Northeast Fisheries Science Center Reference Document 22-17

40th Milford Aquaculture Seminar
January 13-15th 2020

December 2022

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edited by Patricia Widman

NOAA Fisheries, Northeast Fisheries Science Center, 166 Water Street, 212 Rogers Ave, Milford CT 06460

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40th MILFORD AQUACULTURE SEMINAR

January 13-15, 2020

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Milford Laboratory

40TH MILFORD AQUACULTURE SEMINAR
JANUARY 13-15TH 2020

MONDAY JANUARY 13TH
4:00 PM: Registration opens
6:00-8:00 PM: Poster session

TUESDAY JANUARY 14TH
8:00 AM: Registration and Continental Breakfast
8:30 AM: Opening Remarks and Presentations
10:00 AM: Morning Coffee Break
10:30 AM: Presentations
12:00 PM: Buffet Lunch
1:15 PM: Presentations
3:00 PM: Afternoon Coffee Break
3:30 PM: Presentations
5:15 PM: Adjourn

WEDNESDAY JANUARY 15TH
8:00 AM: Registration and Continental Breakfast
8:30 AM: Presentations
10:00 AM: Morning Coffee Break
10:30 AM: Presentations
12:00 PM: Buffet Lunch
1:15 PM: Presentations
2:45 PM: Afternoon Coffee Break
4:30 PM: Closing Remarks

MONDAY JANUARY 13TH; EVENING

TUESDAY JANUARY 14TH; MORNING

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9:00	Terry	Oyster Industry: Opportunities and Risks	p.17
9:15	Carroll	The Nonesuch Journey to Farm Management	p.18
9:30	ODierno	Perceptions of Farmed Seafood in The Food-Service Community	p.19
9:45	Ciaramella	Connecting Producers to End Users Through Free Customizable Marketing Resources	p.20
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10:45	Madley	Ocean Farming and The Coastal Community: A Story Map to Document Resiliency Through Diversification	p.22
11:00	Hayes	Further Development of Aquaculture and Ecosystem Approaches for Shellfish Restoration with Communities for Stakeholders Engagement	p.23
11:15	Madley	Evaluation of U.S. Shellfish Aquaculture Permitting Systems	p.24
11:30	Getchis	Connecticut Shellfish: Planning for Conservation, Management, Restoration	p.25
11:45	Rheault	Hatchery Certification to Simplify Interstate Transfers of Seed	p.26
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TUESDAY JANUARY 14TH; AFTERNOON

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1:30	Dewhurst	Engineering Analysis of Mussel Backbone Systems for Open-Ocean Sites	p.28
1:45	Maney	Offshore Longline Aquaculture Will Not Likely Adversely Affect Protected Species	p.29
2:00	Concepcion	Nurturing The Successful Growth and Maturation of a Domestic Seaweed Aquaculture Industry	p.30
2:15	Lindell	Selectively Improving Strains of Sugar Kelp *Saccharina latissima* for Food and Fuel	p.31
2:30	Hudson	Investigation of The Shelter Effects of Sugar Kelp, *Saccharina latissima*, On Pelagic Animals in Long Island Sound Kelp Farms	p.32
2:45	Doall	Diversifying New York's Marine Aquaculture Industry: Integrating Sugar Kelp into Shallow-Water Oyster Farms	p.33
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3:45	Flimlin	Aces: A Free Online Short-Course for Seaweed and Microalgae Aquaculture	p.35
4:00	Cowperthwaite	Maine Scallop Aquaculture Development Initiative: Community Development Through International Tech-Transfer	p.36
4:15	Dixon	Measuring Sea Scallop, *Placopecten magellanicus*, Feeding and Filtration Rates to Inform Aquaculture Siting in Coastal Maine	p.37
4:30	McMahan	Expanding Oyster and Quahog Polyculture in Maine	p.38
4:45	Acquafredda	Diversification of Bivalve Aquaculture in New Jersey: New Species and Seed Lines for High-Salinity Back Bay Habitats	p.39
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WEDNESDAY JANUARY 15TH; MORNING

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11:00	McNally	Examining The Potential Effects of Ocean Acidification and Parental History On Eastern Oyster (*Crassostrea virginica*) Larvae Morphology	p.49
11:15	White	Impacts of Ocean and Coastal Acidification On Seed Oysters Reared in Upwellers, With Shell Hash as A Potential Mitigation Strategy	p.50
11:30	Solomon	The Sound School Artificial Oyster Reef Project: Habitat Restoration in New Haven Harbor Utilizing Lab Cultured Oyster Sets and Reef Balls™	p.51
11:45	Wilcox	A Comparison of Condition and Survival in The Ctenophore, *Mnemiopsis* sp., Being Cultured with Two Different Microalgae	p.52
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WEDNESDAY JANUARY 15TH; AFTERNOON

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1:45	Padilla	Effects of Multiple Stressors On Survivorship and Growth in Juvenile Blue Mussels	p.55
2:00	Pales Espinosa	Regulation of Mucosal Lectins in The Oyster *Crassostrea virginica* in Response to Food Availability and Environmental Factors	p.56
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3:30	Phillips	Use of ARIS Sonar to Assist in Viewing Oyster Aquaculture Gear	p.60
3:45	Munroe	Oyster Aquaculture Does Not Affect Spawning Beach Access for Atlantic Horseshoe Crabs, *Limulus Polyphemus*	p.61
4:00	Reitsma	Exploring Value in Potential New Products for The Shellfish Aquaculture in Massachusetts	p.62
4:15	Sadler	Breeding The Barrens Topminnow, An Endangered Freshwater *Fundulus* species, For Reintroduction	p.63
4:30	**CLOSING REMARKS**		

QUANTIFYING NUTRIENT REMOVAL BY LOCAL GREENWICH OYSTERS THROUGH BIODEPOSITION AND EXCRETION MEASUREMENTS

Skylar R. Bayer*[1], Mark S. Dixon[2], Adam Armbruster[3], Suzanne Bricker[4], Shannon L. Meseck[2], Matthew E. Poach[2], Emilien Pousse[1], Gary H. Wikfors[2], Julie M. Rose[2]. [1]NRC Postdoctoral Research Associate, NOAA NEFSC Milford Laboratory, 212 Rogers Avenue, Milford, CT 06460; [2]NOAA Fisheries, Northeast Fisheries Science Center, Milford Laboratory, 212 Rogers Avenue, Milford, CT 06460; [3]Department of Biology and Environmental Science, University of New Haven, 300 Boston Post Road, West Haven, Connecticut 06516; [4]NOAA National Estuarine Eutrophication Assessment, National Centers for Coastal Ocean Science, 1305 East West Highway, Silver Spring, Maryland 20910.

An overabundance of nitrogen in coastal and estuarine systems, a condition called eutrophication, is a major problem that concerns scientists, marine resource managers, policy-makers, and many other local stakeholders. Eutrophication stimulates excess plant growth, including macro- and microalgae, and has been linked to loss of marine habitats, algal blooms, fish kills, and hypoxia. Bivalve shellfish are particularly good at feeding on this excess phytoplankton, assimilating some of the nitrogen in their food into tissue and shell as they grow. In locations with an established shellfish aquaculture industry, bivalve morphometrics and tissue and shell nitrogen contents can be combined with harvest numbers to assess aquaculture contributions to nutrient reduction and improved water quality. This approach only accounts for the removal associated with harvest, and most aquaculture operations have several year-classes growing simultaneously. Measurement of bivalve feeding activities combined with knowledge of total farm stock can provide a more complete assessment of farm-scale nitrogen removal. In collaboration with local stakeholders (Greenwich Shellfish Commission and Stella Mar Oysters) we collected data needed to estimate farm-scale rates of nitrogen reduction for cultivated eastern oysters in Greenwich Bay, Connecticut. These data include: (1) monthly water samples, (2) monthly oyster samples from Stella Mar Oysters, (3) field measurements of oyster filter feeding, including nitrogen absorption, and (4) oyster excretion measurements conducted at the Milford Lab. Here we present biodeposition and excretion measurements for organic matter and nitrogen, measured for a range of a) oyster sizes from seed to harvest, and of b) temperatures at which oysters are actively filtering. Combining these data with calculated nitrogen removal through harvest of legal sized oysters, we will estimate the total amount of nitrogen removed by the oyster farm by more than just harvest activities in Greenwich Bay. The methods we employ in this project may also be applied elsewhere and for other shellfish industries and marine spatial planning efforts across the world.

POPULATION DYNAMICS OF EASTERN OYSTERS (*CRASSOSTREA VIRGINICA*) BETWEEN A COMMERCIAL SITE AND AN ASSOCIATED NATURAL BED IN THE DAMARISCOTTA RIVER ESTUARY, MAINE

Pauline Kamath, Grant Dickey, Alexander Lora, Charles Clark, James Prescott and Timothy, J. Bowden*. School of Food & Agriculture, University of Maine, Orono, Maine, 04469.

Around 70% of the commercial oyster production in Maine occurs in the upper reaches of the Damariscotta River Estuary. As a consequence, any impact on that area could have significant impact on Maine oyster production. The presence of archeological shell middens along the estuary indicate the long-term presence of oysters in the estuary. However, very little is known about the impact of the commercial production on the natural populations within the estuary. In 2010 there was an outbreak of MSX in the commercial operations. In 2011 the industry started to move to disease resistant strains in an effort to reduce the impact of the parasite. We have been sampling a number of sites for parasite prevalence over the subsequent time period. We used a subset of those samples to investigate the population dynamics between a commercial site and a nearby natural bed population in 2012, 2014 and 2016. Using 20 microsatellites that have previously been identified we carried out a fragment analysis study. Principal component analysis segregates the populations although it appears they are not in Hardy Weinberg equilibrium. We will discuss the possible implications in relation to the information we have regarding changes in commercial strains and the possible consequences of the presence of the parasite within these populations.

OPTIMIZATION OF FIELD NURSERY PRACTICES FOR OYSTER SEED CULTIVATION IN THE DELAWARE BAY, NEW JERSEY

Lisa Calvo*[1]and Daphne M. Munroe[2]. [1]Sweet Amalia Oyster Farm, PO Box 475, Newfield, NJ 08344; [2]Haskin Shellfish Research Laboratory, Rutgers University, 6959 Miller Avenue, Port Norris, NJ 08349.

A critical bottleneck to growth and development of the shellfish aquaculture industry in New Jersey, is the limitation of hatchery and nursery capacity for seed production. In New Jersey, demand for oyster seed well exceeds the in-state production capacity of the State's sole oyster hatchery. In order to meet the increasing demand for seed, the facility has limited production and sales to seed less < 3 mm in size, shifting the nursery phase of production to oyster farmers. Likewise, importations of out-of-state seed, most often target small seed 2 mm or less, to minimize disease transfer risks. Not all growers have access to appropriate land-based nursery sites and must nursery the seed in the field where environmental control is not possible and many challenges persist. Little attention has been paid to optimize strategies for the field nursery of 2-4 mm oyster seed. This study evaluated the performance of field nursery systems for the field nursery of 2 mm oyster seed at a high energy, inter-tidal farm site in the southern Delaware Bay, NJ. A crossed factorial experimental design was used to test the performance of cage type (Low Pro with seed bag and SEAPA with 1 mm sock), position (fixed or floating), and stocking density (2000 and 8000 seed per cage). Survival, growth, and shell morphology were tracked over time. Seed in floating cages, which were under water on most low tides, experienced faster growth than seed grown in fixed aerial exposed cages. Seed grown in Low Pro cages demonstrated greater shell heights that those in SEAPA cages under floating conditions, but this trend was reversed for fixed cages. Shell morphology varied among treatments. Seed grown under floating cage conditions had a greater proportion of down-turned and up-turned hinges than those grown in cages fixed to racks, and SEAPA cages yielded oysters with a deeper cup, but less fan than those grown in Low Pro cages. The most uniform shell shape was produced by holding oysters in SEAPA cages that were fixed to racks. Seed survival during the first six weeks was on average 70%. Attentive husbandry proved critical. Seed escape losses occurred in worn and torn seed bags and careful examination was necessary to detect mudding inside the cages. Though encouraging, additional work is needed to enhance survival of field nursery operations.

DIVERSIFICATION OF BIVALVE AQUACULTURE IN THE NORTHEAST: TESTING SURVIVAL AND GROWTH OF BAY SCALLOPS IN NEW JERSEY

Nicole Deck*[1], Michael P. Acquafredda[1], Michael Whiteside[1], Daphne M. Munroe[1], Lisa M. Ragone Calvo[1], David Bushek[1], Michael De Luca[1], Ximing Guo[1]. [1]Haskin Shellfish Research Laboratory, Department of Marine and Coastal Sciences, Rutgers, The State University of New Jersey, 6959 Miller Avenue, Port Norris, New Jersey 08349.

Bivalve aquaculture along the Atlantic Coast is dominated by the eastern oyster (*Crassostrea virginica*) and hard clam (*Mercenaria mercenaria*), with respective production values of 94 and 46 million dollars in 2015 (FAO, 2017). Sustainable development of bivalve aquaculture is threatened by diseases, weather fluctuations, unpredictable mortality, and the lack of crop diversity. The bay scallop (*Argopecten irradians*) is a promising aquaculture species for high-salinity (25-32) coastal waters of NJ and the Northeast. This native species exhibits fast growth, but faces challenges of thermal-related mortalities in winter. In 2019 a breeding program for bay scallops was initiated to select for fast growth, which would enable harvest within a single year. Selected lines of bay scallops were produced from the largest animals in the parent population and from a randomly-selected group across the remaining broodstock cohort. Seed was deployed at three farms in Barnegat Bay in mid-July in box bags held in bottom cages. Sampling at the farms in September indicated that the offspring of the large-selected groups had higher survival but slower growth than random-selected controls with some variation among the three sites. The slower growth in the large-selected group may have been caused by higher density as a result of higher survival relative to the random-selected controls. The deployed lines will be sampled and monitored throughout 2020.

