). There was a question about the potential for behavioral implications associated with alternative baits.

How can we continue gaining funding for alternative bait projects when the bait crisis is slightly mitigated, and likely temporarily?

We know about the use of different baits and their effectiveness. What works in one place does not work in others.

Session topic: Lobster Institute Updates – 1:30-2:45 pm
Moderators: **Christina Cash** (Lobster Institute, University of Maine, christina.cash@maine.edu) and **Dr. Rick Wahle** (Lobster Institute, University of Maine, richard.wahle@maine.edu)

Christina Cash (Lobster Institute, University of Maine, christina.cash@maine.edu) – *U.S.-Canada Lobster Town Meeting Review*

The presenter provided an overview of the Town Meeting, which took place February 3-4 in Portland, Maine. The theme of the meeting was lobster fisheries and North Atlantic right whales. The meeting involved 129 attendees from eight U.S. states, 57 attendees from five Canadian provinces, and 20 additional walk-ins. Of the attendees that provided information, there were 48 lobstermen, 33 researchers, 10 dealers, six processors, 15 fisheries managers, and 42 with other affiliations (i.e., non-profits, political delegates, gear manufacturers). The session on the status of regulations and new funding opportunities provided an in-depth overview of the prevention and mitigation measures for entanglement in Canada, as well as other protection measures and tools (e.g., adding more traps per end line, sinking lines, and making gear easier for whales to shed if entanglement occurs). Patrice McCarron of the Maine Lobstermen's association provided an overview of the risk reduction plans and measures in the U.S., including, adding more weak points, state-specific gear marking, trawling up, and speed restrictions. In the market impacts session, panelists discussed the impacts of the loss of the Marine Stewardship Council's certification in the U.S. and Canada, as well as how tariffs impact trade with China. The meeting also included a science session that discussed shifting distributions in changing climate. Those panelists discussed challenges associated with tagging whales, as well as how a warming Gulf of Maine impacts lobsters, whales, and the copepod *Calanus finmarchicus*. Scientists are trying to link changes in oceanography and environmental conditions with shifting distributions to better understand where whales might be going. The final panel discussion focused on future technology and innovation. Panelists discussed the need for collecting more data on where whales are (and where they might go), as well as challenges associated with alternative fishing gear (e.g., on-demand/pop-up gear). The Maine Lobstermen's Association is

partnering with Maine Sea Grant and Maine DMR to start testing spring-release and timed-release gear, and gear marking with geolocation. Fishermen stressed the importance of acknowledging that the risk of gear to whales is different across fishing areas, that one approach will not work for everyone given the diversity of the fleet, and that alternative gear technology will not work if the market is not developed.

Dr. Rick Wahle (Lobster Institute, University of Maine, richard.wahle@maine.edu) – *New NSF-supported Arctic Impacts Initiative*

This presentation provided an overview of the Navigating the New Arctic (NNA) Lobster Network. This effort is part of the National Science Foundation's (NSF) NNA Program, which is focused on rapid Arctic change and its implications for fisheries and fishing communities of the western North Atlantic. This program is considered one of the NSF's "10 big ideas", and, "seeks innovations in fundamental convergence research across the… sciences, and engineering… connections among natural and built environments and social systems, and how these connections inform our understanding of Arctic change; [and]... its local and global effects". It is broadly focused on understanding how changes in the Arctic influence the Labrador current. Specifically, this project is interested in exploring the changes resulting from an increase in the Gulf Stream's intrusion since 2008, which has increased of temperatures in the Gulf of Maine and decreased the intrusion of the Labrador Current. This has also been accompanied by a decrease in the abundance of both *Calanus finmarchicus* and young-of-year lobsters. These topics were discussed in detail with both U.S. and Canadian stakeholder over the course of two scoping workshops to develop the scope of work. The first phase of the project's rescoped objectives ($3 million over three years) includes developing a coupled atmosphere-ice-ocean-ecosystem model to evaluate how changes in the Arctic will effect ecosystem and fishery productivity in the lower latitudes of the Northwest Atlantic (i.e., natural environment focus); and developing a bio-economic model of the fishing fleet and evaluate economic reliance on this fishery (i.e., social system focus). The outcomes of this first phase would set the stage to advance decision support tools through a second phase of potential research. The NNA Lobster Network was launched February 4, at which time the project team reviewed rescoped project objectives; clarified connections among objectives; discussed project governance and connections; and provided updates on network business.

