ABSTRACT BOOK

Seaside, OR
September 2023

NOTE: only those who submitted full abstracts are included in this book. Check out the Conference Program for a full list of presentations.

Tuesday, September 19, 2023

OCEAN CONDITIONS

Riverside B

Response of eastern oysters (Crassostrea virginica) and soft shell clams (Mya arenaria) repeated hypoxia during heatwaves

Jasmine, Talevi (Dalhousie University), Shelby Clarke, Michael Coffin, Luc Comeau, Takashi Sakamaki and Ramon Filgueira*

Bivalves are both economically and environmentally valued species that play a vital role in coastal ecosystem functioning through water filtration and nutrient cycling. Coastal marine environments are becoming increasingly stressful habitats due to anthropogenic nutrient inputs and climate change increasing extreme events. Extreme events, such as heatwaves and hypoxia, cause sudden and intense changes in the environment leading to adverse effects and mass mortalities of bivalve populations globally. The purpose of this study is to understand how eastern oysters (*Crassostrea virginica*) and soft shell calms (*Mya arenaria*) behaviourally and physiologically respond to hypoxia and heatwaves under field conditions. To investigate this, bivalves were repeatedly exposed to hypoxia during a heatwave using natural seawater. Behavioural responses related to valve gaping were monitored using a Hall element sensor valvometry system and physiological responses including oxygen consumption rate, feeding rate, assimilation efficiency, and scope for growth were measured. Despite exposure to heatwave conditions and severe hypoxia, both species were able to cope under this stress. The results suggest that in the short-term, eastern oysters and soft shell clams can withstand these extreme conditions, though extended and cumulative effects may potentially impact the survival of these species. This information can help improve the accuracy of ecosystem models to assess the vulnerability of eastern oysters and soft shell clams under future climate scenarios, which will be informative for aquaculture and fisheries as cultivation of more resilient bivalve species will be important to maintain revenue.

Exploring adaptation and plasticity to ocean warming in blue mussels (Mytilus edulis) from Atlantic Canada

Shelby B. Clarke (Dalhousie University), Tiago Hori, Luc Comeau, and Ramon Filgueira*

As waters are progressively warming with climate change, the aquaculture industry will need to identify sources of mussels that are able to perform well under elevated temperatures. Sober Island Pond in Nova Scotia (NS), Canada, is a shallow inlet that experiences limited water exchange between the pond and the open ocean, exposing wild mussels to anomalously high summer temperatures. These environmental conditions could trigger local adaptation on mussels from this area, making them more adept at coping with and responding to climate change induced thermal stress. The objective of this study was to investigate and compare the thermal biology of two sources of mussels from Atlantic Canada, Sober Island Pond, NS and Georgetown, Prince Edward Island (PEI). Mussels were held under four temperatures (20, 25, 30 and 35°C), and four metrics were used to characterize their thermal biology: (1) lethal thermal thresholds (LT50), (2) valve gaping behaviours, (3) RNA sequencing (RNA-seq), and (4) thermal performance curves. The results showed differences between the mussel sources in the four metrics, suggesting that individuals from Sober Island Pond, NS outperform individuals from Georgetown, PEI under elevated temperatures. The RNA-seq identified putative markers of temperature resilience and generated over 5000 differentially expressed genes to characterize the response of heat stress in mussels. This information could have important applications to breeding programs for mussel hatcheries and the aquaculture industry in Canada.

Examining the impacts of elevated, variable pCO2 on larval Pacific razor clams (Siliqua patula) in Alaska

Marina Alcantar (University of Alaska Fairbanks), Jeff Hetrick, Jacqueline Ramsay, and Amanda Kelley*

An increase in anthropogenic carbon dioxide is driving oceanic chemical shifts resulting in a long-term global decrease in ocean pH, colloquially termed ocean acidification (OA). Previous studies have shown that OA can have negative physiological consequences for calcifying organisms, especially during early life-history stages. This study examines the effects of OA on embryonic and larval Pacific razor clams (Siliqua patula), a bivalve that produces a concretion during early shell development. Larvae were spawned and cultured over 28 days under three pCO2 treatments: a static high pCO2 of 867 µatm, a variable pCO2 of 357 to 867 µatm, and an ambient pCO2 of 357 µatm. The calcium carbonate polymorphism of the concretion phase of S. patula was identified as amorphous calcium carbonate that transitioned to vaterite upon complete calcification, prior to settlement--suggesting potential vulnerability to dissolution under OA. Despite exhibiting a more soluble form of calcium carbonate during larval development, there was no significant impact of exposure to elevated or variable pCO2 conditions on S. patula growth. However, it appears that exposure to elevated pCO2 appeared to accelerate the transition of larval S. patula from the concretion stage of shell development to complete calcification. There was also no significant effect of treatment conditions on the expression of heat shock protein 70, a gene associated with OA stress, or calmodulin, a gene involved in shell building and maintenance. This is the first experimental study examining the response of a bivalve that produces a concretion to future predicted OA conditions, and has important implications for experimentation on larval mollusks and bivalve management.

Environmental Priming for Ocean Acidification: Potential hatchery practices to build resilience for clam aquaculture in the Puget Sound

Larken Root (University of Washington/NOAA), Mackenzie Gavery, Ryan Crim

Ocean Acidification (OA) is likely to have a major impact on marine shellfish, especially in early developmental stages when larvae are growing rapidly and accreting their first shell material. Understanding impacts of OA on adult and larval clams is crucial for climate resilient aquaculture and developing adaptive strategies. Two promising strategies include parental environmental priming and species portfolio expansion. Parental priming shows promise because evidence indicates that exposing adults to an environmental stressor, especially while they are undergoing gametogenesis, can improve performance of offspring when exposed to the same stressor. Portfolio expansion is promising because species native to the Puget Sound may be more tolerant to OA. Comparisons of adult Manila and Littleneck clams exposed to OA conditions for over two months did not show clear physiological effects in terms of metabolism, growth, reproductive maturation, or feeding behavior. On the other hand, spawning success and larval survival analysis indicate beneficial effects for larvae of exposing adult clam parents to OA in Manila clams, providing support for the practice of environmental priming. Further research will help determine the mechanisms for improved performance in larvae spawned from environmentally primed parents, as well as whether these effects are also seen in native littleneck clams.

Potential of the macroalgae dulse (Devaleraea mollis) to mitigate effects of ocean acidification on larval Pacific oysters (Magallana gigas) in land-based co-culture.

Leah Wessler (University of British Columbia), Dr. Andrea Frommel, Dr. Jennifer Clark*

Ocean acidification (OA) conditions along the west coast of Canada and the US are corrosive and can negatively impact economically important marine calcifiers such as Pacific oysters. Currently, shellfish hatcheries combat ocean acidification by making seawater, transporting larvae to other countries during vulnerable stages, or buffering water chemically. These methods can be unsustainable, expensive, or can affect the health of oysters later in life. Through photosynthesis, marine macroalgae uptake carbon from seawater, functioning as a potential tool for mitigating OA while providing a range of important products such as nutritious food, cosmetics, and biofuels. To quantify effects and fill knowledge gaps, our research examines the potential of tank cultivated macroalgae (dulse) to mitigate the harm caused by OA on oyster larvae in land-based co-culture. We hypothesize that negative effects of OA on oyster larvae survival and calcification, and changes to the larval microbiome due to OA, will be mitigated by co-culturing the oysters with dulse. Carbonate chemistry will be modified to represent three OA conditions corresponding to ambient (400 µatm CO2), local upwelling (1000 µatm CO2), and upwelling + future projections (3000 µatm CO2). Two groups of larval oysters, one in co-culture with dulse and one in monoculture, will receive water from each OA level. Oyster samples taken across both 48-hour and 40-day timescales will be analyzed for survival, growth, shell shape, and shell formation gene expression. At the end of each timescale, larvae from each experimental unit will be pooled for microbiome analysis, which has been linked to oyster immune function. Study findings will provide data that supports models on the Co2

uptake potential of macroalgae, applicable to industry and restoration efforts for both shellfish and macroalgae. Outcomes of this study will aid the shellfish industry in adapting to climate change while increasing sustainability and net income through increasing yield and providing crop diversification.