DEVELOPMENT OF INCREASED SAMPLE CAPACITY FOR GEN2 ENVIRONMENTAL SAMPLE PROCESSOR (ESP)

Thomas Fougere*[1], Ivory Engstrom[1], Don Anderson[2], Mike Brosnahan[2], Bruce Keafer[2], Greg Doucette[3], Tina Mikulski[4], Jim Birch[5], Roman Marin III[5], Brent Roman[5]. [1]McLane Research Lab, Falmouth Technology Park, 121 Bernard Saint Jean Drive, East Falmouth, MA 02536; [2]Woods Hole Oceanographic Institute, 86 Water St, Woods Hole, MA 02543; [3]NOAA/NOS/NCCOS, HAB Monitoring & Reference Branch. National Centers for Coastal Ocean Science,1305 East West Highway, Rm 8110,
Silver Spring, MD 20910; [4]NOAA/CSS, HAB Monitoring & Reference Branch, 1305 East West Highway, Rm 8110, Silver Spring, MD 20910; [5]Monterey Bay Aquarium Research Institute, 7700 Sandholdt Rd, Moss Landing, CA 95039.

As part of a NOAA-funded PCMHAB project (Grant Number: NA11NOS4780022), the Gen2 Environmental Sample Processor (ESP) has undergone design modifications in order to accommodate a shorter-profile reaction chamber or 'puck'. This newly developed short puck ESP option increases the device's capacity from 132 to 198 pucks, reducing the need for sensor recovery/redeployment cycles and thereby substantially decreasing the average cost per observation. The ESP is an advanced electromechanical fluidic device capable of *in situ* collection, filtration, processing, and analysis of water samples, for quantifying the presence of target organisms and/or biological toxins in near real-time. The instrument utilizes a complex fluidic system designed to autonomously collect and filter water samples. The device then either preserves and archives the sample for analysis following recovery or directly applies molecular detection technology to detect targets of interest in the sample in near real-time. Mechanical and fluidic modifications were investigated during the development of the short puck ESP, while ensuring equivalent detection results as compared to the standard Gen2 ESP design. Initially, lab-based experiments were conducted, operating the standard Gen2 ESP and short puck ESP side-by-side. Once consistent lab-based results were obtained, the short puck ESP was field-tested in two separate deployments in April 2018 (Cape Cod, MA) and May 2019 (Orr's Island, ME). Both field deployments focused on determining *Alexandrium catenella* concentrations in areas known to have annual localized blooms. Each of the successful field deployments produced accurate, near real-time measurements of *Alexandrium* cell concentration, verified through comparison with data from co-deployed instruments and field samples. Future work planned for September/October 2019 (Bar Harbor, ME) will include preparation and deployment of a short puck ESP equipped to detect saxitoxin, the toxin produced by *Alexandrium* that may cause paralytic shellfish poisoning (PSP).

ALLELOPATHIC EFFECTS OF INVASIVE RED MACROALGA (*GRATELOUPIA TURUTURU*) FOR THE MITIGATION OF HARMFUL ALGAL BLOOMS

Lyle Given*, Holly Turner, Kirk Shadle. Bridgeport Regional Aquaculture Science and Technology Education Center, 60 St. Stephens Rd, Bridgeport, CT 06605.

Allelopathy has been demonstrated as a potential method for the mitigation of harmful algal blooms (HABs). HABs are an increasing problem with vast environmental, economic, and health impacts, so a feasible solution for bloom mitigation is needed. However, most suggested methods raise concerns of further harming the environment, being expensive, or simply not practical. Allelopathic compounds can be derived from macroalgae, a natural and abundant source, reducing both potential cost and environmental harm. Current studies have found success in laboratory experimentation with bloom-forming species such as *Ulva* and *Sargassum* (Zerrifi, El Khalloufi, Oudra, & Vasconcelos, 2018). Additionally, allelopathy has been suggested as a method for invasive species to thrive in non-native habitat (Jeschke et al., 2012). Thus, *Grateloupia turuturu*, an invasive red macroalga, could use allelopathy to inhibit the growth of HAB-forming microalgae. The project will also consider the efficacy of allelopathic macroalgae as a method to mitigate HABs. Extracts from *G. turuturu* will be added to bloom-forming microalgae cultures to determine the allelopathic effects on the microalgae.

IMPACT OF HARMFUL ALGAE BLOOMS (HAB) OF *ALEXANDRIUM CATANELLA* ON THE MOLECULAR STRUCTURE AND FUNCTIONALITY OF BLUE MUSSELS HEMOCYTES, *MYTILUS EDULIS.*

Olivier Grenier*[1], Gary H. Wikfors[2], Dror Warschawski[3], Isabelle Marcotte[3], Réjean Tremblay[1]. [1]Institut des Sciences de la Mer, de Rimouski, Université du Québec à Rimouski, Rimouski, Québec G5L3A1, Canada; [2]NOAA Fisheries Service, Northeast Fisheries Science Center, 212 Rogers Ave, Milford, CT 06460, USA; [3]Département de chimie, Université du Québec à Montréal, P.O. Box 8888, Montréal H3C 3P8, Canada.

Climate changes have multiple effects on HABs, inducing longer HABs period and more recurring. This study uses solid state nuclear magnetic resonance (SS-NMR) to identify damages done to the blue mussels (*Mytilus edulis)* hemocytes cellular membrane as well as different metabolites possibly present after an exposition to toxic algae. Blue mussels have been fed with enriched ^{13}C microalgae to significantly augment the signal obtained while doing ^{13}C SS-NMR. Hemolymph was withdrawn from the adductor muscle after 24 and 120h after exposition to *Alexandrium catanella* (toxic microalgae) and *Tetraselmis suecica* (negative control). Hemocytes were put on ice and analysed with a *Bruker Avance III, 400 MHz SS-NMR*. ^{1}H, ^{31}P and ^{13}C were the chosen nuclei to evaluate the potential damages caused by the exposition. Saxitoxin content will be quantified during 2020 winter and the observations made on the SS-NMR spectra will be linked.

ASSESSING THE ROLE OF MEDIA ON PUBLIC PERCEPTIONS OF SHELLFISH AQUACULTURE IN SOUTHERN NEW ENGLAND USING CONTENT ANALYSIS

Kristen Jabanoski*[1,2], Tessa Getchis[3] and Lisa Milke[1]. [1]NOAA Fisheries, Northeast Fisheries Science Center, Milford Laboratory, 212 Rogers Avenue, Milford; [2]Integrated Statistics, 16 Sumner Street, Woods Hole, Massachusetts 02543; [3]Connecticut Sea Grant, University of Connecticut, Avery Point, Marine Science Building, 1080 Shennecossett Road, Groton, Connecticut 06340.

One of the most significant challenges limiting the growth of the shellfish aquaculture industry is siting new or expanding aquaculture operations in the face of negative public perceptions. Media coverage is not a direct measure of public opinion, but often provides the foundation for forming opinions in the absence of first-hand experience. To better understand the breadth and depth of media coverage of shellfish aquaculture in Southern New England, we will conduct a quantitative and qualitative content analysis of online and print articles in newspapers covering shellfish aquaculture in CT, RI and MA. We will use LexisNexis Academic and ProQuest Newsstand to obtain articles published between 2014 and 2019 from 2-3 key local to regional newspapers from each state. Each article will be coded based on publication date as either before the launch of that state's shellfish initiative or after, and we will evaluate temporal trends in coverage. Sentiment toward shellfish aquaculture will be categorized as positive, negative, or neutral, and referenced sources will also be categorized. In addition, we will code articles for one or more variables based on themes in their content, including: environment, science, sustainability, health, economy, benefit and risk. The goals of this project are: 1. to understand trends in media coverage of shellfish aquaculture in southern New England over time, 2. to determine whether state shellfish initiative outreach efforts are informing or having an impact on media dialogue, and 3. to explore which outreach activities (if any) are having a measurable effect on how aquaculture is covered by the media. Undertaking a thorough media analysis of local news coverage will help the state shellfish initiatives plan more effective public and media outreach, as well as prepare strategic responses to controversy.

LED LIGHTING FIXTURE FOR ALGAE GROWING IN AQUACULTURE

Jack Jiang. Illumination Technology, Inc. 17-A Marlen Drive, Hamilton, NJ 08691.

Energy efficient LED lighting products are replacing many traditional lighting products (fluorescent lamp, High intensity discharge lamps) in many applications including indoor algae growing for aquaculture. But the need of light for growing algae is different for general lighting. Design and application consideration of LED lighting fixture for algae growing are discussed and addressed in the areas of light spectrum, wavelength selection, dimming, moisture damage to LED and circuit and fixture, reliability and serviceability.

EFFECTS OF COMMERCIAL SEAWEED EXTRACTS, AMPEP and KELPAK®, ON THERMAL TOLERANCE OF *PYROPIA YEZOENSIS*

Jang K. Kim*[1], Sookkyung Shin[1], Hyein Song[1], Sol Han[1], Schery Umanzor[2] and Charles Yarish[2]. [1]Department of Marine Science, Incheon National University, 119 Acamedy-ro, Yeonsu-gu, Incheon 22012, Korea; [2]Department of Ecology and Evolutionary Biology, University of Connecticut, 1 University Place, Stamford, CT 06901, USA.

Seaweed derived biostimulants have been used at agriculture to enhance crop production and quality. Seaweeds extracts are noted to enhance root vigor and nutrient uptake, and to increase fruit yield and pigment content. Acadian marine plant extract powder (AMPEP) and Kelpak® are commercial extracts from the brown algae, *Ascophyllum nodosum* and *Ecklonia maxima*, respectively. This study was to examine if AMPEP and Kelpak® can enhance thermal resistance of *Pyropia yezoensis*. *Pyropia yezoensis* was cultivated in von Stosch enriched (VSE) medium with different concentrations (Control: 0, Low: 0.001, High: 1 ppm) of AMPEP and Kelpak® for 6 and 7 days, respectively. *Pyropia yezoensis* was then cultivated at different temperatures (10, 15, 20 and 25℃), 12:12 L: D photoperiod and 100 μmol m^{-2} s^{-1} of photosynthetically active radiation (PAR) for 15 days without an addition of AMPEP or Kelpak®. *Pyropia yezoensis* reproduced at 20 and 25℃ regardless of exposure concentrations of both biostimulants within 10 days. At lower temperatures (10 and 15℃), Kelpak® treated *P. yezoensis* didn't reproduce, while AMPEP treated *P. yezoensis* reproduced asexually only. These results suggest that AMPEP and Kelpak® may not enhance the thermal resistance of *P. yezoensis* however; AMPEP may stimulate asexual reproduction at lower temperatures.

USING CHLOROPHYLL *A* AS A PROXY FOR PHYTOPLANKTON – PRACTICAL CONSIDERATIONS WITH THE CHEMICAL EXTRACTION METHOD

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Shellfish grow-out depends entirely upon natural phytoplankton and other organic particles present in the water. Accordingly, phytoplankton measurement is critical for evaluating food availability and interactions between shellfish aquaculture and the environment. Most commonly-used phytoplankton quantification methods (without taxonomic information) measure chlorophyll *a*, either through chemical extraction (followed by fluorescence or absorption reading) or through *in vivo* fluorescence. For chemical extraction methods, different sample storage temperatures and durations of storage (days to months) have reportedly yielded varying results for chlorophyll *a* quantification. Currently there is no standard, recommended method for sample storage; therefore, it is difficult to compare results from different studies. Using cultures of three single phytoplankton species, we tested the effect of temperature (-20°C vs. -80°C) and duration of storage time upon chlorophyll *a* yield, with the most-commonly-used 90% acetone extraction followed by fluorescence reading. For all three species tested, *Prorocentrum minimum*, *Thalassiosira pseudonana*, and *Ditylum brightwellii*, there was a significant decrease in chlorophyll *a* yield after one week of storage in both -20°C and -80°C, although the magnitude varied between species. Samples stored in -80°C yielded significantly higher chlorophyll *a* than those in -20°C. Our preliminary results suggested that storage time should be limited to one week and -80°C is preferable.

THE EFFECTS OF OCEAN ACIDIFICATION ON THE FEEDING PHYSIOLOGY OF SURFCLAMS, *SPISULA SOLIDISSIMA*

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Carbon dioxide (CO_2) released into the atmosphere is absorbed by the world's oceans. CO_2 reacts with water (H_2O) to form carbonic acid (H_2CO_3), which dissociates into bicarbonate (HCO^{3-}) and hydrogen ions (H^+). This addition of H^+ is decreasing ocean pH, which is a phenomenon known as ocean acidification (OA). This change in water chemistry could be detrimental to fishery resource organisms, especially those with calcium carbonate shells. The commercial and recreational fishing industry is vital to the United States economy, supplying 1.62 million jobs and bringing in 208 billion in sales. Atlantic surfclam, *Spisula solidissima*, harvest is one of these important fisheries, grossing $31 million in 2016. The effects of OA upon surfclams are largely unknown. Physiological functions (i.e., growth, feeding rates) also may be affected by OA conditions. We conducted an experiment to test the effects of OA upon filtration and feeding of surfclams. Surfclams were grown under three different CO_2 conditions: 641 ppm (pH 7.84, the control), 1369 ppm (pH 7.53), and 2180 ppm (pH 7.33) from April 11 –July 5, 2019. Filtration and feeding variables were measured five times during the exposure period using the biodeposition method to determine any response to OA. A significant difference was found in average assimilation efficiencies and absorption rates between treatment groups, and a significant interaction was found in filtration and clearance rates. Moderate increases in CO_2 (1369 ppm CO_2) tended not to significantly change measured rates, but high exposure (2180 ppm) did, resulting in lower values.

A FISH'S-EYE-VIEW: SHELLFISH FARMS AS MARINE HABITAT IN NEW JERSEY

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Shellfish growers routinely observe fish and invertebrates interacting with their aquaculture gear. To quantitatively assess these observed interactions, point-of-view (GoPro) cameras were used to document fish activity in and around oyster cages, floating bags, and a natural marsh habitat on an oyster farm in the Little Egg Harbor region of Barnegat Bay, New Jersey in 2018. At least 21 species from 4 phyla were observed across all days and sites; phyla included chordata, arthropoda (sub: crustacea), mollusca, and ctenophora. Nekton abundance was determined using MaxN, defined as maximum number of individuals of a given species present within each 1-minute segment of video. Species of both ecological and economic importance in the local ecosystem utilized the farm gear as habitat. Most frequently, juveniles of a given species were observed suggesting that the oyster farm habitat may support and enhance the natural nursery function of the marshes. This collaborative work is part of an ongoing effort underway in Long Island Sound by the NOAA Milford Lab and is a first step towards a comprehensive regional network characterizing and evaluating fish habitat provisioning on off-bottom oyster farms.