Session topic: Social-ecological coupling in the lobster industry – 1:30-2:45 pm
Moderators: **Dr. Jonathan Grabowski** (Northeastern University, j.grabowski@northeastern.edu), **Jennie Rheuban** (Woods Hole Oceanographic Institution Sea Grant, jrheuban@whoi.edu), and **Dr. Amalia Harrington** (Maine Sea Grant, amalia.harrington@maine.edu)

Dr. Jonathan Grabowski (Northeastern University, j.grabowski@northeastern.edu) – *The American lobster fishery's observations and perceptions of range-expanding species*

The goal of this session was to share some ongoing social-ecological work with the lobster industry, and to have a conversation on how scientists can better engage with industry to avoid negative externalities and in a way that leads to more meaningful science that is informed by industry needs and insights. The presenter started the session by sharing an update on some of the research his team is working on. The impetus for this research is the fact that the Gulf of Maine is warming and changing in ways that make it more hospitable for range-expanding

species, like blue crab and black sea bass (BSB). This presentation focused on the survey work that complements the experimental work presented in the *Range expanding species* session (see H. Cheng). The team conducted industry surveys in 2015 and 2021 to capture fishers' observations on BSB, as well as their perceptions of perceived risk associated with BSB. They found that region was the best predictor of whether or not fishers observed an increase in BSB, with 56% thinking that temperature was the primary driver. In both 2015 and 2021, the perceptions of whether an increase in BSB was beneficial to the fishery was driven by whether or not a fisher thought BSB eat lobster (i.e., if they think BSB eat lobster, perceive a negative interaction). They also found that fisher satisfaction of current regulations of BSB was dependent on both region and number of years fished (i.e., longer career of fishing resulted in less satisfaction). The presenter also reviewed the process of developing a mental model for this work. Overall, this work indicates the importance of the lobster industry's ecological knowledge when understanding and mapping species range expansions. This information provides the most holistic view of BSB expansion. They are currently working to identify concerns and perceived risks, and to build greater adaptive capacity within the lobster fishery.

Theresa Burnham (University of Maine, theresa.burnham@maine.edu) – *Building sentinel indicators of socioeconomic resilience in Maine's American lobster fishery*

The presenter shared an update on a collaborative research project that involves a number of partners. This project was inspired by conversations with the Maine Lobstermen's Association (MLA), with a direct ask for socioeconomic monitoring that would be equivalent to the biological monitoring of the resource. The goal of the project is to develop tools to monitor the industry in the face of an increasingly complex and challenging landscape. This wok was also inspired by the existing social indicators developed by Lisa Colburn at NOAA that are based on census data (i.e., every 10 years), but the focus here is at higher spatial and temporal resolution to support faster adaptation. The project started with a series of interviews, and their survey tool was co-developed with fishery experts that combined open-ended questions with more specific questions. The team also collected additional non-fishery dependent data through an extensive data-mining exercise. These data were then combined into candidate indicators, which have a latent construct (i.e., something that cannot be directly measured). Future and ongoing work will then validate these indicators by going back to the industry to ground-truth them before they can be considered "final" indicators. The presenter walked through an example indicator, *Coastal Accessibility*, to demonstrate the process before inviting anyone to participate in the team's monthly meetings and making a request for fine-scale data to inform their work. During the question and answer period, the presenter commented on how they might consider applying indicators once they are defined. They are looking into potentially sharing them to inform the 2025 stock assessment, but they are not aiming to recommend specific actions at this point.