Recovery from an atmospheric heatwave in Midori and Miyagi strains of the Pacific oyster

Hollis Jones (University of California, Davis), Cassidy Cooper, Anne Todgham*

Evolutionary history shapes a species' response to ongoing and future environmental change. Pacific oysters from the Miyagi Prefecture in north-east Japan (Miyagis) are the most commonly farmed oysters in the world, but in 2004 a new strain of Pacific oysters from the Ariake Sea in the Midori Prefecture of Southern Japan (Midoris) was introduced to the US West Coast commercial oyster industry. Midoris were introduced to increase genetic diversity and because it was hypothesized that these individuals, because of their more southern origin, may be less sensitive to higher water temperatures. Atmospheric and marine heatwaves are predicted to become hotter, more frequent, and longer-lasting in global coastal areas. This study compares the ability of two strains of the Pacific oyster, Miyagi and Midori, to physiologically recover from an atmospheric heatwave. I hypothesize that evolutionary and domestication history impact an oysters' resilience profile and predict that because the Midori strain evolved in a warmer region and has a shorter history of domestication, it will have higher tolerance for unpredictable thermal stress. All oysters used in this experiment were provided by Hog Island Oyster Company and were brought to the UC Davis Bodega Marine Laboratory in March 2023. Oysters were acclimated to a tidal cycle (20hr immersed; 4hr emersed) for two weeks before being exposed to two consecutive days of an atmospheric heatwave and two days of recovery. During the heatwave air temperatures were ramped until the oysters reached an internal temperature of 24?C (air temperature of 26?C) by the end of the low tide. Respiration rate was measured daily before, during, and after the heatwave — directly before and after the low tide. This will allow us to determine the routine metabolic rate of oysters from each strain and whether one strain has a higher physiological capacity to return to pre-stress levels (full compensation) before the next low tide, or after the heatwave. The analysis of this data has not yet been completed but will be reported at the PCSGA & NSA conference in September 2023. The results of this project aim to support the inclusion of Midori oysters in more farms for diversification of the US West Coast aquaculture industry for reduced vulnerability to extreme environmental events associated with climate change.

Triploid Pacific oysters exhibit stress response dysregulation and elevated mortality following heatwaves

Matthew George (University of Washington), Olivia Cattau, Mollie A. Middleton, Delaney Lawson, Brent Vadopalas, Mackenzie Gavery, Steven Roberts

Triploidy has been shown to negatively impact environmental stress tolerance within a variety of marine organisms, resulting in increased susceptibility to extreme climate events. In this study, we compared the genomic and physiological response of diploid (2n) and triploid (3n) Pacific oysters (Crassostrea gigas) to conditions that replicated those experienced by shellfish populations during the atmospheric heatwave that impacted the Pacific Northwest during June

of 2021. Climate stressors were applied either singly (single stressor; elevated seawater temperature, 30°C) or in succession (multiple stressor; elevated seawater temperature followed by aerial emersion at 44°C) within a hatchery setting. Oyster mortality rate was elevated within stress treatments with respect to the control and was significantly higher in triploids than diploids following multiple stress exposure (36.4% vs. 14.8%). Triploids within the multiple stressor treatment exhibited signs of energetic limitation, including metabolic depression, a significant reduction in ctenidium Na+/K+ ATPase activity, and the dysregulated expression of key genes associated with heat tolerance, the inhibition of apoptosis, and mitochondrial function. Functional enrichment analysis of ploidy-specific gene sets identified that biological processes associated with metabolism, stress tolerance, and immune function were overrepresented within triploids across stress treatments. Our results demonstrate that triploidy impacts the transcriptional regulation of key metabolic processes that underly the environmental stress response of Pacific oysters, resulting in downstream shifts in physiological tolerance limits that may be detrimental to survival. The impact of triploidy on the climate resilience of marine shellfish has important implications for domestic food security, especially as triploidy induction has become an increasingly popular tool to elicit reproductive control within oyster aquaculture.

Environmental effects on biological characteristics of Pacific oyster Crassostrea gigas cultured in the Seto Inland Sea, Japan, from 1990 to 2022

Yumeng Pang (University of Washington), Tsuneo Ono, Takehiro Tanaka

The Pacific oyster (Crassostrea gigas) is a commercially important cultured species, which has been cultured in the Seto Inland Sea, western Japan, over the last half century. However, the long-term effects of various environmental factors (water temperature, salinity, pH, and food availability) on C. gigas biological characteristics remain unknown. To effectively manage oyster production under future climate challenges, this study investigated the long-term changes of C. gigas growth and its associated environmental factors in the natural ocean environment. Environmental data and oyster biological data were obtained from observations in Hinase waters, Seto Inland Sea, and compared for the two periods 1990 and 2015-2022. Biological characteristics were obtained from the oysters in each raft, including dorso-ventral height (DVH), shell width (SW), shell depth (SD), total weight (TW), shell weight (SW), dry and wet meat weight (DMW and WMW). Shell thickness index (STI) and conditional index (CI) were calculated for each individual. Higher TW, DMW, WMW and CI were found in 2022 than 1990, while shell shape (SH/SD and SH/SW) showed no remarkable changes. This implies that oyster cultured in 1990 might have experienced poor food conditions and achieved limited growth due to ecosystem degradation. The concentration of chlorophyll-a was fluctuating in 1990, but stable during 2015-2022. Eelgrass restoration in the Seto Inland Sea since 1985 may have improved water quality and facilitated the presence of abundant food material, perhaps contributing to a high growth rate and high meat weight at harvest during the period 2015-2022. Heavy seasonal rainfalls led to low salinity in July of recent years, which had a significantly negative impact on oyster growth. Although SW showed no significant difference between year of 2022 and 1990, higher STI was found in oysters of 1990. That is, oyster shells become thinner with increased density, which might provide the protection against unfavorable environmental conditions, such as decreased pH or fluctuating salinity. In addition, great raft difference of DVH was found in 2015-2022, which indicates that inland environmental factors might also affect greatly on oyster

size, such as freshwater runoff. Local fishing community should raise the awareness of changes in oysters, to enhance future stable oyster production.

WORKSHOPS

Necanicum

Social License Workshop

Moderated by Emily Whitmore and Anne Langston (Maine Aquaculture Innovation Center)

Emily and Anne will dive deeper into the social license topics Emily will introduce in the plenary. They will share the social license guide they've created in Maine and seek input from growers on the West Coast regarding their experiences with broader social impacts on shellfish farming.

Social Media workshop

Moderated by Cora Hirashiki (Fat Moon Creative)

Learn how to use social media more effectively to share your stories and increase your reach with broader audiences.

GENETICS, GENOMICS, AND BROODSTOCK

Riverside A

Genetic Variation in Growth of Pacific Oysters is Primarily Non-Additive

Dennis Hedgecock (University of Southern California), Xiaoshen Yin

Genes influence individual variation in growth and other quantitative traits in additive and non-additive ways, with implications for strategies to improve farmed stocks. Additive gene action on growth results from independent effects of individual alleles, such that growth responds linearly to the cumulative number of alleles affecting growth. Additive genetic variance is the basis for selection, as breeding of faster-growing individuals steadily enriches broodstock populations in alleles with positive effects on growth. Non-additive gene action on growth, mainly dominance and overdominance (heterozygote advantage), results from interactions among alleles, with consequent non-linear effects on growth. Non-additive genetic variance can be utilized by crossing of genetically different lines that produce high-yielding hybrids.