CONTINUING GENETICS, BREEDING AND GENOMICS APPROACHES FOR THE MUSSEL, MYTILUS EDULIS, IN AQUACULTURE PRODUCTION AND RESTORATION: USE OF GENETIC TOOLS FOR SHELLFISH ENHANCEMENT

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The United States production of aquaculture seafood was worth $1.3 billion dollars in 2014. Shellfish aquaculture in particular included bivalves such as mussels and oysters which are among the top species used as food and as filter feeders in ecosystems, contributing to an increase in the domestic economy and jobs, and a decrease in the trade deficit. Mussels also are used as sentinels for pollution studies and as test organisms for offshore aquaculture. As in agriculture, aquaculture genetics technology could advance such efforts through marker-assisted selection (MAS) by improving desirable traits such as fast growth, better survival, disease resistance and greater tolerance and adaptation to changing environmental conditions. To this end, genetic, breeding and genomics approaches were initiated to evaluate thermal tolerance based on shell color phenotypes in mussels to improve growth and survival. Major components of this shellfish genetics initiative encompassed breeding, molecular genetics, and site evaluations. Selective breeding for shell phenotypes was initiated, DNA was extracted from tissues and shells, and mussels were provided to an industry partner to evaluate an ocean farm site for growth and survival. With a goal of continuing and adding to this work, objectives include:1) selective breeding for improved growth and survival ;2) molecular genetics for genotypic or marker-assisted selection; and 3) the evaluation of the habitat and the performance of stocks in industry siting trials. In addition, we plan to investigate another factor that could affect production, trematode infection and pathogen resistance. Mussels can become infected with the parasitic trematode, *Proctoeces maculatus*, which affects the reproductive capacity and propagation of mussels in the wild and in aquaculture. We plan to detect and characterize parasite molecules for the assessment and possible decrease of infection rates.

NON-TOXIC PHOTOACTIVE RELEASE COATINGS FOR BIOFOULING CONTROL

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Novel non-toxic coating technology for biofouling control developed for the aquaculture industry is presented that relies on the photoactive generation of hydrogen peroxide to reduce the settlement of biofouling organisms rather than the leaching of pesticides.

Biofouling, the unwanted growth of biological organisms on underwater surfaces, has long been recognized as a major problem for commercial aquaculture. Biofouling dramatically increases labor costs, reduces the value of product, and can harm cultured species. Fouling clogs gear, stops water flow and food delivery, can compete with culture organisms for food or space, and can directly affect the growth and survival of cultured organisms. As a result, considerable physical and economic effort is directed toward the prevention and control of biofouling at culture facilities. Cleaning of gear and use of toxic coatings are the primary methods employed by the industry to maintain biofouling-free surfaces. Time and energy expended to keep gear clean taxes aquaculturalists consuming as much as 30% of labor costs and contributing 15% to operational costs.

A novel bio-based release coating was developed that, when immersed in water, controls the settlement of biofouling organisms. Biofouling control is accomplished by the release properties of the polymer that degrades and dissolves when exposed to sunlight. Catalysts in the formula generate low levels of hydrogen peroxide when exposed to sunlight. Peroxides are oxidizing agents known to thwart the settlement of biofouling organisms. Peroxides also facilitate the gradual breakdown of the bio-based coating resulting in a release of the surface layer, and along with it any biofouling that may have attached. This solution to the biofouling problem is sustainable because peroxides quickly dissociate back to oxygen and water after leaving the coating surface, and all ingredients in the bio-based coating are generally regarded as safe (GRAS). Results from biofouling resistance testing on PVC test panels and aquaculture gear (bags, trays and cages) performed from 2015 to 2018 are presented. Oysters and scallops grew significantly larger in treated bags and trays over a three month grow-out period. Treated gear requires less maintenance and can be reused without cleaning. Results from field testing demonstrate that photoactive release coating technology is a viable solution to the biofouling problem experienced by shellfish farmers, who rely on gear changes and cleaning to control biofouling.

WITH A FLICK OF THE WRIST: WHEN OYSTERS WERE NEW HAVEN'S WORLD

Neil R. Berro

If it seems that it has been a long time since New Haven was known for something other than Yale, pizza and maybe the claim of being first with the hamburger sandwich, well it has.

The New Haven oyster industry was at one time a world leader, employing technology and methods of industrialization that were remarkable for their success. What made New Haven so great that oystermen traveled from around the country and from overseas to observe its long running success?

Yet eventually, the success would not last. What happened? How did a city manage to lose its memory of this once ubiquitous association with oystering? Now some 150 years from its industrial start line, can oysters make a comeback? Can that comeback serve to bring New Haven up a notch or two? Can the future be found in the past?

Using interviews, primary sources and in all over 100 separate citations that yielded over 300 notes, a story is fleshed out about a food source, an industry, a city and twenty first century urbanism. It is told in a warm even caring manner from a nearly 20 year resident of the city who like many has asked, can New Haven be doing better? The leaders of the industry at the two poles of studied time emerge as wonderful reflections of their respective eras. Unbridled, iconoclastic and feisty, Henry C. Rowe is driven and over the top but helped make New Haven great for commercial oystering success in the latter nineteenth century of an ascendant capitalism and country. Integrated and cooperative with many of the broader agendas of controlling and reducing the accrued water pollution of the Long Island Sound, as well as extremely soft spoken, Norm Bloom and his son and partner Jimmy Bloom are seemingly modeled for the twenty first century as they build relationships and goodwill among numerous stakeholders. The reader joins the roller coaster of success, failure and uncertainty. And for the often poor little oyster, a certain empathy develops that could symbolize the unpredictable fortunes of New Haven itself.

UNDERSTANDING THE OYSTER INDUSTRY

Chip Terry, Ph.D., Oyster Tracker, 31 Water Street, Castine, ME 04421.

The oyster (shellfish) industry is rapidly changing and growing. Having just visited over 100 farms in the last couple years, we wanted to share some of our observations about the industry in North America. What does the oyster industry look like regionally? Why is it growing? What are the different growout techniques? What are the risks? What should a farmer do?

This is not a scientific study. We are responding to the questions we always get from farmers--what is going on and what should I be planning for?

NONESUCH OYSTERS: OUR JOURNEY ON FARM MANAGEMENT

Abigail Carroll. Nonesuch Oysters.

Nonesuch started accidentally. However, the key was/is building a farm that is profitable, serves the community and delivers a consistently excellent product. We have done that, but getting there has been tough. One of the key things is figuring out how to manage the farm so I don't need to be there every day. Here is our journey on farm management

1) Whiteboards and notebooks.
2) Getting organized using AirTable
3) Moving to Oyster Tracker

The key learnings so far:

1) You need something. This is a big data world with lots of moving parts.
2) Keep it simple. There is a lot of data you could collect. Figure out what matters.
3) Have team buy in. My farm manager didn't really like AirTable.
4) We are not good at IT
5) Have a partner you can grow with.

Where I would like to see this go.

1. Track from seed to harvest to table. Being able to see from end to end and know what customers enjoyed would be powerful.
2. Make compliance easier.
3. Add in environmental data

Before accidentally becoming a Maine oyster farmer, Abigail worked in finance and in numerous start-ups, in industries ranging from telecoms to fashion. Abigail speaks French and Spanish and has lived, worked, and/or studied in several countries in Europe and Latin America, including over 12 years in France. She has a Master's Degree in International Affairs from Columbia University and an undergraduate degree in French and Spanish literature from Barnard College. Abigail's publishing credits include The Telegraph (UK daily), This City Paris Magazine, and most recently The Portland Press Herald. She serves on the board of Friends of Scarborough Marsh, Biddeford Shellfish Conservation Commission, World Affairs Council of Maine, and, despite her tendency to get sea sick in the open ocean, she is Rear Commodore of the Biddeford Pool Yacht Club. *https://www.abigailcarroll.com/*

PERCEPTIONS OF FARMED SEAFOOD IN THE FOOD-SERVICE COMMUNITY

Linda ODierno. The National Aquaculture Association, PO Box 12759, Tallahassee, FL 32317.

With funding from the National Sea Grant Program, New York Sea Grant and the National Aquaculture Association partnered to develop positive attitudes and perceptions about farm-raised seafood products in the foodservice community. By developing an appreciation of U.S. farm-raised seafood among educators, the project can reach thousands of culinary students who will become the new generation of celebrity chefs and food trend-setters.

Seafood is a daunting and confusing commodity with thousands of species farmed and fished in a variety of ways. However, most culinary schools do not offer a specific seafood course. To gain a better understanding of this sector and develop public relations strategies, the team constructed an in-depth survey to assess current attitudes, identify knowledge gaps, build databases and initiate conversations.

Initial results revealed that most educators realize that in order to provide seafood for future generations, we need to turn to aquaculture but there are concerns about sustainability, use of antibiotics, GMO products, environmental degradation, and impacts on wild stocks.

Educators voiced concerns about the affordability of seafood. Cost severely limits the students' exposure to such products. Frozen seafood predominates with use of whole fish reserved for meat fabrication courses. If a farmer provides product for the classroom, it is not only an opportunity to familiarize students with the product, but can also build markets and serve to develop a positive image of the farm.

Nutritional medicine is a trending topic in the foodservice community, but many educators are unaware of the recommendations of the *Dietary Guidelines for Americans* and the FDA advice for pregnant women. Many educators perceived farmed seafood as less flavorful and nutritious than wild products. The level of unawareness of the seafood HACCP program and other seafood safety programs was distressing.

Salmon was the most commonly used product. A concern for the entire seafood industry is how to expand the market beyond the usual top ten seafood choices. Familiarizing chefs with abundant, affordable and available species can help spread the word and acquaint consumers with non-traditional seafood options. These efforts seek to help build connections between the U.S. growers and future chefs

If you would like to learn more about future activities, please complete our grower survey online at https://bit.ly/2RgiHmE . A number of growers have already taken advantage of opportunities to participate in trade shows and other events to promote their products at no charge.

CONNECTING PRODUCERS TO END USERS THROUGH FREE CUSTOMIZABLE MARKETING RESOURCES

Michael Ciaramella*[1] and Linda ODierno[2]. [1]NY Sea Grant/ Cornell University, 146 Suffolk Hall, Stony Brook University, Stony Brook, NY 11794-5002; [2]The National Aquaculture Association, PO Box 12759, Tallahassee, FL 32317.

The complexities surrounding seafood production, the short shelf life, and the perceived safety risks make seafood preparation daunting for most home cooks. In the United States, consumers rely heavily on culinary professionals to select and prepare their seafood for them. This transfers the burden of sourcing safe and sustainable seafood onto the culinary professionals and affords them a great deal of power over consumption patterns in the U.S. As trendsetters, innovators, and influencers it is important to ensure that culinary professionals are well educated and knowledgeable about the safety, nutrition, sustainability, and production of the seafood they source. To complicate the task of sourcing seafood, the modern day consumer is more in tune with the foods they consume and are more attentive to where and how the foods they eat are produced. To assist in bridging the gaps between producers and end users New York Sea Grant has been working with the National Aquaculture Association to create marketing resources that will provide producers and chefs with affordable tools to educate their buyers/patrons.

Marketing resource cards were created to assist producers in educating foodservice providers with information about the origins and sustainability their product. They can also be used by the foodservice industry to market their dishes to consumers by sharing where and how the seafood they serve is produced and prepared.

Each card is fully customizable, allowing users to help promote their brand and adjust as needs and resources change. The cards will be available for free online as fillable PDF's, making them affordable and easy to print at home or in the office. A guide to using these resources will be presented along with the species available. Feedback on additional species resources will be encouraged and the web platform housing them will be introduced.

CONNECTING SEAFOOD PRODUCERS AND CULINARY PROFESSIONALS WITH AN AQUACULTURE PRODUCTS AND RESOURCE GUIDE

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Increased efforts to educate culinary professionals about the value and sustainability of farm raised seafood often fall short when chefs start asking where they can access such products. While aquaculture production is on the rise in the U.S., access to such products can be limited, especially when looking to source "locally." To support the growth of a domestic aquaculture industry, an effective education program that highlights the need for farmed U.S. seafood to complement wild capture fisheries and directs chefs to where they can find those products is necessary. In addition, small scale start-up operations often struggle to effectively market their products affordably. Building a platform to connect these farmers with potential buyers locally and nationally can reduce this burden.
New York Sea Grant in collaboration with the National Aquaculture Association has been collecting data on farmed products that are commercially available and are drafting a resource to direct chefs to U.S. farmed products to incorporate into their menus. The guide will also include links to additional resources about aquacultured products and various culinary and aquaculture organizations to assist in creating linkages between chefs and seafood growers. Partnerships with chefs will be used to highlight the various uses for currently available seafood products and showcase recipes utilizing U.S. farmed seafood.

This session will discuss progress and engage attendees to identify additional resources, operations, and topics that would be relevant and important for inclusion in such a resource. Farmers are encouraged to share their information to be included in the final resource developed.

OCEAN FARMING AND THE COASTAL COMMUNITY: A STORY MAP TO DOCUMENT RESILIENCY THROUGH DIVERSIFICATION

Kevin Madley*, Kimberly Thompson, Cynthia Sandoval, Mark Rath, and Mackenzie Nelson. USDOC, NOAA, National Marine Fisheries Service, Greater Atlantic Regional Fisheries Office, Gloucester, MA 01930.

Responsible marine aquaculture can complement well-managed wild capture fisheries and responsible land-based agriculture to support a long-term strategy to create a safe, secure, sustainable, and more resilient global food system. While there is robust research and data to support the ecological, technological, and regulatory capacities of the United States to expand marine aquaculture in its waters, there is little information on how incorporating marine aquaculture into local seafood production impacts the economic, social, and cultural identities of coastal communities. Marine aquaculture has the potential to support a more stable source of income year-round by providing alternative or supplementary ocean-based livelihoods for coastal community members whose employment status is made insecure by the unpredictable impacts of climate change, urban coastal development, and policy changes on wild fisheries. Throughout the U.S., there are examples of fishermen and coastal communities that have benefited from adding marine aquaculture to their seafood production portfolios. Telling these stories can help inform understanding of how marine aquaculture contributes to the economic and social viability of coastal communities as well as identify gaps in knowledge about these interactions that can guide formal research in this area.