Dr. Kanae Tokunaga (Gulf of Maine Research Institute, ktokunaga@gmri.org) and **Dr. Alexa Dayton** (Maine Center for Coastal Fisheries, adayton@coastalfisheries.org) – *Economic diversity of Maine's American lobster fishery*

This project aimed to understand how climate change might impact socioeconomics of Maine's lobster fleet, with the expectation that impacts would not be felt uniformly. The goals were to quantify the diversity of operation characteristics and harvester decisions; and to perform a benchmark analysis of the lobster fleet's economic performance in the pre-warming period (i.e., 2010). To do this, they conducted in-depth phone surveys with support from the Maine

Lobstermen's Association. The team managed to achieve a completion rate of 95-100% with surveys of fishermen from Maine, New Hampshire, and Massachusetts. They then used these data to characterize latent classes that represented a lobster fishery business model that were then analyzed using latent class stochastic profit frontier analysis. This approached allowed them to group the fleet into different categories based on latent traits, such as vessel size, how often individuals fished, and number of traps per line. From this analysis, they identified five unique latent classes that differed tremendously in profit efficiency strategy. They also shared how the latent classes were distributed across Maine's fishing zones, suggesting a potential connection to underlying ecological stock productivity. During the question and answer period, the presenters mentioned that this study did not take into account the existence of shrimp fishing in 2010, which is a great reason to repeat it. They were also asked about how they captured skill level of different captains in reference to calculating the profit variable. They responded that the survey asked for folks' information from tax returns at high resolution, so they had enough information to directly calculate profit/loss. Experience was also a separate demographic included in the survey. For more information, please review the teams recent publication here.

Panel discussion

Additional panelists:

- **Jennie Rheuban** (Woods Hole Oceanographic Institution Sea Grant, jrheuban@whoi.edu)
- **Alison Krepp** (NOAA/National Sea Grant Office, alison.krepp@noaa.gov)
- **Joelle Kilchenmann*** (University of Maine, joelle.kilchenmann@maine.edu)

What do you see as the major social science gaps from the perspective of the fishery and from the economic perspective?

There is a need to work with the policy and data needs at NOAA for them to understand how to be a more interdisciplinary agency. One way to do that is through longitudinal data and replicability in studies, but NOAA currently does not support very many studies that do that. Another major need is data accessibility. There are many instances where the data exist, but scientists cannot get to them based on how they are formatted (e.g., websites or PDFs). There is a need to better align all of the datasets that currently exist, which would also help address industry fatigue. If we can use existing datasets to answer questions we can avoid needing to go back to communities with additional surveys. The panelists also mentioned survey bias and the need to ensure researchers get good coverage and that they are not just sampling the same group over and over. One suggestion was to expand the types of surveys employed (e.g., Qualtrics or computer-based surveys), but sometimes the most successful mode is through the phone. Each method comes with its own challenges. The panelists also discussed equity in access as there are fishermen who simply cannot afford to take an hour to do a survey. There is a lot of valuable information we could get from crew members, but crew may have a captain telling them not to answer in addition to having limited spare time. One way to get around that is to compensate fishermen who work with us. Panelists also discussed the fact that most surveys are in English and some fishermen cannot understand them if English is their second language. Literacy in general is an issue with some communities. Finally, the panel discussed challenges in accessing confidential, fishery-dependent data.

With large scale shifts in the communities, is there a way to integrate questions around well-being and/or stress into the profitability model to more holistically understand things?

One panelists mentioned that there was some work that happened in the Gulf of Maine that tried to get at some of those factors. NOAA has been grappling with different social vulnerability indices and what is actually being looked at in those indices. An audience member referenced Tora Johnson (University of Maine at Machais) and the work her group is doing along those lines. The more stressed people are, the less trust they have in governance, so tying that to economic indicators could be really powerful.

Question around profit – what is profit? And what do they (fishermen) do with profit besides buy snow mobiles? The tax incentives would incentivize re-investing into business and not showing profit – how do you handle that?

When developing social indicators of resilience (T. Burnham's presentation), the research team kept profitability kind-of general in terms of just the business, but also broke that down further into personal and business spending. There is concern, though, if you only have one fishery to invest into, does that maximize risk (i.e., think, all eggs in one basket)? With all the profit, folks tried to just reinvest it to buy bigger engines, for example. If everyone has the incentive to reinvest, it should not skew the profitability efficiency index, but there is no real way of grasping who is most likely to overinvest and overcapitalize versus who is less likely to do so. A point was made that lobster fishermen who survived in southern New England had diverse portfolios. What is the opportunity [in Maine] to diversify, with other fisheries or with work off the water? A final comment on this topic suggested that performing the analysis presented by Tokunaga and Dayton would get at some of the extreme change that has happened in the industry in the past couple of years. For example, folks are investing in things like tractors that help with lobster fishing but might also have multiple uses.