We recently mapped 42, growth-influencing genomic regions, across six F2 families of yearling Pacific oyster. Individuals in these families were tagged, weighed monthly through their second summer, and sexed on the fifth weighing in fall; 1,041 individuals were genotyped for an average of 478 markers per family, and quantitative-trait loci (QTL) were mapped using PROC QTL, for log live weights, gains in log live weight over various intervals, parameters of fitted linear and sigmoidal growth curves, and growth measures derived from sigmoidal growth curves. Most QTL had multiple traits mapping to them; we selected the most significant trait at each QTL to determine gene action but used the combination of traits mapped to a QTL and a principle component analysis (PCA) of all traits to categorize QTL into those affecting size,

growth rate, and shape of the growth curve. Because we could classify mapped genotypes as inbred (grandparental) or as one of two reciprocal hybrids (Yin & Hedgecock, 2021, Genetics, doi: 10.1093/genetics/iyab165), we could identify whether QTL had additive or non-additive effects on growth. Only 19% of growth QTL showed additive gene action, whereas 81% of growth QTL showed non-additive gene action. At two-thirds of the growth QTL, genetic effects differed between reciprocal hybrids. QTL for size and growth-rate showed overdominance (hybrid superiority) in 62.5% of cases and dominance in the remaining 37.5% of cases, while most growth-curve shape QTL (93.3%) showed dominance. These results strongly support crossbreeding as the optimal strategy for improving the growth of farmed Pacific oysters.

Development of an Alternative Sterility Method for Shellfish Aquaculture: Identification of Candidate Genes Involved in Germ Cell Specification

Mackenzie Gavery (NOAA Fisheries - NW Fisheries Science Center), Lauren Saunders, Lauren Vandepas, Brent Vadopalas, Adam Luckenbach, Cole Trapnell, Steven Roberts

Sterile or non-reproductive shellfish are both a market driven need and an ecologically sustainable approach to increasing food production via aquaculture. Current methods for inducing sterility in bivalve shellfish focus on ploidy manipulation. An alternative approach is the induction of sterility by inactivation of genes essential for germ cell (future gamete) formation and development. The power of this biotechnological approach has been realized recently in several finfish species, where suppression of a critical germ-cell specific gene, dead end (dnd), results in germ cell-free, sterile fish. The shellfish industry is now poised to adopt these technological advances. Unfortunately, the use of this technology in shellfish is hampered by a lack of knowledge of the gene(s) essential for primordial germ cell (PGC) specification in bivalves. To overcome this challenge, we used single-cell RNA-Seq (scRNA-seq), a cutting-edge approach that uses high-throughput sequencing to identify genes expressed in individual cells, to identify genes involved in PGC specification. Results of these analyses, including a “transcriptional atlas” of cell states in early Pacific oyster (Crassostrea gigas) embryos, candidate genes associated with PGC formation, and next steps in the development and application of this novel method to induce sterility in shellfish, will be presented.

Shellfish stress and chromosome copies: performance of diploid and triploid oysters under temperature, pH, and dissolved oxygen stress

Craig Norrie, Jacqueline Padilla Gamiño, Paul McElhany, Shalin Busch, and Joth Davis

Triploid Pacific oysters (individuals that possess an additional set of chromosomes) make up a significant portion of farmed oysters in Washington and worldwide. Their faster growth and higher marketability provide significant benefits to oyster growers. Triploid oysters, however, experience higher mortality than diploids. Because these mortalities typically occur in summer when environmental conditions are more stressful, it is hypothesised that they are due to interactions between environmental conditions and chromosome number. The physiological mechanisms behind these differences in mortality, however, are unclear. This study examined the impact of stress on the growth, survival, and metabolic responses of juvenile (<1 year)

diploid and triploid oysters across a range of stressful conditions. We performed a series of laboratory experiments where we exposed chemically induced triploid, mated triploid, and diploid oysters to a range of temperature (7.5, 12.5, 27.5, 22.5, 27.5 °C), dissolved oxygen (20, 40, 60, 80 % oxygen saturation), and pH conditions (pH 6.8, 7.0, 7.2, 7.4, 7.6) for a period of 4 weeks. Chromosome number did not significantly impact the performance of juvenile Pacific oysters across these short (4 week) time scales. No differences in growth or mortality were observed between ploidy or treatment in individuals exposed to any of the three stressors. While temperature did impact the performance of all three groups of oysters, exposure to high temperatures (> 17.5 °C) did not have a significant detrimental impact. No differences in metabolic performance were observed between ploidy groups across temperature treatments. Metabolic performance data from dissolved oxygen and pH experiments is currently being analysed. Metabolic performance was lowest at 7.5 °C and increased at 12.5 and 17.5 °C, however no significant changes in metabolic performance were observed at temperatures higher that 17.5 °C. These results suggest that differences in the susceptibility to stress between ploidy may not be driven by temperature alone, that potential interactions between multiple stressors, other stressors not investigated, or ontogenetic performance differences may be driving higher triploid mortality.

Sex determination in Pacific oysters (Crassostrea gigas): Translating basic science into more efficient oyster production

Bernarda Calla (USDA-ARS), Neil Thompson

Pacific oysters are one of the most important commercial oyster species in the world and important contributors to the U.S. Pacific coast economy. Knowing the sex of individual oysters at the time of spawn is critical for crossing of animals in breeding programs. While Pacific oysters are dioecious (females and males are separate individuals) they lack any secondary sex characteristics, making the sexing of individuals a significant challenge. Pacific oysters show occasional hermaphroditism and multiple events of sex reversal during their lifespan. Understanding the factors that affect and the mechanisms that underly sex determination and reversal in this species will help in developing tools for accurate early identification of the sex outcome during spawns and may eventually allow for the precise control of desired sex ratios. Goals for this project include elucidating molecular mechanisms of sex determination and identifying early markers that can be used to identify sex on maturing individuals. An update on ongoing research and findings will be presented.

Coupling in vitro challenge and transcriptomics to investigate mechanisms of eastern oyster apoptotic response to the intracellular parasite Perkinsus marinus

Erin M. Witkop (University of Rhode Island), Dina P. Proestou, Gary Wikfors, Kathryn Markey-Lundgren, Mary Sullivan, Marta Gomez-Chiarri

The protozoan parasite Perkinsus marinus causes Dermo disease in eastern oysters, Crassostrea virginica, and can suppress apoptosis of infected hemocytes using incompletely understood mechanisms. To further understand apoptosis mechanisms involved in oyster granulocyte response to P. marinus, this study performed in vitro hemocyte assays

coupling flow cytometry and dual transcriptomics of C. virginica and P. marinus. Specifically, the role of caspases, mitochondrial permeabilization, and Inhibitor of Apoptosis proteins in hemocyte P. marinus response were evaluated after hemocyte pretreatment with the IAP inhibitor GDC-0152 and the pan-caspase inhibitor Z-VAD-FMK. Hemocytes were challenged in vitro with P. marinus for 1 h in the presence or absence of caspase inhibitor Z-VAD-FMK or IAP inhibitor GDC-0152. Hemocytes exposure to P. marinus significantly reduced granulocyte apoptosis, and pre-incubation with Z-VAD-FMK did not affect P. marinus-induced apoptosis suppression. Hemocyte pre-incubation with GDC-0152 prior to P. marinus challenge further reduced apoptosis of granulocytes with engulfed parasite, but not mitochondrial permeabilization. This suggests P. marinus-induced apoptosis suppression may be caspase-independent, affect an IAP-involved pathway, and occur downstream of mitochondrial permeabilization. Transcriptomic analysis revealed P. marinus challenge stimulated hemocyte differential expression of oxidation-reduction, TNFR, and NF-kB pathways. WGCNA analysis of P. marinus expression in response to hemocyte exposure revealed correlated protease, kinase, and hydrolase expression that could contribute to P. marinus-induced apoptosis suppression. This research helps elucidate the role of apoptosis in eastern oyster host-parasite interactions and reveals specific hemocyte immune pathways and P. marinus apoptosis-modulatory enzymes for future investigation.

Experimental assesment of POGS YC2023 to OsHV-1 microvar

Neil Thompson (USDA- Pacific Shellfish Research Unit), Marni Rem-McGeachy, Will Schoeneck, Darren DeSilva, Nasif Sarowar

An experimental challenge using the European OsHV-1 microvar was conducted with families 2023-001 to 2023-080 from the POGS first spawning run of Year Class 2023. In this study we evaluated the heritability of survival in Miyagi, Midori and hybrid (Miyagi-by-Midori) families. The variability in survival is compared among the populations and the potential for improving OsHV-1 tolerance is assessed.