In collaboration with NOAA and Sea Grant, the Aquarium of the Pacific's Seafood for the Future program is curating a collection of stories that highlight the interactions between marine aquaculture and the coastal community. These stories are presented in a Story Map, a format that was chosen because it is accessible to a broad audience and with compelling images and stories that can be shown spatially. Our target audiences are legislators and stakeholders, as well as educators and the general public. We hope to expand this project and work with social scientists to help refine and develop more robust criteria to bridge stories with scientific theory to create a more complete and accurate picture of how marine aquaculture affects people and communities.

FURTHER DEVELOPMENT OF AQUACULTURE AND ECOSYSTEM APPROACHES FOR SHELLFISH RESTORATION WITH COMMUNITIES FOR STAKEHOLDERS ENGAGEMENT AND RESILIENCY

Elizabeth Hayes*[1,2], Sheila Stiles[1], Melanie Dore[1], Larry Conaway[3], Lisa Brown[4], Curt Johnson[5], Bill Lucey[5], Lensley Gay[6], Jorge Rodriquez[1], Kirk Shadle[7], John Roy[8], Peter Solomon[8], Timothy Visel[8]. [1]NOAA Fisheries, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT 06460; [2]Integrated Statistics, 16 Sumner Street, Woods Hole, Massachusetts 02543; [3]Riverside Education Academy Magnet, 560 Ella T Grasso Blvd #2, New Haven, CT 06519; [4]Austin College, 900N Grand Avenue, Sherman, TX 75090; [5]Connecticut Fund for the Environment- Save the Sound, 900 Chapel Street, Upper Mezzanine, New Haven, CT 06510; [6]Katherine Brennan School Family Resource Center, 200 Wilmot, New Haven, CT 06515; [7]Bridgeport Aquaculture School, 60 St Stephens Road, Bridgeport, CT 06605; [8]Sound School, 60 S Water St, New Haven, CT 06519.

Aquaculture is not only the fastest growing form of food production; it is also one of the most environmentally efficient ways of producing animal protein. Moreover**,** consumption of seafood has grown considerably, while, the capture or wild fisheries has declined or remained stagnant. Despite the growth of aquaculture and the increase in seafood consumption, there are communities that reside near the coasts that may not have availed themselves of opportunities to become engaged in aquaculture activities for employment, entrepreneurships or related ventures. Therefore, many coastal communities that have been devastated by disasters such as hurricanes or even earthquakes, some of whom might be fishers or harvesters, perhaps could be more resilient, might not be aware of aquaculture opportunities or take advantage of opportunities to become involved in aquaculture endeavors. Moving forward, with community support, restoring tributaries will further support the resiliency of the communities and the environment and will increase spawning and nursery habitats for shellfish, such as oysters and mussels. These communities also are likely to be big consumers of seafood themselves, maybe eating fish, shellfish or other aquatic products, several times a week. A goal of this project is to further increase awareness of aquaculture with outreach services through training, internships, schools, industry, agencies, workshops, partnerships, conferences, meetings or other means of communication, including new technology. Outreach will continue with our partners and the communities. Approaches will be described and discussed.

EVALUATION OF U.S. SHELLFISH AQUACULTURE PERMITTING SYSTEMS

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Fisheries has a long history of supporting shellfish aquaculture development and the agency recognizes that sustainable aquaculture development is critical to the nation's food security. While U.S. aquaculture production is increasing, there remain significant bureaucratic and social constraints. In an effort to compare and contrast the numerous shellfish aquaculture permitting systems and their constraints, NOAA Fisheries supported a comprehensive review of federal, state, and local shellfish permitting systems around the nation.

This report, prepared by Earth Resource Technology Incorporated, provides 15 recommendations based upon a review of 22 shellfish aquaculture permitting systems in 2016 covering all coastal states in the continental United States (East Coast, West Coast, Gulf of Mexico, and Alaska). Permitting systems in Hawaii/Pacific Islands and Puerto Rico/Caribbean are not addressed in this report. The report acknowledges the importance of fostering sustainable shellfish aquaculture in the United States and the challenges and opportunities for moving the industry forward.

Implementation of the 15 recommendations will require an executive level commitment at the federal and state level. This study also revealed the need for improved communication among federal and state shellfish aquaculture coordinators and regulators across the nation. The 'stage' of each state's shellfish aquaculture development varies significantly. In many instances, problems which exist for one state have already been experienced and addressed by another. Establishing, sharing and maintaining a depository of shellfish aquaculture permitting information will enable coordinators to more quickly identify proven solutions. Using research obtained to support this study, a state-by-state spreadsheet summarizing shellfish permitting systems and industry characterization information for 22 states was prepared. This state-by-state spreadsheet and the full Evaluation of U.S. Shellfish Aquaculture Permitting Systems report will be discussed.

CONNECTICUT SHELLFISH: PLANNING FOR CONSERVATION, MANAGEMENT, RESTORATION

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Bivalve shellfish including oysters, clams, mussels and scallops are part of a healthy Long Island Sound and play a role in improving impaired estuarine environments. Natural shellfish reefs and cultivated shellfish beds provide numerous ecosystem services including habitat and food provision for marine organisms, water filtration and erosion control. However, not all of these habitats are in the optimal condition to support the provision of ecosystem services, fisheries or aquaculture production, or their status is simply unknown. Historically, the state's shellfish beds have been impacted by pollution, severe storms, overfishing and development. Today, changing environmental conditions pose new threats including sea temperature change, sea level rise, ocean acidification, severe weather and increasing frequency and intensity of rainfall and drought. Given their ecological and economic importance, environmental managers proposed the development of a plan to conserve, manage and restore Connecticut's native shellfish resources. The plan will recommend actions to protect existing shellfish beds from human and environmental threats; to create or enhance shellfish beds for ecosystems services such as providing habitat, improving water quality, and stabilizing shorelines against erosion; and to rehabilitate historic shellfish beds for fisheries and aquaculture production. The process will involve an analysis of environmental and human use data and will engage key players to: 1) identify and address current barriers to restoration; 2) provide outreach about regulatory requirements; and 3) recommend high priority restoration projects and practices.

HATCHERY CERTIFICATION TO SIMPLIFY INTERSTATE TRANSFERS OF SEED

Robert Rheault. East Coast Shellfish Growers Association, 1623 Whitesville Rd., Toms River, NJ 08755.

The goal of the Shellfish Hatchery Certification Program is to streamline the process for permitting the interstate commerce of bio-secure bivalve shellfish seed and larvae being sold directly from qualifying hatchery facilities along the East Coast. The Program is voluntary and relies on three prerequisites: 1) the hatchery must adhere to a set of Best Management Practices and submit to an annual inspection of facilities and records, 2) the hatchery must have a history of clean pathology reports for the three most recent years (no detection for most pathogens, low detection for ubiquitous pathogens like dermo), and 3) the qualifying seed must have never been exposed to raw, unfiltered seawater. Use of a hatchery's certification to bypass batch testing for diseases prior to transfer of seed is contingent upon voluntary acceptance of the Certification Program by authorities in receiving states.

The rationale for certifying hatcheries relies on the young age of seed, which are unlikely to acquire infections in the hatchery phase; the high level of water filtration limiting exposure to pathogens; and the reliability with which a history of disease freedom can be established, maintained, and demonstrated via surveillance as compared with older, nursery or field-planted seed.

Qualifying certified hatcheries shipping into states or waters within a state where certifications are recognized would be able to avoid some of the need for batch testing of seed, avoiding costs and delays associated with batch testing. Hatcheries not participating would be able to continue to utilize batch testing if required. An independent entity will oversee the program. States will be able to assess whether or not the program meets risk requirements and whether or not a certified hatchery is meeting participation requirements by reviewing annual audits and other documentation.

MEASURING WAVE AND CURRENT FORCING AND MOORING TENSION RESPONSE OF AN AQUACULTURE SYSTEM OF *Saccharina latissima*

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Specifying mooring system aquaculture gear requires an understanding of component loads in response to forces due to waves and currents. The objective of this presentation is to describe engineering measurements from *in-situ* field instrumentation used at an exposed aquaculture site of *Saccharina latissima* (sugar kelp) in Saco Bay, Maine USA. The aquaculture system consisted of a single, 122 meter kelp-line that was deployed in November and seeded in December 2018. By the end of April 2019, the sugar kelp had grown to lengths between 1-1.5 meters with an estimated biomass of 8 kg/m. To capture mooring system tensions, submersible load-cell instruments were deployed on each anchor leg from April 24 to May 1. The waves and currents were measured at the same time with two Acoustic Wave and Current (AWAC) sensors built by the Nortek Group (www.nortekgroup.com). The two AWACs were deployed adjacent to the load-cells. Maximum current velocities measured with the AWACs exceeded 0.5 m/s. The AWACs also measured a wave event having a significant wave height of 2 meters with a maximum wave approaching 4 meters. Both load-cell instruments measured the anchor-line tension response to the wave and current forcing during the deployment period yielding average values between 540-630 N with a maximum value over 2700 N. Relationships between waves, currents, biomass and tensions are being developed to understand system dynamics and for the purpose of validating computational modeling techniques.

ENGINEERING ANALYSIS OF MUSSEL BACKBONE SYSTEMS FOR OPEN-OCEAN SITES

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Sustainable open-ocean shellfish farms must be properly designed to withstand extreme waves and currents, while simultaneously allowing for efficient operations, maximum biomass production, and budget considerations. An engineering approach was used to determine an appropriate backbone design for the Ventura Shellfish Enterprise (VSE) project to be located in federal waters outside Ventura Harbor, California. Several designs were tested using numerical models to address regulatory concerns about the backbone structure's ability to withstand storms at the selected site.

Extreme wave, wind, and current values were quantified for 100-year and 20-year return periods at the selected project location by fitting Gumbel distributions to historical data for the site. The dynamic behavior of the system was quantified under the extreme storm conditions using a hydro-/structural dynamic finite element approach. The engineering approach considered four factors: Survival (minimum required capacities of lines and anchors); operations (force required to lift the backbone for maintenance and harvesting, installability, and navigability); performance (RMS accelerations of mussel ropes as a proxy for mussel drop-off; ability to facilitate predation avoidance); and budget (minimum required component sizes and availability of components). Multiple design alternatives were compared based on those four factors. Additionally, a theoretical limit for the percentage of mussel weight that should be supported by submerged buoyancy was established as a function of incident current speed. This limit is based on the force balance between the wet weight of the mussel ropes and the vertical component of normal drag on the mussel ropes as they lay back at an angle due to the incident current. For the maximum expected mussel growth considered in this application, it was found that the maximum submerged buoyancy should be limited to two-thirds of the wet weight of the mussel droppers.

OFFSHORE LONGLINE AQUACULTURE WILL NOT LIKELY ADVERSELY AFFECT PROTECTED SPECIES

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As aquaculture expands into offshore waters and the EEZ, farm sites must be properly sighted to avoid common migratory routes of protected or endangered marine species while minimizing any potential negative effects from interactions through design and monitoring. The NEMAC offshore mussel farm has been operating in the Atlantic Ocean EEZ for over three years with no negative interactions with any threatened or endangered species listed under the ESA of 1973, as amended. We will present our monitoring efforts and the effectiveness of the gear design to ensure offshore shellfish aquaculture activities are not likely to adversely affect protected or endangered marine species.

Aquaculture longlines are anchored structures under tension and have been falsely associated with “fixed” fishing gear as a potential risk for entanglement. Vertical pick-up lines to the surface are required to utilize break-away links or weak line strengths that reduce the potential risk of entanglement. Our longlines have been deployed since 2016 with no interactions with any protected or endangered species even though whales have been sighted in the area. We will also present data from other offshore longline farms that demonstrate this activity is not likely to adversely affect protected or endangered marine species and should be allowed to develop commercially in the EEZ.

NURTURING THE SUCCESSFUL GROWTH AND MATURATION OF A DOMESTIC SEAWEED AQUACULTURE INDUSTRY

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Seaweed aquaculture is an emerging industry in the United States and several states are actively cultivating seaweed at commercial or research/investigative scale. Although there are many challenges still preventing the industry from becoming commercially viable, the following four main challenges have been identified:

1. Lack of identified and established diverse markets for domestic seaweed;
2. Lack of commercial-scale post-harvest processing, storage, and transportation infrastructure, and associated policies and regulations;
3. Increasing food safety concerns and lack of guidelines and standards for handling, processing, storage, and distribution for different domestic seaweed products, species, and production methods which may be impacted by regional and/or state differences with regard to oversight responsibility; and
4. Lack of clarification in the permitting process for seaweed aquaculture.

There is a need to compile the available science-based, non-proprietary, practical resources related to previous and current research and outreach efforts into a mechanism that is easily accessible by everyone. A national effort led by Sea Grant is underway to address these challenges and look for viable opportunities for domestically produced seaweed through several processes:

1. A thorough needs assessment of all seaweed stakeholders in seaweed producing states;
2. The first National Seaweed Symposium will be convened to disseminate results from the needs assessment and refine challenges and opportunities to be addressed;
3. Stakeholder-driven work groups will be established to address challenges and opportunities identified from the needs assessment and Seaweed Symposium;
4. A website dedicated to this effort will be established providing up-to-date information and status of on-going efforts including work group projects and outputs.

Through this nationally-focused and collaborative effort, the Sea Grant established Seaweed Hub will provide current and prospective seaweed stakeholders information on the status of the domestic seaweed industry in order to make more informed decisions as well as provide a chance to participate in addressing challenges and pursuing viable opportunities.