Survey fatigue–we have a lot of institutions here. How do we combat this? How do we prevent this?

One idea is to convene some kind of group of social science projects after a funding call goes out and awards are made to better coordinate efforts. Even NOAA is trying to do something like that to work together to build a common survey instrument. On the back end, from funded efforts, NOAA is looking to build a data integration space that shares survey instruments and data so other folks can use them. This is in its early days, but it is really needed. There was some discussion of creating a database with project topics, objectives, and who is doing what work. A panelist also mentioned that the UK does an annual survey that folks expect and respond to, maybe we could do something like that. It is also critical to bring results back to participants for feedback and to share results.

Session topic: ME DMR lobster monitoring programs – 2:45-4:00 pm
Moderator: Kathleen Reardon (Maine Department of Marine Resources, kathleen.reardon@maine.gov)

In this session, Maine Department of Marine Resources (DMR) staff provided an overview of the sampling programs that monitor lobsters across all age classes. Before diving into each program in detail, the session moderator provided some background information. The Maine DMR Landings Program has data available since 2008, including dealer data and harvester logbooks (note: shifted from 10% to 100% reporting in 2023). Across the sampling

programs, the typical biological data collected for lobsters includes: carapace length, sex, claw status, molt status (new vs. old shell), V-notch characterization, shell disease (based on standard index of severity), and egg status (newly extruded, developing, hatching, or spent). The moderator also described the historical port sampling program, which ran from 1967-2011. This program collected fishery dependent data through ~500 interviews per year conducted from April-December. This program involved random selection of 10 lobster dealers per month, and sampling of 10 lobster from each boat to collect biological data and weight of each lobster. Each boat was also interviewed to capture information on effort (e.g., total catch, traps hauled, crew number, soak time, bait). These data were then used as an index for landings and effort.

Rebecca Peters (Maine Department of Marine Resources, rebecca.j.peters@maine.gov) – *Maine-New Hampshire Inshore Trawl Survey*

The presenter stated that this survey occurs in 1-75 fathom of water and it collects fishery independent data. The survey started in 2000 and occurs both in the fall and the spring. This is a multi-species survey that employs a random stratified design using a modified shrimp net to provide indices of abundance. The program conducts 120 tows per season with a standard tow running for 20 minutes at 2.5 knots. The survey samples four depth strata across five regions, and collects site information, basic biological data on each lobster, weight of total catch by sex, and CTD cast data. In looking at the composition of lobster catch, it is roughly 90% sublegal and 10% legal sized lobsters. This program is supported by NOAA funds.

Kathleen Reardon (Maine Department of Marine Resources, kathleen.reardon@maine.gov) – *DMR Lobster Monitoring Programs: Sea Sampling and Ventless Trap Survey*

The Commercial Sea Sampling program collects fishery dependent data on commercial trips. From 1995-1998, DMR staff conducted three trips per month from May-November. In 1998, the program shifted to conducting three trips per month per Zone from May-November, and starting in 2006 added one trip per month per statistical area from December-April. The program collects biological and effort data, as well as trip information and is supported through NOAA and dedicated state funding. From April through June, the majority of lobsters sampled are of sublegal size, with 40% of samples consisting of legal sized lobsters. The program's catch is typically 10-20% V-notched females. A subset of these data help to determine catch per unit effort (CPUE) through metrics of how many traps are measured and hauled each day.

The Ventless Trap Survey collects fishery independent data at depths from 1-30 fathom. The program started in 2006 and is a regional effort from Rhode Island to Maine. The survey targets juvenile lobsters (i.e., catch is 90% sublegal in size) and runs in June, July, and August. The survey employs a random stratified design by depth and statistical area. The survey has three depth strata (0-20, 21-40, and 41-60 m) and the number of sites has varied over time. Since 2015, all traps were ventless across 276 sites, but sampling prior to 2015 included both ventless and vented traps. The program was originally funded by ASMFC, but is currently funded through NOAA and the Maine Lobster license plate fund.