Center for Aquaculture Technology Canada (CATC) developed OsHV challenge model to assess family resistance in controlled laboratory condition

Nasif Sarowar (The Center for Aquaculture Technologies)

Bivalve aquaculture is a continuously expanding industry with global increases in tonnage of multiple species in the last 20 years. Culture of bivalve species has a comparatively low carbon footprint (lb/lb) to other livestock industries. However, knowledge of optimal growth conditions, and effects of environmental stressors is limited. For example, mortalities associated with marine heat wave and emerging diseases are only a few to mention here. Empirical data indicates such events are projected to increase in frequency and severity in the future. Hence, there is significant interest in the aquaculture industry to understand means to mitigate risks to commercial stocks.

Wednesday, September 20, 2023

POLICY AND PERMITTING

Riverside A

NAHMS: A trusted data oyster with a clam-like formula and statistical mussel helping to meet information needs!

Diana Short (USDA APHIS VS NAHMS)

Learn about the services and opportunities for shellfish growers available through the USDA's National Animal Health Monitoring System (NAHMS) program.

A Report on Work By NOAA Fisheries and Partners to Assess and Enhance The Permitting and Regulatory Landscape in Washington State

Jeff Bash (NOAA Fisheries)

This talk will provide an overview of recent and on-going work by NOAA Fisheries and partners to assess and enhance the permitting and regulatory landscape in Washington state.

ELAP: Opportunities and Challenges from a National Perspective

Charlie Culpepper (National Aquaculture Association)

An overview of USDA Farm Service Agency\'s Emergency Assistance for Livestock, Honeybees and Farm Raised Fish Program (ELAP). The presentation will focus on aquaculture eligibility and the claims process, recent changes that expanded aquaculture commodity access, challenges from aquaculture farmers around the nation, and NAA\'s efforts improve ELAP efficacy for U.S. aquaculture.

Shellfish Farming and the Endangered Species Act

Amanda M. Carr (Plauché & Carr LLP)

The federal Endangered Species Act has long played a significant role in permitting shellfish farms on the Pacific Coast. With several species of salmon, Southern Resident Killer Whales and several birds protected under the Endangered Species Act, every shellfish farm being permitted in Washington, Oregon and California must go through a consultation process under the Endangered Species Act.

In recent years, Endangered Species Act consultations in Washington State have been primarily accomplished through a Programmatic Biological Opinion, which allowed most shellfish farms to move forward without an additional layer of individual review. However, that programmatic consultation does not completely do away with issues around the Endangered Species Act. There are several shellfish farming activities that are not covered under the Programmatic Biological Opinion, some growers would like to undertake farming activities using methods not

covered under the Programmatic Biological Opinion, and there is some indication that the National Marine Fisheries Service might consider moving to a different strategy for Endangered Species Consultations on shellfish farms.

This presentation will provide an overview of the Programmatic Biological Opinion and discuss what activities are and are not covered by that document. The presentation will also address other strategies for Endangered Species Act consultation, including the recently released National Oceanic and Atmospheric Administration (NOAA) Mitigation Policy as well as the NOAA Fisheries Puget Sound nearshore habitat conservation calculator.

Legal Issues Impacting Shellfish

Samuel W. (Billy) Plauché (Plauché & Carr LLP)

For the past decade, shellfish growers have been dealing with a variety of legal challenges to the federal, state and local permits governing their operations. While those challenges have ultimately led to some positive outcomes (individual Corps permits for most growers, no need for Hydraulic Project Approvals from Washington Department of Fish and Wildlife), legal challenges are ongoing and could lead to further shifting of the regulatory landscape.

This presentation will provide an update on the pending federal court challenges to the Corps permitting regime, as well as an update on the permitting process for shellfish farms in the Corps' Seattle District. Implications of changes in federal law on shellfish farming, from the Supreme Court's decision on the reach of Clean Water Act jurisdiction to the recent legislation amending the National Environmental Policy Act, will also be covered.

Finally, this presentation will discuss state and local legal issues for shellfish farming, including the Washington State Supreme Court's review of ownership issues related to abandoned railroad corridors (a case PCSGA participated in as *amicus curiae*) and recent decisions from the Washington State Environmental Land Use Hearings Office that could impact local permits for shellfish farms.

Washington State Department of Health Commercial Shellfish Enforcement Program Overview

Dani Toepelt, R.S. (WA Dept. of Health)

While WADOH prides themselves on an "education first" regulatory program, sometimes enforcement actions are necessary. DOH Shellfish Licensing and Certification Manager, Dani Toepelt, will share how their enforcement process was developed, is implemented, and the process operations go through when in enforcement.

An electronic aquaculture production data system for Washington

Chris Eardley (WA Dept. of Fish and Wildlife), Bobbi Hudson, Dani Toepelt, David Beugli, Laura Butler, Kim Thompson, Kevin Decker

Complete, accurate, and reliable production data is critical to supporting shellfish aquaculture in the state of Washington. This information is key for describing the economic value and significance of shellfish aquaculture here—and to assessing changes, opportunities, and impacts to the industry. Examples include consumer and market evaluations, outreach programs, extension efforts supporting sustainable U.S. aquaculture growth, and economic relief programs following catastrophic events like the COVID-19 pandemic and natural disasters. Shellfish production reporting in Washington is currently hampered by the requirements of two state agencies, outdated paper-based processes, competing requirements, and user confusion. A NOAA-funded collaboration between the Pacific Shellfish Institute, industry, three state agencies, and the University of Washington is working to develop a new, single system for reporting shellfish harvest data electronically. This talk will preview an easier, more efficient, and smarter system for Washington shellfish aquaculture.

Public Engagement Toolkit

Kim Thompson (Pacific Coast Shellfish Growers Association)

Our coasts are getting more crowded and public opposition to coastal development is growing. Those who have been navigating the permitting process have gone through public comment periods and have seen the volume of opposition statements increase. This doesn't necessarily reflect the perspectives of the broader community, but the louder voices of opposition tend to dominate the narrative. PCSGA has created a Public Comment Toolkit to make it more convenient for grower members to support each other and help balance the narrative about aquaculture by ensuring that the positive benefits of our industry are represented in public comments. We would love to hear from our growers on how to make this product more user-friendly.

Shellfish Farm Permitting Toolbox

Kelly McDonald (Confluence Environmental Company), Marlene Meaders, Jesse DeNike, Samantha Klein

Permitting can be confusing and convoluted, but it doesn't have to be something that requires an expert to get through the process. There are a bevy of agency-led websites that provide information related to permitting. However, none of these websites include information from the grower's perspective. Together with the Pacific Coast Shellfish Grower's Association (PCSGA), we have created a permitting toolbox to fill this need. PCSGA launched a project in 2022 through a Builders Initiative Grant to help growers with permitting and other communication needs. In collaboration with PCSGA, Confluence Environmental Company and Plauché and Carr have created a web-based permitting toolbox that works through the federal, Washington and Oregon state, and local permitting processes, as well as other needs (e.g., tribal interests). The permitting toolbox includes a series of flow charts that relate to specific shellfish activities and necessary materials for the permitting process. The toolbox also includes helpful templates to modify and submit to appropriate resource agencies, and details about what to expect during

the process. The information developed is intended to guide the grower through the process without the need for outside support. However, PCSGA is available with additional resources, as necessary. This presentation introduces how a grower could work through the questions and answers to develop appropriate materials to then submit for permits. It also provides a description of the additional resources provided in the permitting toolbox. At the end, we will ask for interested parties to participate in beta testing for the web-based tool. The goal is to release the permitting toolbox for full usage by the beginning of 2024 for all PCSGA members.

FEDERAL AGENCY UPDATES AND LISTENING SESSIONS

Necanicum East

West Coast Federal Shellfish Research Updates and Listening Session

NOAA Fisheries Office of Aquaculture, US Department of Agriculture (USDA)

NOAA Fisheries' West Coast Fisheries Science Centers and the USDA's Research team will share updates from their respective and collaborative efforts to help build our scientific understanding of impacts to shellfish farming on the West Coast. This session will expand more broadly on various areas of research beyond the genetic and genomic efforts that will be presented by the Pacific Shellfish Research Unit in their session. There will also be open discussion for the shellfish community to weigh in on how NOAA and USDA can work together to best support the industry.