SELECTIVELY IMPROVING STRAINS OF SUGAR KELP *Saccharina latissima* FOR FOOD AND FUEL

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As part of ARPA-E's MARINER program, we are pursuing a selective breeding program to improve the productivity and composition of *Saccharina latissima*, which could serve as feedstock for biofuels. A MARINER goal is to develop tools and a pathway toward low-cost (< $80/DWT) feedstock that could ultimately supply 10% of US liquid transportation fuels. In our progress to date, USDA/Cornell and HudsonAlpha have employed PacBio and Illumina sequencing to create a deep-sequenced reference genome and establish a variant catalog for our founding populations and families. WHOI, UCONN and GreenWave have started a second season of field trials of hundreds of founding families. Each family consists of hundreds of unique sporophytes resulting from crosses generated from hundreds of microscopic gametophytes isolated from more than a dozen wild collections in New England. These families were planted in "common garden" farm arrays in New Hampshire (2018 and 2019) and in Connecticut (2019). Analysis of our phenotypic and genotypic results will be presented along with our progress in identifying variants significantly associated with primary productivity and composition traits. One project goal is to develop methods to predict offspring (sporophyte) performance based upon genotype and breeding values of parents (gametophytes) for rapid cycle breeding approaches and to improve the efficiency on-farm testing. Ultimately, our goal is to select sugar kelp best suited for offshore farm environments and possessing qualities of 10% increased dry matter yield per unit area per generation, and improved composition for use as a bioenergy feedstock.

INVESTIGATION OF THE SHELTER EFFECTS OF SUGAR KELP, *SACCHARINA LATISSIMA*, ON PELAGIC ANIMALS IN LONG ISLAND SOUND KELP FARMS.

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Sugar kelp, *Saccharina latissima*, is currently cultivated in Long Island Sound by a number of artisanal operators. With a profound impact of agriculture, impervious surface runoff, lawn fertilizer, and other human nutrient impacts on the Sound, kelp and shellfish aquaculture holds potential for improving water quality through bioextraction and providing an economic incentive for restoration of fisheries (Rose et al. 2015). Numerous studies have shown an increase of abundance and biomass of early life stages of fish associated with kelp forests (Steneck et al. 2002). It has been reported that the LIS waters are high in resident and migratory finfish diversity and are the feeding and nursery grounds for over 100 species (Gottschall & Pacileo 2010, Latimer et al. 2014). We successfully deployed a novel mounting system for cameras to monitor down kelp lines, and were able to produce about one hour of footage per deployment, regardless of weather conditions. To determine finfish usage of these systems, a GoPro Hero4 camera with a magenta filter was deployed viewing along the longitudinal direction on kelp aquaculture lines. The design successfully monitored pelagic animals, particularly lion's mane jellies, *Cyanea capillata*, during the April deployments. We found that this method allowed for a stable observation of animals using the lines and that we can also observe kelp growth as a proxy for shelter quantity. For winter 2020, an additional component we hope to add are bottom surveys utilizing TMA divers and its ROV, on both farmed sites and natural sites. These will be completed each month, concurrent with the deployment of cameras. We are also going to use the winter 2018-2019 lessons to improve deployment frequency, and continue to avoid the camera flooding problem that was prevalent early last season.

DIVERSIFYING NEW YORK'S MARINE AQUACULTURE INDUSTRY: INTEGRATING SUGAR KELP INTO SHALLOW-WATER OYSTER FARMS

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New York's marine aquaculture industry is almost exclusively focused on the Eastern oyster *Crassostrea virginica*, and this lack of crop diversification leaves NY marine farmers financially vulnerable to downturns in oyster crop production or pricing. Sugar kelp (*Saccharina latissima*) is an emerging marine crop in the U.S. with several features that make it ideal for integration into NY oyster farms: 1) an opposite growing season from oysters; 2) vertical integration with oysters creating additive revenue streams; 3) growth benefits to oysters when in combined cultivation. Previous work has developed profitable sugar kelp cultivation methodologies using suspended horizontal longlines in deep waters (i.e. > 6 m), with the conventional wisdom being that kelp blades need to be kept off the bottom to avoid fouling and grazers. However, most NY oyster farms are located in waters shallower than 6 m at MLW. In this study, we customized cultivation methods and compared kelp growth and quality between shallow and deep water environments. Horizontal longlines were seeded with kelp in December 2018 at a shallow water oyster farm (MLW ~0.5 m) in Moriches Bay (MB) on Long Island’s south shore, and at a deeper water farm (MLW ~ 6.5 m) in the Long Island Sound (LIS). At the shallow water site, horizontal lines were staked at a fixed distance (0.38 m) above the bottom. At the deep water site a more conventional suspended longline system was installed, with the kelp line buoyed at a fixed distance (1.5 m) below the surface. Sugar kelp grew successfully at both sites, however the timing and patterns of kelp growth and quality differed. Growth was greater at the shallow MB site during the first 3 months after seeding, with very little growth observed at the deeper LIS site during this time. In April, growth began to accelerate in LIS, and decrease in MB. Peak biomass (wet weight) was observed in mid-April in MB (5.9 kg m^{-1}), but not until mid-June in LIS (6.1 kg m^{-1}). Kelp blades in MB remained in high quality and largely free of grazing and fouling into mid-April, and then began to noticeably deteriorate as water temperatures warmed. Kelp quality remained high in LIS through mid-June. Our demonstration of shallow water kelp farming unlocks potential opportunities for NY marine farmers previously thought implausible, and may provide NY oyster farmers with a means to diversify crops and create additive revenue streams.

EPIBIOTIC COMMUNITIES ON AQUACULTURED SUGAR KELP SACCHARINA LATISSIMI, THE VISIBLE AND THE INVISIBLE

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The sugar kelp, *Saccharina latissima*, is being developed as a winter aquaculture crop in southern New England coastal waters. Timing of harvest in the spring is a compromise between quantity, as blades continue growing, and quality, mainly related to epibionts that colonize blades and decrease marketability. Monitoring of epibiota, including epiphytes and epifauna, was conducted on aquacultured sugar kelp collected from a commercial farm near Groton, CT during March to May of 2018. Intent of the study was to inform farmers about maximizing production while minimizing undesirable fouling. Visual observations, bacterial culture targeting the *Vibrio* group, and SSU (16S and 18S) rDNA amplicon-based, next generation sequencing (NGS) were employed to characterize epibiotic communities, with ambient sea water samples also collected for NGS analysis. Visually, less than 1% of blade surface was covered by epibionts, with colonial hydroids being the dominant species, and brown and red algae also present. Among the extremely diverse eukaryotic communities identified using NGS, diatoms *Tabularia*, *Navicula*, *Nitzchia*, *Fragilariales* and *Cylindrotheca*, ciliates Conthreep and Phyllopharyngea, brown algae Ectocarpales and *Scytosiphon*, and red algae in the Rhodymeniophycidae were significantly more abundant on blades than in the ambient sea water. Thiosulfate-Citrate-Bile-Sucrose Agar culture revealed presence of *Vibrio* bacteria on the surface of one distal third of blades (not in the middle or stipe) in May samples only, and none were found to be the pathogenic strains through PCR tests. NGS confirmed the presence of *Vibrio* bacteria in May. Classification to species level will be conducted through Sanger sequencing on isolated *Vibrio* strains. NGS identified Flavobacteria *Muricauda* and *Aquimarina*, Alphaproteobacteria *Litorimonas*, Hyphomonadaceae, and *Hyphomonas*, Virrucomicrobiae Verrucomicrobiales, and 6 genera of Gammaproteobacteria *Saccharospirillum*, *Marinobacter*, *Alcanivorax*, *Marinobacter*, *Arenicella*, and *Porticoccus*, to be statistically more abundant on blades than in the ambient sea water. This may suggest that, compared to the free-living bacteria in seawater, bacteria associated with blade surface could be more efficient at degrading hydrocarbon compounds. Follow-up on Vibrio bacteria associated with kelp blades is suggested, but marketability of kelp was not severely compromised by the termination of sampling in May when the farm was harvested.

ACES: A FREE ONLINE SHORT-COURSE FOR SEAWEED AND MICROALGAE AQUACULTURE

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The Algae Foundation's Algae Technology Educational Consortium (ATEC) formed the Algae Cultivation Extension Short-course (ACES) to serve as a workforce preparedness program for those interested in growing both micro- and macro-algae.

The seaweed course is a free online compendium of videos chosen and newly created to give a thorough initiation into the culture of various commercial seaweeds, including kelps, for those interested in getting started in algal-based aquaculture. The course includes: a large number of videos produced by several New England Sea Grant programs; international content; guided PowerPoint presentations. Additionally, newly created videos include: industry pioneers; history of wild harvesting and culturing macro-algae; seaweed products; longline setting; harvesting methods; drying techniques; conversations about peoples' experiences in seaweed culture; and the permitting process.

The microalgae for aquaculture course is an online compendium of videos and online lectures chosen to give a thorough introduction into the culturing of various commercial microalgae. The course includes: a large number of videos produced by national and international programs, and guided PowerPoint presentations; including selections from the Santa Fe Community College, Introduction to Algae Cultivation online course. Offerings include: cultivation and harvesting technologies, microscopy, algae species collections, nutrient media recipes, algae to fuel, carbon sequestration, food products and interviews with industry experts. There are additional chapters for the online algae culture collections, interviews and Ted Talks. There are several longer webinars and documents about microalgae culture that can be downloaded.

These free courses require a simple registration and analytics about the student's experience with the course recorded for program evaluation. The short-courses can be found on the web at http://www.algaefoundationatec.org/acesintro.html.

MAINE SCALLOP AQUACULTURE DEVELOPMENT INITIATIVE: COMMUNITY DEVELOPMENT THROUGH INTERNATIONAL TECH-TRANSFER

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Climate change has profoundly impacted capture fisheries in the Gulf of Maine. Notably, the largest fishery in the United States is in flux: landings of lobster (*Homarus americanus*) have shifted northeast in recent years. These challenges - not unique to Maine and are experienced by the Japanese fisheries - have caused great uncertainty among fishermen in Maine. In response to wild fisheries challenges, Maine based Coastal Enterprises, Inc. (CEI) a private, nonprofit Community Development Corporation (CDC) and Community Development Financial Institution (CDFI) has been fostering relationships between Maine commercial fishermen and Japanese scallop farmers for the past 10 years. Several exchanges have occurred between Aomori, Japan and Maine to learn, adopt and develop a scallop aquaculture industry in Maine.

Japan produces ~500,000 metric tons of scallops per year with Aomori ranking 2nd (to Hokkaido) in scallop production for all of Japan producing ~90,000 metric tons of scallops annually. Aquaculture practitioners in Maine desire to incorporate Japanese expertise, to effectively ramp up and provide a new source of protein. Through ongoing exchange, we seek advice with lease site set-up and husbandry, growout techniques, biofouling, predators, equipment and machinery, handling, processing, markets and value-added product opportunities. This innovative and unique collaboration offers a one-of-a-kind exchange experience that is helping to further strengthen ties between the United States and Japan. The introduction of Japanese technical knowledge and equipment to the Maine aquaculture industry is the first of its kind in the United States and is groundbreaking for the American aquaculture community.

Commercial production trails are currently underway using specialized Japanese scallop farm equipment in Maine to test the feasibility of the several techniques for growing Atlantic sea scallop. A presentation will include photos and videos illustrating the adaption of Japanese scallop culture methods applied to Atlantic sea scallop (*Placopecten magellanicus*) in the Gulf of Maine. Scallop aquaculture production cycle and various grow out techniques including spat collection, pearl nets, lantern nets and ear-hanging will be presented. Long line system setup, equipment adaption and the use of a typical lobster fishing vessel will also be covered. Participants will gain a better understanding of progress to date and current efforts that are underway in Maine to develop a robust scallop aquaculture industry for growers by implementing techniques adapted from Aomori, Japan.

MEASURING SEA SCALLOP, *PLACOPECTEN MAGELLANICUS*, FEEDING AND FILTRATION RATES TO INFORM AQUACULTURE SITING IN COASTAL MAINE

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Shellfish aquaculture is well established in coastal Maine. The industry provides employment and a strong contribution to local economies, helps maintain working waterfronts, and is an important source of locally-grown seafood. Currently, a group of growers has added the sea scallop, *Placopecten magellanicus*, to the suite of shellfish being cultured. The success these growers have experienced and the emergence of a new market for a “whole animal” product have spurred interest in expanding sea scallop aquaculture in coastal Maine. Scientists from the NOAA Fisheries lab in Milford, Connecticut made a series of farm-site visits and held public meetings with farmers and other stakeholders to gauge the potential value of targeted research projects accelerating development of sea scallop aquaculture. Following a model recently established to support a pilot-scale, offshore mussel aquaculture project in the northeast United States (Mizuta and Wikfors 2019) and incorporating feedback from stakeholders, several research priorities were identified. Site selection criteria for sea scallop farms, establishing reliable hatchery and nursery methods, and mitigating the deleterious effects of harmful algal blooms were all identified by growers as high-priority research topics. Understanding how sea scallops use available trophic resources is an important aspect of siting a farm. In June and September of 2019, a team from the Milford lab visited the University of Maine’s Darling Marine Center to conduct feeding and filtration trials using the biodeposition method. 31.8 mm to 61 mm sea scallops taken from an experimental farm site in the Damariscotta River were used for the trials. Preliminary data show that sea scallops have a very high absorption efficiency, averaging above 0.9. They can be more efficient at acquiring nutritional value from the seston they ingest than other commonly-cultured shellfish tested to date. Sea scallop clearance rates and absorption rates were comparable to other cultured shellfish; whereas, sea scallop filtration rates were lower than other cultured shellfish. These results, coupled with growth rates reported by academic and industry partners, indicate sea scallops have strong potential as an aquaculture species on appropriately sited farms. By conducting more biodeposition trials with sea scallops under varied conditions, it will be possible to establish boundary conditions relative to seston quantity and quality that can act as a site-selection filtering tool.

EXPANDING OYSTER AND QUAHOG POLYCULTURE

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The Gulf of Maine is warming faster than 99% of the world's oceans, threatening the livelihoods of thousands of Mainers who make a living from the sea. Marine resource diversification is essential for adapting to this rapid change and ultimately promoting economic resilience for Maine's coastal communities. Subtidal quahog aquaculture could be an opportunity for sea farmers to expand their operations and diversify their crops by utilizing the vertical space of the water column. This project builds upon research exploring the viability of quahog and oyster polyculture that was initiated by Jordan Kramer, a Maine oyster farmer, in 2017. Preliminary results from Kramer's pilot study indicate that it takes 2-3 growing seasons for quahog seed to reach market size, and that aquaculture grown quahogs fetch a premium market price. In August 2019, we expanded the testing of quahog and oyster polyculture to three additional farms in midcoast Maine to determine if this technique is economically viable and replicable on other farms. We are currently monitoring survival and growth at each farm, as well as environmental variables such as temperature, salinity, pH, and chlorophyll. This project will conclude in the fall of 2020, and results will be used to determine the viability of quahog aquaculture in Maine.