Robert Russell (Maine Department of Marine Resources, robert.russell@maine.gov) – *DMR Settlement Survey*

The Lobster Settlement Survey collects fishery independent data at depths of 1-5 fathom. The survey started in 1989 in the Boothbay Region and DMR expanded it to cover all Zones in 2000. The survey tracks young-of-year lobsters, that is those that are newly settled lobsters. This

is a dive survey that employs a suction sampling methodology to produce an index of settlement that contributes to the larger American Lobster Settlement Index Collaborative. The survey collects information on lobster size and sex, species and size of crabs, algal cover (%), and substrate type (% cover of gravel, cobble, small boulder, large boulder, or ledge). This survey is supported by the Maine Lobster Seed Fund and dedicated state funds.

Dr. Heather Glon (Maine Department of Marine Resources, heather.glon@maine.gov) – *DMR Lobster Research Lab & DMR Larval survey*

The Boothbay Harbor (BBH) Larval Survey collects fishery independent data in the Boothbay Region using neuston tows. The program started in 2018 and runs biweekly or weekly from June-September. This program tracks seasonal larval trends at four historical sites inshore and at the three mile line. The survey mostly observes stage I and stage IV lobsters. The survey is supported through NSF funds and dedicated state funds.

Jesica Waller (Maine Department of Marine Resources, jesica.d.waller@maine.gov) – *Division of Biological Monitoring and Assessment research initiatives and coordination*

This presenter shared that if you would like to use DMR data for research, it is recommended that you reach out early to DMR staff. DMR can help with developing research questions and consulting with staff will ensure researchers will have access to the data needed to complete the work (i.e., address confidentiality). Researchers should also check in as they work on data analysis and interpretation as DMR staff can help mitigate or avoid misunderstandings. Staff are also willing to help with communication of results and engagement. The presenter shared a link to assist in requesting lobster data or specimens and mentioned that survey information is available on the DMR website. The presenter also share a link to the online form for requesting trawl survey data, as well as non-confidential landings data. Researchers can also make more specific requests for landings data by completing a "Harvester and Dealer Data Request Form". Users are also now able to request data from the BBH environmental monitoring program. The presenter shared opportunities to participate in data collection surveys (i.e., trawl survey, ventless trap survey, and larval lobster survey). Please reach out to any of the presenters for assistance or with specific questions. Finally, the presenter provided a brief overview of the three ALI-funded projects DMR staff are involved with: female maturity assessment methods (Waller); evaluating lobster predation (Peters); and integrating and evaluating non-traditional gear technologies (Staples). The presenter also acknowledged the ALI-funded projects they collaborate on, as well as the numerous projects they consult on or collect lobsters for.

Discussion

There was a question about whether DMR is working to develop a habitat map and the presenters stated the Coastal Program is currently working on a habitat "complexity" map (via GeoForm). There was a question about collecting injury data on lobsters and the presenters mentioned that they only collect cull status (i.e., claws present or absent) and do not collect information on piercing or crushing injuries. One of the current DMR staff members shared an experience of how he worked with Kathleen Reardon while he was a master's student to emphasize the benefits of collaborating with DMR staff throughout a research project. The end result was a project that was more robust and had better/more relevant information to share. There was also a comment that one of the newer ALI-funded projects looking at alternative gear aims to help create an offshore data network to reduce gear conflicts. Finally, there was a

discussion on how these DMR datasets align with other Northeastern state datasets. The presenters noted that while the sampling protocols may be different, the fact that trends are consistent allows for more confidence. Staff have also been working with a student in Rhode Island to make sure everyone using a neuston net for larval sampling follows a similar protocol. They also noted that since they use the same boat for the various sampling programs, they talk often, and collaborate across the team

Session topic: Lessons learned from southern New England – 2:45-4:00 pm
Moderators: **Nancy Balcom** (Connecticut Sea Grant, nancy.balcom@uconn.edu) and **Antoinette Clemetson** (New York Sea Grant, aoc5@cornell.edu)

Colleen Bouffard (Connecticut Department of Energy & Environmental Protection, Colleen.Bouffard@ct.gov) – *Trends from Connecticut and the Long Island Sound: fishery statistics and management*