Federal Agency Policy and Program Updates and Listening Session

NOAA Fisheries Office of Aquaculture, US Department of Agriculture (USDA), US Food and Drug Administration, and the National Aquaculture Association

Learn more about the latest programs and opportunities for shellfish growers at NOAA Fisheries Office of Aquaculture, US Department of Agriculture, US Food and Drug Administration, and the National Aquaculture Association. The Agencies also welcome feedback from the grower community to help improve their shellfish programs and services.

ECOP FEEDBACK SESSION

Riverside B

Environmental Codes of Practice (ECOP) Revision Update and Feedback Session – PCSGA Growers Only

Kim Thompson (Pacific Coast Shellfish Growers Association), Samantha Klein, Bobbi Hudson

PCSGA is in the process of updating our Environmental Codes of Practice (ECOP) document with funding from the Builder's Initiative. We encourage PCSGA growers to join us to learn more about the update process and help guide next steps for developing training and implementation tools and resources for the ECOP.

CONSERVATION AND RESTORATION

Riverside B

A population health approach to monitoring oyster disease in Long Island Sound in support of regional restoration and harvest goals

Meghana P. Parikh (NOAA Fisheries Northeast Fisheries Science Center), Mariah L. Kachmar, Stephen Arnott, and Katherine McFarland

Oysters in Long Island Sound (LIS) provide major economic and ecosystem services to the region's waters and coastal communities in the forms of harvested seafood and job creation, as well as denitrification, coastal protection, and habitat provisioning benefits. To more-fully realize these potential contributions, increasing shellfish production from aquaculture, recreation, and restoration has been identified as an ecosystem target by the LIS Study, a national estuary program dedicated to restoring and protecting the Sound's waters and watershed. Expanding existing natural beds presents a desirable opportunity to increase oyster-related ecosystem services; however, little is known about how expansion may affect the proliferation and transmission of oyster pathogens between restored and harvested populations. Development of risk-based guidance for mitigating bivalve diseases is essential to the successful restoration and cultivation of oysters throughout LIS and may translate to other coastal regions in the United States.

We will present a newly established oyster health monitoring program funded by the LIS Study, that monitors the population health of four natural and restored oyster beds in the region. The primary objectives of this program are to 1) ascertain a quantitative understanding of the seasonal dynamics of disease and reproductive success in unmanaged oyster populations; 2) identify the key water quality and physical oyster bed characteristics that best relate to the population burden of disease; and 3) establish a standard methodology for incorporating disease burden in oyster population health assessments for future evaluation of restoration projects. Using this comprehensive approach, which considers disease progression in the context of the environment and overall population health, we aim to fill critical information gaps needed to guide restoration planning in a way that promotes the success of natural, restored, and cultivated oysters and in turns supports healthy, resilient ecosystems and coastal communities.

Determination of gonad reproductive state using non-lethal ultrasonography in endangered black (Haliotis cracherodii) and white abalone (H. sorenseni)

Sara E. Boles (Bodega Marine Laboratory, University of California, Davis), Laura Rogers-Bennett, Wendy K. Bragg, Jessica Bredvik-Curran, Suzanne Graham, & Jackson A. Gross

Populations of California abalone (Haliotis spps.) were once abundant; however, due to historic overharvesting, disease, kelp forest decline, and habitat degradation all of these species have declined dramatically. Today, the black (H. cracherodii) and the white abalone (H. sorenseni) are federally listed as endangered species in the United States. Research efforts to conserve and protect endangered black and white abalone have been enacted by the United States Navy Pacific Commander Fleet, the National Oceanic and Atmospheric Administration, and the

California Department of Fish and Wildlife, as well as industry and non-profit stakeholders. Conservation efforts include captive breeding programs; however, determination of the reproductive state of individual abalone is notoriously difficult using traditional visual assessments. Ultrasonography is a well-recognized technology used to accurately and non-lethally assess gonad reproductive condition in cultured and wild fish, and more recently cultured red abalone (H. rufescens). Here, we implemented the use of ultrasound imaging technology to monitor the gonad condition of endangered black and white abalone. Repeated ultrasound assessments of the gonad were used to assess seasonal changes in reproductive development in wild black (n=20), and captive white abalone (n=25). A modified ultrasound gonad index score was developed to incorporate multiple species of abalone. The ultrasound index scores ranged from one to five, with an index score of one being the lowest (gonad margin is thinly wrapped around the digestive gland or not present) and an index score of five being the highest (gonad margin is thick and significantly compressing the digestive gland). We show that non-lethal ultrasound imaging technology is useful for tracking cyclical changes in the gonad reproductive condition as well as more precise selection of individuals that are in peak reproductive condition for captive breeding programs.

Integrating aquaculture to improve Olympia oyster restoration in the Elkhorn Slough, CA

Jacob Harris (Moss Landing Marine Laboratories, San Jose State University), Luke Gardner, Amanda Kahn, Kerstin Wasson*

Conservation aquaculture is emerging as an important restoration strategy to recover Olympia oyster populations in North America. Facilitating reproduction in a hatchery and outplanting offspring back into the estuary habitat can enhance abundance and generate shoreline habitat. However, oysters are most vulnerable to environmental stressors during their first year after outplanting and long-term restoration may be constrained by conditions that reduce growth rates during this critical period such as desiccation, predation, and competition. In winter 2021, we outplanted 11,300 aquaculture-raised juvenile oysters into Elkhorn Slough, CA. We conducted a series of experiments to determine how growth and survival related to initial oyster outplant size, tidal emersion, and other outplanting parameters. Initially, tidal emersion strongly affected oyster growth and survival, but after one year there was no difference in growth or survival between elevations. Size had no effect on oysters' initial survival after moving into the estuary. Size at outplant did have a positive relationship with long-term survival. The smallest and youngest outplanted oysters had lower survival than the older and larger oysters after one year. Restoration design parameters for caging and substrate type showed only moderate influence on oyster performance. These experiments help us understand how conservation aquaculture practices can be optimized to increase the effectiveness of restoration for the native oyster species. Results from this study directly support Elkhorn Slough's habitat restoration program, and oyster conservation aquaculture in general, by guiding targeted outplanting decisions.

A Novel Social-Ecological Clam Garden Site Selection Process

Joe Williams (Swinomish Indian Tribal Community), Courtney M. Greiner, Julie S. Barber, Jamie Donatuto, Melissa Poe, James McArdle, Lindy Hunter, Michal Heidt

Clam gardens are intertidal features modified by Northwest Coastal Indigenous people to enhance clam habitat for optimal shellfish production. The Swinomish Indian Tribal Community (SITC) recently initiated a clam garden project to address declining clam populations and community concerns regarding climate change and ocean acidification. This effort will integrate traditional ecological knowledge into contemporary resource management and climate adaptation strategies, encourage local food security and sovereignty, and promote sustainable seafood production. SITC's Fisheries Department and Community Environmental Health Program have co-designed a social-ecological site selection process focused on community participation to promote the long-term success of the project. This presentation will discuss clam gardening and SITC's work to revive the ancient practice into modern day use.

Baskets of cockles in fields of geoduck: Assessing Clinocardium nuttallii abundance in geoduck farms across Puget Sound

Ryan Crim (Puget Sound Restoration Fund), Emily Buckner, Elizabeth Unsell, Darbhi Durvasula, Hannah Garfield, Jodie Toft

Basket cockles (Clinocardium nuttallii) are a fast growing, medium-sized bivalve native to the west coast of North America that are prized by many Native American Tribes in the region. Over the past several decades, there has been a noted decrease in their availability by indigenous subsistence harvesters, prompting new avenues of research into this species' population genetics, vulnerability to a transmissible cancer, and opportunities for restoration. These investigations led collaborators at the Suquamish Tribe and Puget Sound Restoration Fund (PSRF) to connect with shellfish farmers and learn of an unlikely source of wild-caught basket cockles - PVC tubes and mesh sleeves used for planting geoduck seed, which inadvertently protect any cockles that settle inside. Many farmers see these basket cockles as a nuisance as their densities can be so high they are believed to be competing with geoduck for resources. Therefore some farmers will make the effort to remove cockles from tubes, leaving them on the beach or selling them for minimal profit to crab fishers. Here, we identified an opportunity to build a bridge between shellfish growers and Coast Salish Tribes interested in increased access to basket cockles. We have conducted population surveys at several geoduck farms to estimate the scale of this potential resource. We have also developed and tested a pathway for harvesting, transporting, and distributing cockles collected from geoduck farms to the Suquamish Tribal community. Here we will share our results to date and discuss the restoration implications moving forward.