DIVERSIFICATION OF BIVALVE AQUACULTURE IN NEW JERSEY: NEW SPECIES AND SEED LINES FOR HIGH-SALINITY BACK BAY HABITATS

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Bivalve aquaculture is one of the most important aquaculture industries in the US and has the potential for significant growth; however, further development of this industry is threatened by diseases, unpredictable mortality, and a lack of crop diversity. Supporting this growth requires selective breeding, and testing novel species for performance in the nursery and at farms. In New Jersey, like many east coast states, shellfish farms primarily cultivate eastern oysters (*Crassostrea virginica)* or hard clams (*Mercenaria mercenaria).*

As farm opportunities expand into high salinity coastal habitats, it becomes important to identify new species, and to support selective breeding of existing species to produce seed lines that will excel in these habitats.

In 2019 we began a program to broaden performance of our selected lines of oysters and include two additional native species, bay scallop (*Argopecten irradians*) and Atlantic surfclam; all focused on performance in high salinity environments. The two new species are promising aquaculture crops with rapid growth rates, but both face challenges of thermal-related mortalities in winter and summer, respectively.

The Atlantic surfclam (*Spisula solidissima)* represents a target species for crop diversification because it is native, grows rapidly, and fits into the established farming framework. Surfclam aquaculture is not entirely novel, and culture techniques were developed previously, yet commercial-scale nursery and grow-out methods remain understudied. We recently evaluated the feasibility of surfclam production in New Jersey by testing nursery rearing conditions, grow-out techniques across multiple farms, and post-harvest aspects like shelf-life and marketing. Surfclams are known to be vulnerable to high temperatures - an issue that will be exacerbated by climate change and one that may already be problematic on shallow coastal farms. Therefore, high temperature stress may be a limitation to surfclam production. Consequently, we assessed the potential for heat stress tolerance in surfclams and found evidence suggesting the trait may be heritable. Likewise, we are using selective breeding techniques to improve bay scallop growth and enable within-year harvest, hence avoiding exposure to the coldest temperatures of the year.

In 2019, multiple selected lines of oysters, bay scallops, and surfclams were produced, and subsequently deployed with replication at three farms in Barnegat Bay, NJ for evaluation of growth and survival. Identification of the best-performing stocks will pave the way for the growth of high-salinity shellfish farms along the Northeast coast.

CORRECTING THE EFFECTS OF NONPHOTOCHEMICAL QUENCHING ON CHLOROPHYLL *A* QUANTIFICATION IN COASTAL ECOSYSTEMS

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Available food for suspension-feeding mollusks, mainly consisting of phytoplankton, is extremely important for sustainable aquaculture. Chlorophyll *a* (Chl*a*), often used as an index of phytoplankton biomass, is measured routinely by one of two methods: 1) the extraction method, or 2) the *in vivo* fluorescence (IVF) method. The two approaches, however, often disagree with each other for a number of reasons. In this study, we aimed to find a solution to correct for the effects of nonphotochemical quenching (NPQ) on Chl*a* IVF. In the lab, *Thalassiosira pseudonana* and *Thalassiosira weissflogii*, two coastal diatoms, were cultured under a sinusoidal, bright-white light regime; Chl*a* IVF was monitored continuously, and NPQ was measured every 2 to 3 hours. Based upon the results, we will present an explicit mechanism of how NPQ affects Chl*a* IVF. Accordingly, a Diatoxanthin ─ Nonphotochemical quenching ─ Fluorescence (DNF) model can be developed to predict the NPQ magnitude, thereby estimating the unquenched Chl*a* IVF. Further work is required to verify the combined model of NPQ and colored dissolved organic matter (CDOM) corrections for Chl*a* determination in the natural coastal environment.

IT ONLY LOOKS COMPLICATED: A DISSECTION OF HORN POINT OYSTER HATCHERY'S USE OF AN AUTOMATED FEEDING SYSTEM TO REAR OYSTER LARVAE

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An important component of any successful shellfish hatchery is the ability to feed the produced larvae. Traditionally, many hatcheries have relied on hand feeding of live algae, continuous pumping of batch cultures or use of preserved algae diet. At the original Horn Point Oyster Hatchery, eastern oyster *(Crassostrea virginica)* larvae were fed once a day by hand using a pump, hose, and timer. When the Aquaculture and Restoration Ecology Lab was built circa 2003, to include the Broddus and Margaret Ann Jones Oyster Culture Facility (Horn Point Oyster Hatchery), the goal was to become more efficient by designing systems to automate several processes. While the system continues to be modified regularly, the earliest version of the "Automated Algal Feeding System" (AAFS) revolutionized rearing of oyster larvae in the Horn Point Lab Oyster Hatchery and is still a cornerstone in the algae rearing system today. The AAFS is broken down into several components, all of which include the need for user input. Processes that have been automated include regular sampling to measure fluorescence of both algal and larval rearing tanks, calculations of feed volumes, and delivery of algae to larval tanks inside the building from the greenhouse where it's grown. Using the AAFS, oysters are able to receive a fairly consistent diet throughout the day versus bombarding them with a single meal and causing a binge-starve cycle. Additionally, they are able to receive up to four species per feeding due to the system's division into four zones. Since implementation, Horn Point Oyster Hatchery has witnessed a significant improvement in setting efficiency. This is largely attributed to the innovative technology of the Automated Algae Feeding System.

CORNELL COOPERATIVE EXTENSION OF SUFFOLK COUNTY: SHELLFISH HATCHERY EXPANSION

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In September of 2017, The Long Island Shellfish Restoration Project was announced by Governor Andrew Cuomo in effort to improve Long Island's water quality and to boost the economies and resiliency of coastal communities by restoring native shellfish populations to coastal waters. Cornell Cooperative Extension of Suffolk County's Marine Program has been tasked with the production of millions of shellfish needed to meet the project goals. In order to reach these numbers, one of the of key components of the project included the development and expansion of the shellfish hatchery at the Suffolk County Marine Environmental Learning Center in Southold, NY. This expansion meant the top to bottom construction of a new larger hatchery building to replace the smaller pre-existing hatchery. This new hatchery would include four brood stock tanks, thirty conicals, twelve down-welling tanks, four large round spat-on-shell tanks, twelve up-welling tanks, a forty bag SEA CAP algae system, four Industrial Plankton Bioreactors, and a separate algae lab. This presentation will take a look into and highlight aspects of the new hatchery's development and construction processes, trial and errors, what moving from a small to larger scale hatchery entailed, and a look at the final outcome of the shellfish hatchery expansion.

CORNELL COOPERATIVE EXTENSION OF SUFFOLK COUNTY ALGAE EXPANSION CONTINUED

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Algae culture is an essential component for shellfish aquaculture. For over 20 years Cornell Cooperative Extension of Suffolk County (CCE) has cultured various algae strains for shellfish cultivation. Recently Cornell Cooperative Extension has expanded their existing hatchery with the development of a second hatchery in order to increase shellfish production numbers. With this expansion, algae production needed to increase as well. To meet this demand CCE purchased a 40 bag SEA CAP algae system as well as four 1250L bioreactors made by Industrial Plankton. The SEA CAPS algae system is a continuous bag system that is used by many hatcheries around the world. Water, nutrient, and algae inflow and outflow is all contained in a system of glass tubes. Water flowing into the system passes through a pasteurizer ensuring a constant source of clean water, nutrients are directly injected into the system via a peristaltic pump. The bioreactors however are new technology that has the capability to grow high density algal cultures in a hyper-controlled environment. The machine, as advertised once inoculated automatically adjusts light, PH, temperature and nutrient amounts based on the density of the culture. CCE is beyond ecstatic to have the ability to expand their algae production capacity using both the SEA CAPS system and bioreactors. I will be discussing the differences in algal output, cost, benefits and drawbacks of each system. In addition to the comparison I would also like to expand and share our experience after running each system for a year. This comparison will give other people who are considering these systems insight into choosing which system would work best for them.

SPAT-ON-SHELL OYSTER PRODUCTION FOR NEW YORK STATE'S LONG ISLAND SHELLFISH RESTORATION PROJECT

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Starting in 1991, Cornell Cooperative Extension of Suffolk County (CCE) founded a municipal hatchery that has grown shellfish seed for a number of townships on Long Island, as well as working on applied research projects. In 2010, working with the New York City Department of Environmental Protection and other partners, we built a pilot-scale oyster reef and deployed 12 small Reef Balls in two locations in Jamaica Bay. This project required building an outdoor remote setting system, as we had only produced small quantities of spat-on-shell oysters in the hatchery up to this point.

In 2017, New York Governor Andrew M. Cuomo announced a $10.4 million effort- the Long Island Shellfish Restoration Project (LISRP) to improve Long Island's water quality and bolster the economies and resiliency of coastal communities by restoring native shellfish populations to coastal waters. We were tasked with growing tens of millions of oysters and hard clams for this effort over two years. With a budget of $5.25 million CCE built a state-of-the-art hatchery, 70 floating upweller systems and a larger oyster setting system for spat-on-shell production.

In 2018-19 CCE produced 35 million spat-on-shell oysters for the LISRP which were planted at four sanctuaries in Nassau and Suffolk counties. We will discuss how we scaled up production for this project and what was required in terms of equipment, seawater and shell handling before and after setting.

EFFECTS OF A NEW FORMULATION OF PROBIOTIC STRAIN OY15 IN PREVENTING BACTERIOSIS IN LARVAE OF THE EASTERN OYSTER (C*rassostrea virginica*).

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The livelihood of the U.S. seafood aquaculture industry, valued at $1.5 billion in 2016 (FAO), depends upon healthy larvae to sustain dependable hatchery seed production of shellfish. Yet under intensive cultivation, bacterial disease is a major constraint to commercial shellfish larviculture, causing massive mortalities and financial challenges for the oyster industry. In an effort to improve hatchery production of Eastern oyster (*Crassostrea virginica*) seed for aquaculture and restoration, NOAA's Milford Laboratory has discovered and evaluated a naturally-occurring beneficial bacterial isolate, probiotic strain OY15 (*Vibrio alginolyticus*), from the digestive gland of an Eastern oyster from Long Island Sound. This benign bacterial strain has shown significant, protective effects against a shellfish larval pathogen B183 (*Vibrio corallyliticus*) in experimental larval trials and improves survival by 20-35% in pathogen-challenged larvae of the Eastern oyster. OY15 improves survival by stimulating immune defense functions of white blood cells (hemocytes), critical in pathogen elimination in shellfish. To make OY15 available to commercial oyster aquaculture facilities, NOAA's Milford Laboratory has established a Material Transfer Agreement (MTA) and partnership with Prospective Research, Inc. Prospective Research has produced a stable, powdered formulation of probiotic OY15, which has been tested for efficacy in pilot-scale trials on Eastern oyster larvae. Results from this trial will provide the necessary insight to move toward the final testing phase in commercial hatchery-scale trials and subsequent commercialization of probiotic strain OY15.

EAST COAST HARD CLAM SELECTIVE BREEDING COLLABORATIVE

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The hard clam, *Mercenaria mercenaria*, is among the most economically valuable bivalve species in the United States. It is extensively cultured along the Atlantic seaboard and represents the most important marine resource in several states including New York, Virginia and Florida. Maintenance and growth of this aquaculture industry relies on hatchery production of seed, and billions of seed clams are produced annually to fulfill aquaculture and restoration needs. Several states regularly suffer losses in aquacultured and wild hard clam stocks due to disease (e.g. QPX disease in the Northeast) and environmental stress (e.g. extreme heat waves in Florida). In this context, the production of quality seed able to survive under harsh biological and environmental conditions represents a major priority for the aquaculture community. This collaborative initiative builds on ongoing cooperation and new partnerships among Sea Grant programs, scientists and extension teams in five Atlantic states to develop a hard clam selective breeding program using state of the art genomic tools, for the benefit of clam farmers throughout the region. The team is about to complete the sequencing and assembly of the hard clam genome that will be used to develop an efficient and cost-effective genotyping platform (SNP array) for *M. mercenaria*. The genotyping platform will then be used to enable genome-assisted selection for traits relevant to various regions supporting the growth of the hard clam aquaculture industry. These activities will serve as a basis for the establishment of clam breeding programs linking scientists, extension network and the industry to provide growers with superior clam stocks.

COASTAL ACIDIFICATION EFFECT ON THE PHYSIOLOGY OF THE EASTERN OYSTER, *CRASSOSTREA VIRGINICA*

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Global carbon dioxide emissions have increased significantly since the 1900s. The ocean absorbs one third of the CO_2 emitted, resulting in the ocean becoming less basic. Coastal ecosystems, where high nutrient levels and rapid growth of plankton further reduce pH, are especially vulnerable to pH declines. Facing abnormal CO_2 levels, marine organisms may expend more energy to regulate physiological chemistry and to build and maintain shells. The eastern oyster (*Crassostrea virginica*), an economically important bivalve in the United States, responds physiologically to ocean acidification (OA) with lower growth and effects on metabolic rates.

The effect of OA on eastern oyster bioenergetics was explored through a 10-week laboratory experiment in which 900 oysters were exposed to different pCO_2 levels (2100, 1500, 800 ppm), with half unfed and the other half exposed to natural seston supplemented with microalgae. Every two weeks, 180 individuals were sampled for length and weight. On weeks 2, 4, 8 and 10, respiration rates and feeding rates were measured in 7 individuals per condition. Results showed that assimilation efficiency and clearance rate were lowered with a decreasing pH; however, cumulative effects over 10 weeks were not sufficient to cause a significant difference in growth.

From these data, a bioenergetics model based upon the Dynamic Energy Budget (DEB) theory was calibrated. DEB modeling has been applied widely to bivalves and has allowed researchers to quantify effects of physical conditions upon physiological rates and maintenance costs. A DEB model was applied to different scenarios to predict how, in the future, oyster population could respond to elevated pCO_2 in the environment.