The presenter provided an overview of the fishing areas of the Long Island Sound and surrounding fishing areas before showing the trends in the number of licenses issued in Connecticut. From 1979-2022, there has been dramatic decline in the number of Connecticut resident and non-resident fishing licenses, as well as recreational licenses, issued each year. The presenter also shared data on Connecticut's lobster landings and value from all gear types over the same time period, which demonstrated a dramatic decline following a peak in the late-1990s. The speaker also presented data from the Long Island Sound Trawl Survey that also showed a massive decline in the catch of lobster in both spring and fall survey efforts. Although data were not yet available for 2022, the presenter shared that only four lobsters were caught across all survey days. Similar declines have been observed in lobster larval surveys in both the Eastern and Western Long Island Sound. The presenter also discussed the commercial fishery for whelk, as well current regulations for this fishery. There was one question on potential management strategies to create a more sustainable whelk fishery into the future, and the presenter mentioned that fishermen are advocating for limited commercial licenses as well as setting a minimum size as a good place to start.

Dr. Conor McManus (Rhode Island Department of Environmental Management, conor.mcmanus@dem.ri.gov) – *SNE lobster: population, commercial fishery, young-of-year statuses*

This presentation began with an overview of the trends in the southern New England lobster stock, including an increase in spawning stock biomass through the 1980s and 1990s that was followed by a precipitous and ongoing decline that started in the late 1990s. This trend holds true for both male and females lobsters, and as such has translated to a similar trend in commercial landings over time. The presenter also reviewed the stock-recruitment pattern in the region, emphasizing the decrease in juveniles with little change in adults in from 2006-2013 that was followed by concurrent declines in spawners and recruits from 2013-2018. There are a number of potential stressors on the stock, including warming temperatures, shell disease, increased predation, and other environmental changes (e.g., ocean acidification, low oxygen, habitat loss, and pollutants). The presenter also discussed the emergence of the Jonah crab commercial fishery as an alternative for lobster, and raised the question of similar options for other species that may be doing poorly. Finally, the presenter shared an update on the trends in Rhode Island's contributions to the American Lobster Settlement Index program to monitor for

newly settled lobsters. During the question and answer period, an audience member asked for clarification on the variability in the spawner-recruit relationship from 1995-2005 and how that might be correlated to collapse. The presenter mentioned that Rhode Island had an oil spill at that time and it is uncertain how this contributed to the mass die-off. However, this resulted in localized die-offs that led to reduced egg production and ultimately recruitment. Shifts in potential predators also resulted in changes in predator-prey dynamics for lobster that likely contributed as well. The young-of-year interannual variability also contributes to change through changes in the timing of spawning and predator interactions at both the surface and bottom.

Kim McKown (New York State Department of Environmental Conservation, retired, kamckown@yahoo.com) – *NYS and ASMFC updates*

The presenter provided an update on the status of lobster landings in New York, which followed similar trends that were shown in the previous presentations. The presenter also discussed the commercial whelk fishery and explained current size limits for both whelk and lobster in New York. This presentation also included updates from the Atlantic States Marine Fisheries Commission (ASMFC) on the southern New England (SNE) stock. The presenter reviewed the SNE abundance indicators, including young-of-year indices, trawl survey recruit abundance, trawl survey encounter rate, and ventless trap survey abundance. In recent years, many of these indicators have remained negative, signaling that the SNE stock remains severely depleted with poor prospects of recovery. When asked if there were any documented cases of collapse in the whelk fishery, the presenter responded by stating that Virginia reported an offshore collapse due to increased effort in Maryland. Virginia Sea Grant organized a whelk workshop in response and there was also a shift in demand to the northeast.

Dr. Katherine Maltby (Gulf of Maine Research Institute, kmaltby@gmri.org) – *Exploring social resilience in the southern New England lobster fishery: lessons learnt and future opportunities*