Watching from Above – Monitoring Eelgrass Habitats in Humboldt, Samish, and Willapa Bays

Phil Bloch (Confluence Environmental Company), Kelly McDonald, Whelan Gilkerson and Bobbi Hudson

Aquaculture and eelgrass co-exist at many aquaculture sites, however increasing regulatory interest in protection of eelgrass as habitat for estuarine species has led to regulatory

challenges in permitting new aquaculture sites in or near eelgrass. Past research has characterized effects to eelgrass density and cover in areas where oyster culture and eelgrass co-occur. Technological advances in aerial data collection with unmanned aerial vehicles (UAVs) have made it possible to economically map eelgrass habitats at large scales in estuarine environments. Over the past 6 years, we have led eelgrass monitoring efforts at sites in Humboldt Bay (CA), Willapa Bay (WA) and Samish Bay (WA) using UAVs. Systematic, repeated mapping of these sites has facilitated mapping eelgrass responses to installation of aquaculture gear and observations of responses of eelgrass to natural and anthropogenic stressors. High resolution aerial imagery, where each pixel represents approximately 0.4 to 1 square inch, allows for binary mapping of eelgrass presence and absence throughout intertidal and shallow subtidal areas. Mapped areas range from several acres to several hundred acres and capture both potential impacts to and observed changes in eelgrass cover in response to natural and anthropogenic conditions. By monitoring these sites annually or seasonally, we have documented interactions and responses of eelgrass beds over time including declines, neutral responses and recovery. Mapped interactions include eelgrass responses to newly installed longlines and basket longlines, removal of longlines, placement of shell, wind-wave exposure, and low tide heat stress. Responses were often influenced by local or regional site characteristics. For example, a high intertidal site exposed to a multi-day heat stress event exhibited immediate loss of a large fraction of eelgrass with gradual recovery ongoing several years later, while low intertidal sites showed no apparent change in eelgrass cover. Similarly, removal of culture gear caused variable responses in eelgrass cover depending on site conditions, with some sites showing substantial positive effects of removal while others showing little or no change. Through monitoring with UAVs, field observations demonstrate the compatibility of aquaculture activities with maintaining eelgrass cover in some situations, while also quantifying and characterizing the potential impacts to and recovery of eelgrass beds when impacts occur.

Recovery mechanisms of eelgrass (Zostera marina) following dredging disturbance

Fiona Boardman (University of Washington), Elena Subbotin, Jennifer Ruesink*

In Washington state eelgrass and oyster culture are found in overlapping distributions. Oysters that are cultured directly on the sediment often involve dredging to maintain optimal ground conditions and harvest oysters. As a byproduct, this process can remove or damage co-occurring eelgrass, resulting in a disturbance event. Eelgrass serves several ecosystem services, such as providing nursery habitat for ecologically and commercially important estuarine species, so understanding eelgrass recovery following disturbance is of management interest. In Bruceport, WA, over the course of three years, we studied six adjacent oyster beds with eelgrass that were dredged at different times. We tracked the recovery of the eelgrass via clonal growth and development of seedlings. Factors including season of disturbance and frequency of disturbance affect the mechanisms of recovery, as well as the degree to which eelgrass recovery is possible. Findings from this study will inform management of eelgrass on oyster culture beds to support the resilience of these habitats.

Nekton Use of Seagrass (Zostera Marina) Habitat on Oyster Flip-bag Farms

Katie Houle (Pacific Shellfish Institute), Kalloway Page, Fiona Boardman, Jennifer Ruesink

Shellfish farms in Washington State have been exploring the use of flip-bags, an off-bottom growing method, to produce high-quality oysters for the singles, half-shell market. The interactions of these structurally complex systems in native seagrass Zostera marina habitat have yet to be comprehensively explored. This study is the first to examine nekton use of Z. marina habitat within and adjacent to oyster flip-bag farms. In 2020 and 2021, nekton communities were assessed at six farm locations in Washington State in four habitat types: flip-bags with and without Z. marina, Z. marina with no culture, and bare mudflat. Sampling in each habitat type occurred in both spring and summer seasons using a modified seine net to collect nekton >5mm in size and underwater GoPro cameras with intervalometers set to record for 2 minutes every 10 minutes during the diel incoming tide through high slack. Nekton abundance, taxa richness, community composition, individual species associations and two key behaviors: transiting and foraging were quantified. Results from both seine net tows and video indicate spring nekton were more abundant and diverse with significantly more transiting behavior observed with Z. marina present, with or without flip-bags. Summer nekton from the seine net tows were more abundant and diverse with Z. marina present, however summer videos indicate more abundant and diverse nekton in flip-bags with more foraging behavior observed compared to habitats without flip-bags. A small number of species were strongly associated with the presence of Z. marina in both seasons and occurred with or without flip-bags. Most nekton appear to be generalists, utilizing the broader habitat mosaic of mudflat, seagrass and aquaculture. These results will inform key stakeholders producing and regulating shellfish aquaculture in Z. marina seagrass habitat.

Can coralline algae habitat bolster the climate resilience of Washington's endangered pinto abalone?

Eileen Bates (University of Washington), Josh Bouma, Ryan Crim, Jodie Toft, Jacqueline Padilla-Gamino*

Since 1994, Washington State has seen a 97% drop in the native pinto abalone population. Since 2007, restoration aquaculture efforts have been underway to return the wild population to a self-sustaining density. Restoration groups spawn pinto abalone in hatcheries and rear them for 1-2 years before releasing them to subtidal sites. However, the success of abalone not only depends on restoration efforts but also on the capacity of abalone to survive and reproduce as threats of ocean acidification and warming increase. In a preliminary hatchery study, we found that pH and temperature influence larval survival, but pH has a stronger effect on settlement success. Crustose coralline algae can play an important role in the success of restoration efforts by serving as a natural settlement inducer and creating a pH refuge for juvenile abalone. In this study we examined settlement of pinto abalone under different environmental conditions (7.95pH, 14°C (control); 7.95pH, 18°C; 7.6pH 14°C; and 7.6pH, 18°C) using two substrates: clean fiberglass with GABA (a neurotransmitter typically used to induce larval settlement) and CCA covered fiberglass. If presence of CCA can improve settlement and mitigate effects of ocean acidification on larval and juvenile abalone, we may be able to improve the efficacy of abalone restoration efforts in Washington. We tracked settlement rate and then survival, growth, and substrate microbial composition for the first three months of juvenile growth. Our findings

will unblock bottlenecks in the hatchery rearing process and provide insights into ideal wild abalone habitat as climate change continues.

LIGHTNING TALKS

Riverside B

WDFW's Safeguard Our Shellfish Campaign

Nam Siu (WA Dept. of Fish and Wildlife), Katy Davis, Matt Hoehn, Chris Eardley

The Washington Department of Fish and Wildlife (WDFW) is tasked with preserving, protecting, and perpetuating fish, wildlife and ecosystems while providing sustainable fish and wildlife recreational and commercial opportunities. To that end, WDFW's Shellfish and Seaweed Health Unit works to prevent the introduction and spread of marine pathogens and pests, which could harm the state's economically and ecologically important shellfish resources. Movement of live shellfish and shellfish products can come with risk of introducing or spreading harmful pathogens and pests—and growing invasive species issues, expansion in international trade of live shellfish, and a general lack of public awareness of marine disease risks are of concern to WDFW. While the shellfish aquaculture industry is versed in matters of shellfish diseases and pests, the general public is not—and ensuring proper handling and discard of seafood products is an area of focus in WDFW's recent educational efforts. In this lightning talk, we will describe existing management efforts in WA targeting non-aquaculture stakeholders. We will also highlight a new "Safeguard Our Shellfish" or "SOS" campaign. Outreach with the SOS campaign aims to raise awareness of shellfish disease risks and promote responsible handling of shellfish products among the broader seafood industry and general public, who may be increasingly likely to interact with live imported or transferred shellfish.