OCEAN ACIDIFICATION AND THE EASTERN OYSTER, *CRASSOSTREA VIRGINICIA*, SHOULD HATCHERIES BE CONCERNED?

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Environmental changes that have been identified in the Northeast include increases in precipitation, ocean warming, changes in water alkalinity, and ocean acidification (OA), which causes changes in pH and Ω due to increases in dissolved carbon dioxide (pCO_2). The Northeast United States has had an increase in precipitation of 10mm/decade and has had an increase in temperature at rates 3X greater than the global average. Data from the coast of Virginia to the Gulf of Maine indicate that seawater pCO_2 increased by an average of 2% from 2007 to 2015. For the Eastern oyster to remain an important aquaculture species the industry may need to account for ocean acidification and other climate change issues. The Milford laboratory used a combination of laboratory experiments and Dynamic Energy Budget (DEB) model to determine energetics costs of OA on pre-set oyster larvae.

Oyster larvae were exposed to three treatments levels of pCO_2 (control, mid, and high) and two levels of food (low and high). Growth rates, respiration rates, and lipid analysis were run during the 18-day experiment. Preliminary results indicate that when exposed to high pCO_2 oysters grew at a slower rate. At low food concentrations the oysters did worse under high pCO_2 than under high food availability. With high food availability, at day 18 cells were 32% smaller in size than oysters grown under control conditions at high food availability. Combined with the DEB, oysters will grow slower under increase acidity in the hatchery. These results suggest that monitoring and reducing the acidity of incoming water into a hatchery would be beneficial for growth.

EXAMINING THE POTENTIAL EFFECTS OF OCEAN ACIDIFICATION AND PARENTAL HISTORY ON EASTERN OYSTER (*CRASSOSTREA VIRGINICA*) LARVAE MORPHOLOGY

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Ocean acidification (OA) threatens shellfish production because it reduces the availability of carbonate ions in seawater, which calcifying organisms use to build their shells or skeletons. Larval stages are particularly vulnerable because of their rapid rate of calcification and their increased exposure of crystal nucleation sites to seawater. Changes in the growth rate and function of larval shells could result in longer time to larval settlement, increased stress during metamorphosis, and increased susceptibility to desiccation and predation. Most previous studies have assessed the impacts of OA on larvae with parents naïve to the effects of OA. However, history of parental exposure to OA could play a role in determining larval response to OA through nongenetic inheritance mechanisms. We examined the effects of parent and larval exposure to OA on the biomineralization and functional morphology of eastern oyster (*Crassostrea virginica*) larvae. Adult oysters were exposed to control (400 ppm pCO_2) or OA (2800 ppm pCO_2) conditions for 30 days. We produced zygotes with naïve and OA-exposed parents. We then exposed larvae from each cross to the control and OA conditions for three days. Larval exposure to OA, regardless of parental history, resulted in more rounded larval shells and increased the proportion of larvae with visibly extruded cilia – indicating a potential change in the ability of the larval shell to contain soft tissue and thus prevent desiccation and/or exposure to predation. Parental history of exposure to OA did impact larval shell size, however, with larvae from naïve parents exhibiting a greater decrease in median shell length when exposed to OA than larvae from OA-exposed parents. These results suggest that parental exposure to OA mitigates some of the negative impacts of OA on eastern oyster larvae.

IMPACTS OF OCEAN AND COASTAL ACIDIFICATION ON SEED OYSTERS REARED IN UPWELLERS, WITH SHELL HASH AS A POTENTIAL MITIGATION STRATEGY

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Detrimental effects of ocean and coastal acidification (OCA) have been determined for a variety marine taxa. Larval bivalves have been reported to be particularly sensitive, compared to juveniles and adults, through laboratory studies and through oyster hatchery production problems on both coasts. Laboratory-based studies with juvenile and adult oysters typically use static carbonate chemistry conditions within treatments -- conditions so different from variable field conditions that results are not easy to relate to conditions found on shellfish farms. Furthermore, hatcheries can mitigate effects of OCA upon larvae by buffering seawater in larval tanks, but mitigation options for oysters once they leave the hatchery are not as straightforward. We tested the responses of seed oysters to OCA in scaled-down, commercial upweller nurseries in a hybrid field-manipulation study. All treatments experienced natural temporal variability with respect to carbonate chemistry, temperature, chlorophyll, salinity, etc. Low pH treatments were created with offsets of 0.2 (T2) and 0.4 (T3) pH units below the ambient treatment (T1) by bubbling with an air-CO2 mixture. A fourth treatment (T4) of 0.4 below ambient also included oyster shell hash (500 µm) to test potential to mitigate OCA conditions in upwellers. We measured calcification rates, tissue weight, and shell height weekly over five weeks, along with characterizing the carbonate chemistry and food availability. Expression of genes associated with stress response was analyzed at week 1 and week 5 of the experiment. Calcification rates and tissue weights for T3 and T4 were consistently lower than T1 and T2. Calcification rate in T4 were higher than in T3 at weeks 3 and 4, coinciding with a higher saturation state in T4 relative to T3, coincident with dissolution of shell hash at an average rate of 0.12 g/day. Tissue weight means were slightly lower in T3 and T4 than in T1 and T2, with T4 tissue weights lower than T3, but no differences were significant statistically, despite extreme daily pH minima (as low as 7.3 in T1). These results may indicate that seed oysters raised in upwellers show resiliency to naturally variable OCA conditions. Indications were that shell hash may buffer acidified seawater and increase calcification rates in young seed oysters, but not sufficiently to equal present day calcification rates. More research is needed to refine upweller hash delivery mechanisms to maximize buffering potential and minimize impediments to food delivery.

THE SOUND SCHOOL ARTIFICIAL OYSTER REEF PROJECT: HABITAT RESTORATION IN NEW HAVEN HARBOR UTILIZING LAB CULTURED OYSTER SETS AND REEF BALLS™

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Oyster reefs have been documented to provide valuable habitat structure and ecosystem services as well as socioeconomic benefits. Native reefs once dominated many estuaries ecologically and economically. Studies have shown depletion and degradation of oyster reefs worldwide. Successful restoration efforts have further demonstrated the value of oyster reefs to coastal ecosystems and communities.

Reef Ball™ Modules (RBM's) are designed to mimic natural bottom structure and are being used to address a variety of environmental concerns. Initial investigations suggest that these artificial forms may have far reaching effects in habitat and species restoration efforts including; designing and growing artificial reefs, coral propagation and planting systems, estuary restoration, mangrove plantings, erosion control, and oyster reef restoration.

Over the past two years students and faculty at the Sound School built five Mini-Bay RBM's (width: 0.76m, height: 0.53m, weight: 91kg) using oyster shell as a cement additive. In May of 2018 the aquaculture laboratory at the school successfully spawned oysters. After the spawn three RBM's were placed in a set-tank with 200µm spat. The RBM's soaked for ten days. In June 2018 the RBM's, three with set and two unseeded, were deployed in near shore waters by the school campus. This process was repeated in 2019 with the construction of eight additional RBMs. Six were seeded with spat and all eight were deployed expanding the reef.

To date all modules with oyster set demonstrated successful oyster growth and survival over 50% of the surface. Additional recruitment from wild oyster set was documented on both seeded and unseeded RBMs. A variety of crab and fish species were observed using the RBM's. Oyster growth and recruitment, water quality, and biodiversity continue to be monitored.

A COMPARISON OF CONDITION AND SURVIVAL IN THE CTENOPHORE, *MNEMIOPSIS SP.*, BEING CULTURED WITH TWO DIFFERENT MICROALGAES

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Although bioluminescence occurs often in nature, the number of animals that create the actual enzymes/proteins required to bioluminess is relatively limited. Ctenophores, *Mnemiopsis sp.*, can produce their own bioluminescence and are therefore of interest to researchers who seek to use these bioluminescent compounds to track neuropathways in humans. In 2014 staff at the Sound School Regional Aquaculture Center in New Haven, Connecticut began discussions with researchers at Yale University about the possibility of culturing comb jellies in the school's Fish Production Laboratory.

The culture of Ctenophores is relatively new. Two species of the Genus *Mnemiopsis* are recognized on the East coast of the United States. *Mnemiopsis leidyi* is found in northern waters including Long Island Sound; a second, *M. mccraydi,* is found south of Cape Hatteras. During the fall *M. leidyi* are found in great numbers in near-shore waters of Connecticut. When local animals, *M. leidyi,* have not been available *M. mccraydi* have been purchase from Florida.

Two 70-liter pseudo-kriesals were purchased as culture vessels in 2015. They were plumbed and stocked with animals in the fall of 2016. Student engagement also began at approximately the same time. Several cohorts of animals were introduced into the systems with limited culture success. No Ctenophore cohort survived past day 18. In the fall of 2017 efforts were resumed. A variety of methods were introduced in an attempt to extend survival. In the Spring of 2018 one group of animals survived to day 150. During the 2018-19 school year the number of pseudo-kriesals was increased by two. A third identical 70 L vessel was installed as well as a larger 185 Liter tank. Again, numerous variations in the husbandry protocols were implemented as attempts were made to establish a lasting colony of animals. During this time data was collected along with anecdotal facts and information.

A variety of microalgae is grown at the school. Early in the husbandry attempts microalgae was introduced to the culture water. Cohorts that were grown with either a small amount of algae or with no algae failed. This study was designed to qualify whether *Isochrisis* sp., *Tetraselmis* sp., or a mixture of both, produce the best results in Ctenophore cultures. Cohorts were grown in tanks with the microalgaes. Each group was held for 30 days. Currently, three replicates are being performed and the pseudo-kriesals are being rotated to eliminate tank bias. Survival and condition of the animals in each tank are being recorded.

NEWLY-RECOGNIZED, HIGH CALCIUM, AGRANULAR HEMOCYTES UPREGULATED FOLLOWING SHELL DAMAGE IN EASTERN OYSTERS.

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Interest in shell mineralization processes in calcifying marine organisms has been prompted by changes in seawater carbonate chemistry associated with rising carbon dioxide in the atmosphere and hydrosphere. Vulnerability of commercially-valuable bivalves, such as oysters, to "Ocean Acidification" (OA) and "Coastal Acidification" is dependent upon chemical and physiological mechanisms involved in building and maintaining protective shells composed of organic and inorganic structures incorporating the minerals aragonite and calcite. Early reports that OA "makes it harder for shellfish to build their shells" assumed a model of shell mineralization in which crystals precipitate within the environmental milieu where favorable environmental aragonite saturation would be critical to successful crystallization. An alternative model of shell mineralization has been proposed wherein processes involved in mineralization occur within cells and physiologically-controlled spaces, making shell mineralization more resilient to external changes in carbonate chemistry. Among the cells proposed to participate in this shell-construction model are two types of hemocytes: granular cells in which crystallization of calcium carbonate is initiated and agranular hemocytes that contribute concentrated calcium to the location of shell assembly.

In the present study, we stimulated shell mineralization in adult Eastern oysters by "notching" the shell edge with pliers or a rotary saw, simulating damage from a predator such as a crab from which oysters are known to respond by repairing and calcifying the missing shell area rapidly. We sampled circulating hemolymph from the adductor-muscle sinus in a time-series and analyzed circulating hemocytes for hematology (counts and morphology of granular and agranular cells) and for the presence of agranular hemocytes with exceptionally-high intracellular calcium content, as detected with flow-cytometry and a chemical probe with fluorescence intensity proportional to intracellular calcium concentration. Results show consistent up-regulation of high-calcium, agranular hemocytes 7-10 days following shell damage. We also imaged and described the morphology of these cells using confocal microscopy. This is the first description of these cells hypothesized to be involved in shell calcification in the cell-based model.

MECHANISMS OF HEMOCYTE APOPTOSIS IN RESPONSE TO IN VIVO INFECTION WITH *PERKINSUS MARINUS* IN THE EASTERN OYSTER, *CRASSOSTREA VIRGINICA*

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Apoptosis, or programmed cell death, of hemocytes is a critical step in oyster immune defense to *P. marinus* infection in the eastern oyster. Increased hemocyte apoptosis may prevent or reduce *P. marinus* replication in infected individuals. The precise apoptotic pathway and molecules involved in response to intracellular infection with *P. marinus*, however, are poorly understood. In 2015, one-year old oysters from two selected families were injected with an intermediately-virulent strain of *P. marinus* at 5 x 10^6 cells/g wet weight. At time 6 hr, 36 hr, 7 d and 28 d following injection, mantle and gut tissue were preserved and *Perkinsus* levels measured by qPCR. Transcriptome sequencing was performed to assess gene expression in mantle tissues from susceptible (242) and resistant (266) oyster families. Differential gene expression analysis of apoptosis-related genes revealed the resistant family having significant upregulation of genes involved in the intrinsic apoptotic pathway, including inhibitor of apoptosis genes (IAP), TNF- receptor associated factors (TRAF), and interferon induced protein 44 (IFI44) relative to the susceptible family. Genes involved in lysosomal degradation that can also serve as apoptosis triggers also were upregulated significantly. To further investigate the involvement of these pathways during an *in vivo* infection, in September 2019, oysters with known family history and putative susceptibility to Dermo disease were injected with *P. marinus* at 5 x 10^6 cells/g wet weight. At 7 d post-infection, levels of apoptosis, caspase 3/7 activation, and lysosomal permeabilization were assessed by flow cytometry, and tissue was collected for assessment of *P. marinus* levels by qPCR. This study revealed no significant differences between control and Dermo-infected oysters in caspase 3/7 activation or lysosomal permeabilization. Dermo-injected oysters, however, had significantly decreased granular hemocyte apoptosis as compared to the control, suggesting parasite inhibition of hemocyte apoptosis at day 7. Future *in vitro* assays will investigate the role of mitochondrial permeabilization in *P. marinus*-induced hemocyte apoptosis. This study revealed which pathways and enzymes are involved in the apoptotic response to *P. marinus*, informing the design of future functional studies and marker-assisted selection approaches for Dermo resistance breeding.