There are a number of ways to define resilience, but this project views resilience as the capacity of, "individuals, communities, and systems to survive, adapt, and grow in the face of stress and shocks, and even transform when conditions require it" (Brown 2016). The presenter shared that we have a good understanding of lobster but not about lobstermen. Social resilience is key to influencing short- and long-term trajectories in fisheries social-ecological systems. This project wanted to understand how lobstermen have responded to declining SNE stocks and what has influenced their resilience. It also wanted to see what could be learned to inform resilience planning. To do this, the research team conducted both a media analysis and interviews with lobstermen. They determined that there are three types of resilience to consider in this case study: coping (resilience as persistability), adapting, and transforming. They were also able to examine the dimensions of resilience at individual and community levels. They found that emotions are an important socio-cognitive component and highlight the personal nature of responding to change. Individuals show various pathways of resilience that are influenced by interconnecting factors at a range of scales. This level of diversity requires interventions that address multiple resilience dimensions that are beyond traditional fisheries management approaches. There are a number of lessons to be learned from this work, including looking beyond diversification and thinking about long-term decisions in research and management. Finally, the presenter shared that there is an opportunity for co-designed research that encourages

deeper and longer-lasting engagement with communities that is based on their needs, but this requires sustained funding and relationships.

Discussion

There was a comment from the moderator that when southern New England states were in the height of the die-off, the focus was on what caused it with little thought about social issues. For a long time, there was an assumption that this would be a short-term problem that was ultimately incorrect. When thinking about planning for future disasters, it will be important to consider the social dimension even if the problem is short-term. There was also a discussion about how the lobster technical committee recommended closure for SNE as the best chance to engineer change in the stock trajectory that resulted in no change, with a 10% reduction in licenses implemented 10 years after the fact. This was a frustrating experience for scientists and was also a missed opportunity to learn and question what we could have learned. One of the presenters commented that there are modeling efforts underway (i.e., Chen Lab, Stony Brook University) that can include a recruitment function and back-calculate to 2000 and 2006 to understand the potential impact if closures were implemented. This could then help inform the process in the Gulf of Maine to decide if action will make a difference in the future – now is the time to explore what could happen in the Gulf of Maine and prepare. Furthermore, there were actions taken in the mid-2000s and 2010 that were insufficient to address the collapse. The fishery shifted offshore in the 1990s and transformed into a different fishery that continues to persist. The increase in gauge sizes in the 2000s was not enough, changes in trap vent size were not enough, and we need to think about other tools. We are still trying to figure out the combination of factors that affect mortality and disentangle these parameters.

Plenary: group debrief on next steps for ALI – 4:15-5:00pm
Moderators: **Dr. Amalia Harrington** (Maine Sea Grant, amalia.harrington@maine.edu), **Dr. Gabriela Bradt** (New Hampshire Sea Grant and University of New Hampshire Cooperative Extension, gabriela.bradt@unh.edu), and **Jennie Rheuban** (Woods Hole Oceanographic Institution Sea Grant, jrheuban@whoi.edu)

Next steps

Following the conclusion of the Summit, we will generate a summary document from the session notes. We will also send out a follow-up survey and a list of attendees with contact information. Please reach out to the extension team if you are planning an event related to your ALI project and we can distribute details across the network. Sea Grant ALI team members will be at the Maine Fishermen's Forum and the Massachusetts Lobstermen's Association Annual Weekend and Trade Show. We will follow up with results from the research-to-extension survey as well once the regional extension team has a chance to review the responses.

Workshop: Evaluating American lobster stock dynamics under changes to life history and management regulations

Moderators: Dr. Cameron Hodgdon (Stony Brook University, cameron.hodgdon@stonybrook.edu) and Dr. Yong Chen (Stony Brook University, yong.chen.2@stonybrook.edu)

Day 1 summary

From February 6-7, the Chen lab facilitated a workshop to discuss their ongoing ALI-funded research project exploring American lobster stock dynamics under changes to life history and management regulations. The overarching goal of this project is to develop and conduct a simulation study to evaluate the impacts of possible climate-induced changes in lobster life history parameters and alternative fishery management regulations on lobster population dynamics. The research team plans to accomplish the following tasks:

1. To work with stakeholders to help identify "what if" scenarios for simulating realistic ranges of changes in key life history parameters for the Gulf of Maine/Georges Bank (GOM/GBK) and southern New England (SNE) stocks.
2. To develop a simulation framework for predicting the response of lobster populations to changing life history parameters.
3. To evaluate impacts of changing life history parameters on lobster stocks given status quo management.
4. To evaluate the performance of alternative management regulations.