An update on West Coast Shellfish Biosecurity Workshop Series

Chris Eardley (WA Dept. of Fish and Wildlife), Chris Langdon, Maria Haws

In 2020, a consortium of West Coast shellfish partners, including Washington Department of Fish and Wildlife, Oregon State University, and University of Hawaii embarked on a collaborative and conversation-focused effort to advance biosecurity in the region's valuable shellfish aquaculture industry. With stops in Washington, Oregon, and two Hawaiian islands, the series has exchanged expertise, ideas, and concerns among stakeholders and gathered valuable input in the interest of developing tools for West coast growers and regulators alike. The goals of the series include developing biosecurity tools for practitioners, improved communication among stakeholders, and disease preparedness frameworks for West coast states. This lightning talk will provide a brief summary of the work to date and a preview of next steps.

Effect of Biofouling and Stocking Density on Microclimate in off-Bottom Oyster Culture Grow-Out Bags

Julianne Grenn (Virginia Institute of Marine Science) and William Walton*

Oyster farmers growing Crassostrea virginica are increasingly utilizing off-bottom culture practices due to the potential to improve survival, meat quality, and product consistency relative to traditional methods. Despite this potential, sudden spring/summer mortality events impacting on and off bottom farms, occurring without apparent connection to disease or harmful algal blooms, have been observed along the East and Gulf Coasts, with mortality reaching 85% in 2014 at some Virginia farms. These mortality events could not be explained by changes in ambient water parameters and typically, the mortalities do not affect every farm in a given waterbody. This pattern suggests that the seed stock and/or the farming practices could factor into these mortality events. For the latter, farming practices can lead to substantially different grow-out conditions for oysters.

Conditions inside an oyster bag (dissolved oxygen, pH, turbidity, and chlorophyll-a) may vary from ambient conditions due to a spatio-temporal lag induced by reduced water exchange rates which may be exacerbated by biofouling and stocking density. This ongoing project addresses three questions: 1) Do biofouling control (air-dried vs. not air-dried) and stocking density (high, normal, and empty) decisions affect the microclimate (water parameters) inside grow-out bags; 2) Do any observed differences in water parameters correlate with oyster performance, including health and disease prevalence; and 3) What combination of farm practices can growers employ to maximize oyster performance while minimizing costs?

Significant effects of both stocking density and biofouling control on water parameters within floating bags have been observed in work to date. A sampling event on September 19th, 2022, which occurred in the days preceding a split (decreasing the density of oysters within each bag), indicates that stocking density significantly affected dissolved oxygen ($p < 0.01$), and an interaction of stocking density and biofouling control significantly impacted pH ($p < 0.01$), chlorophyll-a ($p = 0.02$), and turbidity ($p = 0.01$). Results from this study suggest that farmers can influence the water parameters within floating bags through husbandry decisions, which could correlate to oyster performance. With the results of this ongoing study, we hope to provide producers with better data so farmers can make more informed husbandry decisions while also identifying factors that could be driving these spring/summer mortality events.

Is water temperature a critical factor dictating OsHV-1 SD Bay µvar infection and mortality rates in Pacific oysters?

Emily Kunselman (Scripps Institution of Oceanography), Daysi Manrique, Zachary Daniel, Colleen Burge, Sarah Allard, Jack Gilbert*

OsHV-1 is an oyster virus that threatens oyster aquaculture all around the world. A microvariant exists in San Diego Bay, but the environmental conditions that permit the virus to replicate are unknown. In other areas of the world, the virus is strongly associated to warming seawater temperatures. This project will investigate how temperature influences OsHV-1 SDB µvar infectivity. We expect that the virus will not replicate or successfully kill oysters below 18°C but it will kill oysters at 20°C and even higher rates of mortality will occur above 20°C. Currently, oysters in San Diego Bay are only farmed below 18°C to prevent viral infection. Our goal is to examine the thermal limits of OsHV-1 replication. In order to do this, we are conducting an experimental infection of hatchery-raised oysters in closed aquaria at the different temperatures from 16 to 24°C. In addition to the virus, we expect that secondary bacterial infections are

responsible for mortality in immunocompromised oysters. Therefore, the study also compares antibiotic treated and untreated oysters to determine whether bacteria also contribute to this disease.

Enhancing access to ocean data and information products from the Central and Northern California Ocean Observing System (CeNCOOS) to support well-informed shellfishery management

Marine Lebrec (Monterey Bay Aquarium Research Institute), Alex Harper

There is a growing need for reliable access to high-quality ocean data and information products to support well-informed shellfishery management decisions. To address this, the Central and Northern California Ocean Observing System (CeNCOOS) has developed tailored data products that offer near-real time and forecast information on physical, biological, and chemical ocean properties from in situ measurements, remote sensing platforms, and models. This talk will showcase ways to visualize, analyze, and download data from the state-wide CalOOS portal, a publicly available platform. In addition, several tailored products relevant to shellfishery stakeholders will be featured, including the California Harmful Algal Bloom Monitoring and Alert Program (HABMAP) data visualization tool, as well as an oyster dashboard used for accessing local water quality information. Impacts of ocean acidification and hypoxia (OAH) are growing threats to organisms with high ecological, economic, and social importance along the U.S. West Coast, driving the need for a more coordinated approach to biological and chemical monitoring, as well as data access. This presentation will also showcase the development of a new California OAH data portal which aims to support the scientific community, resource managers, and other stakeholders in improving our understanding of these stressors on our local ecosystems.

OUTREACH AND EDUCATION

Riverside B

Seaweed farming in the classroom: educational materials

Kristin Jones (Pacific Northwest National Laboratory), Deborah Rose, Molly Grear, Ruth Branch, Candace Briggs

Seaweed farming is an emerging market in the United States, and as such is still relatively unfamiliar to consumers and the general public. We have been developing a week-long experiment for elementary school students to learn about growing and monitoring seaweed. The seaweed the students would grow is named Ulva and is commonly known as sea lettuce. While Ulva is not typically grown for food in the U.S., it is often cultivated for commercial purposes such as biofuels and extracts. Its fast-growing structure makes for easy measurements and a quick experiment in the classroom. Educational materials will be provided to teachers and include a lab protocol and materials list for growing seaweed in a classroom setting and conducting environmental monitoring, as well as an educational comic that incorporates various elements of aquaculture operations, marine energy, and the ocean environment. This classroom activity can also promote interest and curiosity in mariculture operations. Sharing these

resources as well as gaining feedback from active seaweed and shellfish farmers and other scientific experts will support the broader industry and the growing ocean food economy.

Washington Shellfish Perceptions: Survey Results Examining Messages and Attitudes in Shellfish Producing Counties

Brett Veerhusen (Ocean Strategies), Tyler Edgar

In May/June 2023, Ocean Strategies conducted a survey of 500 individuals in Pierce, Mason, Thurston, Pacific and Grays Counties. The survey's goal was to understand attitudes and perceptions of county residents toward shellfish farming to help inform messaging and build social license. Ocean Strategies will present survey results and recommendations to design core messages about shellfish farming in Washington state and develop nuanced communications for the different shellfish regions.

Our results showed strong support for shellfish farming in every county. In this session, Ocean Strategies will outline recommendations for shellfish farmers in Washington to maintain their favorable position — specifically with local, county, state and federal decision-makers. This will include: developing consistent and coordinated messaging, identifying partners and stakeholders in key counties and communities, leveraging public events to further build the industry's reputation and strategic engagement with shellfish opponents should the need arise. Finally, Ocean Strategies will discuss key partnerships that are and will remain critical for the industry.