EFFECTS OF MULTIPLE STRESSORS ON SURVIVORSHIP AND GROWTH IN JUVENILE BLUE MUSSELS

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The latest Intergovernmental Panel on Climate Change (IPCC) Special Report on the Ocean and Cryosphere in a Changing Climate, released in September 2019, highlights the urgency of action needed to address unprecedented and enduring changes in the oceans. This report emphasizes that the oceans have played a major role in absorbing the increase in global heat created by greenhouse gasses, leading not only to ocean acidification, but also to a warming of the oceans. Due to the ecological and economic importance of bivalves, it is well recognized that these animals are facing every increasing frequencies of multiple simultaneous environmental stressors. With continued climate change, heat waves are becoming more, leading to increased thermal stressor during early life stages. Yet, we do no not know the consequences of multiple simultaneous (or sequential) stressors for different life stages of these animals, or the consequences of variable environments. We tested the combined effects of thermal stress and food stress for survivorship and growth in early juvenile blue mussels, *Mytilus edulis.* We had two food treatments (3×10^4 and 1.5×10^4 cells/ml/day), and four temperature treatments (constant 15°C, 20°C, and 25°C, and a variable treatment that switched between 15°C and 25°C and had a mean temperature of 20°C), in a factorial design. There was no significant difference in survivorship among treatments, but there were significant differences in growth. In general, lower food resulted in slower growth, except at 20°C, where food concentration did not affect growth. Animals held at 15°C and given high food concentration grew the fastest. Interestingly, those in the high food treatment and variable temperature grew the same as those in the constant 20°C, but lower food ration resulted in slower growth in this treatment, but not as slow as those experiencing 25°C.

REGULATION OF MUCOSAL LECTINS IN THE OYSTER *CRASSOSTREA VIRGINICA* IN RESPONSE TO FOOD AVAILABILITY AND ENVIRONMENTAL FACTORS

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Lectins are a large and diverse group of sugar-binding proteins involved in nonself-recognition and cell-to-cell interactions. Suspension-feeding bivalves, such as the oyster *Crassostrea virginica*, are capable of using these molecules to capture and select food particles according to their cell surface carbohydrates. The aim of this project was to assess whether the expression of mucosal lectins in *C. virginica* is constant or seasonal, and to determine if lectin expression is linked to environmental parameters and/or internal biological factors (gametogenesis). A total of 130 oysters were placed in cages at a tidal estuary and monitored for changes in lectin gene expression over a 1-year period. In parallel, environmental parameters prevailing in the field site, including seawater physico-chemical characteristics (temperature, salinity, dissolved oxygen) and particulate organic matter and chlorophyll contents, were also monitored. Throughout the study, oysters were dissected and the gills were collected and used for the assessment of the expression of three different mucosal lectin genes (CvML, CvML3914 and CvML3912). Remaining tissues were processed for histology and the classification of the gonad development stage. Results showed that when high quality food is abundant, such as during the spring bloom, lectin gene expressions are low, and inversely lectin levels increase with lower food levels. These findings suggest that oysters increase lectin expression to enhance the capture and ingestion of scarce food while during spring bloom, enough high quality food is already being ingested and lectins are not needed. Furthermore, results showed that as oyster's energy demand increases (gonad maturation), lectin gene expressions also increase to enhance selective ingestion of most nutritious food particles. This study, therefore, demonstrates the seasonality of lectin gene expression in *C. virginica*, and suggests that lectin regulation is related to the reproduction process and abundance of high quality food.

OYSTER (*CRASSOTREA VIRGINICA)* RESTORATION AND SULFATE/SULFIDE METABOLISM

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In the past three decades, groups have expressed interest in restoring local oyster populations. Frequently these efforts have investigated local river habitats free of the serious oyster predators: the oyster drill (*Urosalpinx cinerea)* or starfish (*Asterias forbesi*).

Prior to the 1940s, these same rivers frequently sustained small-scale oyster fisheries – first as direct market to the public, and later as seed for culture. After 1970, many river oyster beds were closed to direct harvesting (bacterial closures) ending recreational and commercial harvesting. These rivers were the source of tong oysters: waters a few feet deep such as the Oyster River in Old Saybrook, CT or Madison's Connecticut's Neck River.

Interest in restoring these river oyster beds has increased for both recreational commercial fisheries (economic multipliers) and habitat services to other organisms that benefit from bivalve shell. These issues are not new; J.R. Nelson, writing in 1971 of the economic loss of shellfish bacterial closures estimated that the dollar loss from 1921 to 1971 from was $500 million, $17 million in 1970.

The environmental services of oysters in estuaries was also acknowledged by Paul S. Galtsoff, a USFWS shellfish scientist, in a Hartford 1958 meeting with Connecticut officials about salt marshes, stating, "Coming to the Connecticut waters of Long Island Sound, there are two species of fish for which your tidal marshes are very important: they are winter flounder and menhaden. The young winter flounder rapidly grows and feeds in the tidal marsh."

In the 1950's, a large diet component for winter flounder was small crabs living amongst oysters.

Oyster reef ecology was highlighted in national studies as providing forage and other species nursery habitats. Bivalve shell litter was found to provide pH moderation benefits in rivers with salmon.

However, most benthic oyster restoration studies fail to consider temperature or energy in long-term restoration goals. As these climate factors change, habitats can exhibit different soil chemistry and substrate features. Restoration proposals tend to underestimate the influence of temperature and energy in long-term habitat change.

This presentation reviews the impact of sulfate/sulfide metabolism upon oyster restoration concepts. The aspect of natural and harvest energy and the climate factor of bacterial sulfate/sulfide metabolism from sulfate reducing bacteria (SRB) are often the largest constraints to current oyster restoration goals.

SHELL SHAPE AND COLOR IN THE EASTERN OYSTER (*Crassostrea virginica*)

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As the commercial production of the eastern oyster, *Crassostrea virginica*, increases, the incorporation of selection for shell attributes in breeding programs may become important. It is therefore necessary to understand and accurately characterize traits, such as shape and color. The ‘curl-back’ hinge shell abnormality found in some cultured stocks is undesirable to consumers and can potentially result in extra work on farms or decrease sales. To study the ‘curl-back’ trait, two cohorts of oysters were selected and crossed amongst each other: one group with ‘curled-back’ hinges and one with ‘flat’ hinges. The progeny from each of the two crosses were grown separately in a common garden experiment, and, in the following year, the crosses were repeated using selected F1s, resulting in two generations of selection for ‘flat’ and for ‘curled-back’ oysters. Forty eleven-month-old F2s from each cohort were subsequently cut ventro-dorsally and the relative curvature of right and left valves were compared following a theoretical morphologic approach. To better understand the nature of shell pigmentation, four color morphs were described and crossed amongst each other. Proportions of color morphs in the progeny suggest color and pattern are under genetic control. A comparative transcriptome study was then conducted to identify differentially expressed genes (DEGs) between dark and light regions of mantle tissue. Several transcripts were found to be differentially expressed in common across three replicates, including several genes involved in the heme pathway. UV/visible spectroscopy results suggest that both black and brown shell colors contain two pigments, and the absence of characteristic peaks indicate neither pigment is a porphyrin. Raman data show no evidence of carotenoid-type pigments, but do show evidence of melanin pigments. Other pigment peaks are consistent with linear tetrapyrroles. To further analyze melanins, demineralized shells were subjected to Soluene-350 solubilization, H_2O_2 oxidation, and hydriodic acid (HI) hydrolysis.

ASSESSING FISH INTERACTIONS WITH OYSTER AQUACULTURE CAGES USING POINT-OF-VIEW (GOPRO) CAMERAS

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Multi-tiered aquaculture cages are becoming increasingly common as a method for raising oysters on a smaller spatial footprint within the Northeast US. Cages constitute complex vertical structure that may create habitat for ecologically and economically important fish species. Documenting ecosystem services provided to fish by aquaculture gear may help inform regulators and fishery managers who make decisions about aquaculture practices and could enhance public understanding of how aquaculture gear interacts with the benthic environment.

A series of field experiments were conducted to quantify fish interactions with aquaculture gear using point-of-view cameras mounted to oyster cages. Two GoPro HERO 3+ Silver® cameras were attached to each cage, one at the top corner looking across the horizontal surface, the second at the cage corner, with a view of two cage sides and the interface between cage and seafloor. Cameras were deployed ~24 hours before the onset of recording to minimize disturbance effects. Video was recorded for 8 minute intervals hourly from 7 am to 7 pm over a complete tidal cycle and during most daylight hours. Seawater temperature, light intensity, and current speed and direction were also recorded during deployments.

Video footage was scored using Observer XT® software, which facilitated viewing of top and side time-synced video recordings simultaneously. Fish abundance was calculated using MaxN, defined as the maximum number of fish of each species observed per 1-minute video segment. Preliminary video observations have detected more than 17 different fish species associated with cages including young-of-the-year, juvenile and adult life stages. A matrix of fish behaviors is under development to describe fish interactions in and around oyster cages to better understand provisioning of services to fish by aquaculture gear.

USE OF ARIS SONAR TO ASSIST IN VIEWING OYSTER AQUACULTURE GEAR

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Oyster cages are a popular method of shellfish aquaculture in New England. Our team has used point-of-view (GoPro) cameras to successfully document how fish interact with oyster cages. Video cameras provide a valuable tool for collecting data on fish activity on cages but are most effective during daylight hours. The addition of an Adaptive Resolution Imaging Sonar (ARIS) supplemented the video observations by capturing footage of fish movements during periods of low visibility, overnight, and may facilitate estimation of fish size and/or life stage. Pilot deployments were conducted during the summer of 2019 in control and field environments to aid in the development of methods for positioning sonar adjacent to an oyster cage and for optimizing the field of view. These preliminary trials suggest that sonar footage, when combined with video, may provide a more complete accounting of fish activity near oyster aquaculture cages over a 24-hour day and night cycle.

OYSTER AQUACULTURE DOES NOT AFFECT SPAWNING BEACH ACCESS FOR ATLANTIC HORSESHOE CRABS, *LIMULUS POLYPHEMUS*

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Although shellfish aquaculture is viewed as an environmentally sound practice, as farm production expands it faces key challenges assuring ecological and social sustainability. Understanding ecological interactions among shellfish farms and mobile coastal wildlife, particularly species of special concern, is among those challenges.

Eastern oyster (*Crassostrea virginica)* farms are commonly located along shallow estuarine shores of the eastern U.S., use a range of farm equipment, and require regular access to care for and harvest livestock. The shores of the Delaware Bay are widely used by Atlantic horseshoe crabs (*Limulus polyphemus*) and migratory shorebirds, yet a small portion is collectively used by crabs for spawning, as shorebird migratory stopover habitat, and is home to intertidal oyster farming. Horseshoe crabs are economically and ecologically important; their blood is highly valuable in the medical industry and migratory shorebirds feed on crab eggs when stopping in Delaware Bay. The overlap in both time and space of these iconic and ecologically important species, and oyster farm activities presents a unique opportunity to examine potential ecological interaction among wildlife and shellfish farms.

Little data has been collected specifically addressing the ability of horseshoe crabs to traverse intertidal rack-and-bag oyster farms to reach their spawning habitat. If crab spawning migrations are impeded by farms, it is possible that crab populations themselves may suffer, and in turn shorebird foraging patterns and opportunities may be altered. In this study, our primary goal was to characterize the interactions of horseshoe crabs passing through farms *en route* to inshore spawning habitat, to determine if the farms themselves present a barrier to crabs reaching beaches to lay eggs, or if farms alter the pattern of egg availability for migrating shorebirds. During the 2018 and 2019 crab spawning season we carried out a range of experiments and surveys during high and low tide, to observe crab behavior at rack-and-bag farm and non-farm sites. We also conducted surveys in the region to see if farms alter the distribution of eggs. In all cases, results indicated that crabs can successfully traverse rack-and-bag farms and reach spawning beaches, crabs do not differentially use farm versus non-farm areas, crab behavior is relatively unaltered by farm gear, and egg distribution is not altered by farm gear. These results provide important context for developing frameworks for managing ecological interactions among farms and wildlife species of concern.

EXPLORING VALUE IN POTENTIAL NEW PRODUCTS FOR THE SHELLFISH AQUACULTURE IN MASSACHUSETTS

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Shellfish aquaculture production has been growing rapidly in Massachusetts (MA) with sales in excess of $28 million, trailing only the sea scallop and lobster landings in seafood production values. Roughly 97% of this shellfish aquaculture production is oysters (*Crassostrea virginica*), with almost the entirety of the harvest utilized in half shell markets. This rapid growth locally and East Coast wide, has some concerned about industry reliance on a single market product, though current opportunities to diversify in MA have been limited. This project evaluated the initial market value in two potential new species, Atlantic surf clam (*Spisula solidissima*) marketed as a smaller "butter clam", the blood ark (*Anadara ovalis*), and a locally processed shucked oyster product. Several methods were taken in conjunction with market consultants to assess what the opportunity is if these products were to be cultured in MA waters. These initial values will be discussed in the context of potential for shellfish aquaculture opportunity.

BREEDING THE BARRENS TOPMINNOW, AN ENDANGERED FRESHWATER FUNDULUS SPECIES, FOR REINTRODUCTION

Bert Sadler*, Sam Siebert, and Sandi Schaefer-Padgett. The Maritime Aquarium at Norwalk, 10 North Water Street, Norwalk, CT 06854.

The Barrens Topminnow, *Fundulus julisia*, is an endangered species from the Appalachian Mountains of Tennessee. It is experiencing challenges related to land use changes and invasive species introductions that are affecting the characteristics of streams in the region. In concert with landowner outreach and protection and restoration of streams, the Tennessee Aquarium started a breeding program a few years ago. The species declined to only two populations in the Duck and Elk River systems in the Tennessee River drainage, consisting of only a few hundred adults from several thousand in the 1980s. Reintroduction efforts are ongoing in historic localities. In 2018, The Maritime Aquarium at Norwalk's aquarists took on a portion of this breeding project to advance the capacity of reintroduction efforts. Currently, the five adults received by the Aquarium produced 123 juveniles, with three of the adults breeding. A single female can produce up to 200 eggs in a breeding season, though fewer were observed in these animals. Aquarists have documented biweekly growth rates in these animals, which are growing quickly enough to be reintroduced in Tennessee Aquarium's next release.

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