To accomplish these tasks, the researchers divided their work into two phases. Phase 1 is focused on understanding how the lobster population might respond to climate-induced life history changes. Phase 2, however, is focused on understanding how management might respond to these changes in the lobster population. The goal of this workshop was to discuss the Phase 1 simulation results and to identify scenarios that should be tested in Phase 2 with the project team and other attendees.

The team presented an overview of the Individual Based Lobster Simulator (IBLS), which is a process-oriented individual-based simulation model. The IBLS was first developed by Chen et al. (2005), with additional modifications by Chang (2015) and Mazur et al. (2018). The team provided a summary of the capabilities, inputs, and outputs of the IBLS before diving into how the model was updated for the GOM/GBK stock with the 2020 assessment and how the model was created for the SNE stock. The team noted that the IBLS is very flexible to run new and/or variated scenarios changing the parameters, depending on what would be useful for science and management. The model cannot describe changes in effort (i.e., by the fishery) based on changes in parameters like recruitment (i.e., from biology); currently, only fishery parameters can influence biological outputs. The team noted that the IBLS is not a formal stock assessment model. Relationships like those between spawning stock biomass (SSB) and recruitment are implicit but not described discretely across different simulations in the IBLS. The data for the model is all based on the 2020 stock assessment. The model can be used to describe potential collapse or stock impacts that will impact the fishery, and this is one of the prime uses for the model outputs. The model can also reflectively look at "what if" scenarios in an attempt to mitigate past issues like the SNE collapse. Parameters can be changed across GOM/GBK stocks, or describe additional stocks, but the life history parameters are uniform across stocks. Variables like predation can be varied over time if data for predator abundance is available. Growth is

sensitive to which abundance level you select for in the model, but abundance is one of the least important parameters overall. The team noted that they could include differences in minimum or maximum sizes across stocks (GOM/GBK), but it would require a retuning of the model as two "separate fisheries"

The team then presented and discussed the Phase 1 simulation results (34 for GOM/GBK, 35 for SNE). During the discussion, the group focused on questions related to the results and interpretations of patterns. The team noted they need to revisit the selectivity/selectivity equation because selectivity of traps and selectivity on deck are different and need to be quantified. Some of the topics for future work focused on including or changing the spatial resolution in the outputs for the IBLS, which could potentially be beneficial but would be a large task. They also discussed the potential to split up the components of the selectivity model to treat each change as a "what if" scenario. The group noted that recruitment changes the outputs the most as the model is very recruitment driven (i.e., need to be confident in the recruitment information and estimations). It was suggested that they smooth the recruitment time series just a little bit to make the tuning a bit easier. There was also a suggestion that the team check their definition of recruitment (i.e., recruitment to the model vs. recruitment to the fishery). The group also thought it might be interesting to see what would happen if they altered the level of V-notching in SNE (or anywhere). How much of a difference does setting it to 0 or 0.2 make? Is there a way to change it so it is not a static number across the full time series? The group thought the team should explore dropping V-notch compliance to zero to capture the full effect or pattern of change. There was also a suggestion to explore changing the carrying capacity over time to explore increasing recruitment or the top threshold. One of the simulations demonstrated a potential change in molt timing, and it was suggested that they re-run the simulation with a comparable change in the seasonality of the fishery (i.e., assume the fishery will pursue molted new size class across seasonal scales).

When discussing SNE, the group noted that nothing but a complete cessation of the fishery in the region would have an impact on future biomass. They wanted to know "what if" management had closed the fishery in 2005 when it was first proposed – would biomass have increased or remained stable at low level? What lessons could we learn from SNE to make GOM/GBK stock more resilient? For example, should we change the minimum legal size before it is absolutely necessary in the GOM to increase resiliency? The group used this line of thinking to transition into a discussion on what kinds of simulations should be tested in Phase 2.

Day 2 summary

The research team provided a quick review of the discussions from the previous day before presenting published papers from this work. The publications presented included: *Climate-driven shifts in growth and maturity induce changes to the population and fishery dynamics of a high-value crustacean* (Khalsa et al. 2023); and *Climate-driven changes in growth and size at maturity of Gulf of Maine lobster stocks: implications for stock assessment models* (Hodgdon et al. 2022). The team then continued discussion of the GOM/GBK and SNE Phase 2 simulations as a group.