DOWN ON THE FARM

Riverside B

The effect of including Nannochloropsis oculata within mixed algal diet on growth and survival of Pacific oyster Crassostrea gigas larvae

Zachary Kowash (Oregon State University), Darren de Silva, Marni Rem-McGeachy, William Schoeneck, Henry Fleener, Neil Thompson

Pacific oyster, Crassostrea gigas, is the most commonly reared shellfish on the Pacific coast and a large percentage of the Aquaculture industry is reliant on hatchery production of animals. Pacific oyster larval rearing techniques use microalgal mixtures that change over time, vary among producers and over geographic areas. Subsequently, the effects of including Nannochloropsis oculata as a food source for Pacific oyster larvae are not well understood. This study quantified the effects of N. oculata introduced into algal mixtures containing Tisochrysis lutea and Chaetoceros muelleri. In addition, two algal ration methods were used to identify differences amongst larval feeding methods; a "grazing" technique where larval "grazing" was quantified and used to calculate the amount of feed each day, and an incremental feeding method analogous to standard hatchery protocols. Two standard ration treatments were used in this study; one including all three algae species, and a second without N. oculata. A single "nongrazing' treatment was used with all three algae species. Larvae were reared in static tanks for 24 hours, then standardized to a density of 40 larvae per milliliter and stocked into Hatfield Ultra Dense Larval System (HUDLS) technology at D-stage. The HUDLS are a flow-through

seawater system that produces more stable environmental conditions between tanks. Larval samples were collected at 24 hours (immediately pre-stocking into HUDLS), six days, and 12 days post-fertilization. Within the standard ration method, inclusion of N. oculata increased growth rate, measured via shell length. No strong effect of ration method was found on larval size. Survival data did not a show a strong difference among algae mixtures, or feeding method treatments. Our data suggest a benefit on growth with inclusion of N. oculata, however given differences in hatchery animal husbandry infrastructure more research should be conducted to evaluate the effect of N. oculata across numerous husbandry environments.

Quantifying Bed Quality: a Comparison of Oyster Yield Across Habitats and Growout Methods

Jennifer Ruesink (University of Washington), Fiona Boardman, Wesley Hull, Aspen Katla, Andy Suhrbier, Emma Beck, Katie Houle

A key element of successful intertidal shellfish farming is recognizing which environmental factors affect yield and are possible to control or modify. On a bed-specific scale, culture practices may alter grain size, allow seagrass co-occurrence, and involve placement of oysters directly on or above the sediment. Bioturbators such as burrowing shrimp also have strong effects on oyster production, but the relationship between their density and oyster yield has not been fully quantified. We use tethered, seeded cultch as an index of bed conditions and track survival, shell growth, and condition of Pacific oysters (Magallana gigas). Survival and condition improved in off-bottom culture relative to ground culture, and on-bottom survival was especially impaired above 75 burrowing shrimp m-2 and in siltier sediment. No oyster performance differences were associated with the amount of surrounding seagrass in three categories (none, sparse, dense), except for a weak negative effect of dense seagrass on survival and positive effect of sparse eelgrass on shell growth after 9 mo. As a consequence, although seagrass may not provide a boost to co-located intertidal shellfish, we found little evidence of tradeoffs in which maintaining seagrass would reduce yield of farmed oysters. Moving oysters out of the boundary layer and away from soft sediment improves both survival and tissue growth aspects of yield.

Experiences With Experimenting with and Developing Floating Oyster Bags

Nyle Taylor (Taylor Shellfish Farms)

Nyle will talk about the floating bags Taylor has developed over the past decade.

Tidal Energy for Mariculture Operations

Candace Briggs (Pacific Northwest National Laboratory), Ruth Branch, Molly Grear, Debbie Rose, Kristin Jones

Oysters and seaweed play an increasing role in the sustainable blue seafood economy of the United States. Siting these mariculture operations is a complicated process, considering

species-specific needs, permitting regulations, existing infrastructure, cost, conflicts with other ocean users, and more. However, one commonality is that locations selected typically have some ocean currents or tides to aid in the circulation of nutrients, and this movement of water can have additional benefits. Marine energy, in particular, tidal or current energy, existing at mariculture sites could be harvested to enable numerous possibilities. These could include powering monitoring devices, tumbling oysters with mechanical or electrical energy, charging electric outboard motors for boats, or even powering onsite facilities such as lighting or housing – though none of these have been demonstrated in the US yet. We have been beginning to explore the opportunities for marine energy at oyster and seaweed farms by assessing power needs, comparing data on marine energy resources at locations of existing farms, measuring localized current speeds, and partnering with local mariculture experts to assess the feasibility of marine energy device installation at oyster and seaweed farms. This research works to spread awareness in mariculture stakeholders of the possible functions of marine energy at oyster and seaweed farms and add to the growing body of literature on the feasibility of collocating marine energy with mariculture.

ECOSYSTEMS AND BEST MANAGEMENT PRACTICES

Riverside B

Do Oysters Reduce or Increase Transmission of Eelgrass Wasting Disease?

Lindsay Alma, PhD (University of California, Davis)

Eelgrass (*Zostera* marina) is ecologically and economically important in coastal waters where it provides vertical habitat for organisms, prevents erosion, and serves as a carbon sink. Eelgrass meadows are rapidly disappearing globally for a variety of factors including eutrophication, sedimentation, temperature increases, and disease. An opportunistic pathogen *Labyrinthula* zosterae (*Lz*), causes eelgrass wasting disease (EWD), characterized by dark lesions which eventually lead to partial then full mortality of tissue. Eelgrass meadows and oyster beds frequently coexist in nature, however not much is known about their biotic relationship and if bivalves assist in propagule removal or exacerbate the disease. It is known that bivalves have the ability to dampen transmission of EWD through filtration, but they may also vector the disease on their shells or inside their tissues, which may be of concern when transferring aquaculture products. To investigate this theory, we conducted a lab-based experiment in Friday Harbor, WA, where we exposed either live oysters (*Crassostrea gigas)* or empty oyster shells to *Lz*. Subsequently we treated oysters and shells with one of three common sanitization methods: 6.25 ppm bleach, 10 ppt saline bath, or 24-hour depuration. Treated oysters were added to tanks with eelgrass and monitored for signs of EWD. We measured lesion severity and collected samples to analyze intensity of infection using qPCR as a proxy from water, oyster tissue, grass blades, and shells. Additionally, we have preserved oyster tissue for histological analysis to determine whether *Lz* can be found infecting oyster tissues. By conducting a carefully controlled experiment and implementing molecular analysis, we can improve our mechanistic understating of disease transmission to inform future management strategies to reduce the risk of EWD.

SHELLFISH AND HUMAN HEALTH

Riverside B

Effects of the harmful alga Cochlodinium (aka Margalefedinium) polykrikoides on clearance rate of the hard clam, Mercenaria mercenaria

Darren de Silva (USDA-ARS), Christopher J. Gobler

Suspension-feeding bivalves are often exposed to harmful algal blooms (HABs) such as those formed by the ichthyotoxic dinoflagellate, Cochlodinium polykrikoides. As part of a genus that is present worldwide, C. polykrikoides has caused significant die offs of bivalves and other marine organisms, although the Northern quahog or hard clam, Mercenaria mercenaria, is one suspension-feeding bivalve that is relatively resistant to this HAB. This study quantified clearance rates of juvenile hard clams (10-20 mm) exposed to three different populations of C. polykrikoides (wild, CP1 strain, CPSB-1G strain) as well as the nonharmful cryptophyte, Rhodomonas salina and the nonharmful dinoflagellate Gymnodinium aureolum. Mixed algal exposures with C. polykrikoides and the cryptophyte R. salina or the dinoflagellate G. aureolum and R. salina were completed to assess selective clearance and multiple biovolume exposures with C. polykrikoides bloom water and R. salina (1,000, 1,500, 3,000 cells mL^-1 C. polykrikoides biovolume equivalent) were completed to assess the effects of particle loads on hard clam clearance rate. Hard clams opened and actively cleared algal mixtures at and below 1,000 cells mL^-1 bloom densities of C. polykrikoides. During single species exposures, strain CPSB-1G and R. salina were cleared significantly faster than wild C. polykrikoides and strain CP1. During mixed exposures, R. salina was cleared significantly faster than CPSB-1G but not other C. polykrikoides populations and there was no significant difference between hard clam clearance rates of G. aureolum and R. salina. Clearance rates of C. polykrikoides at 1,500 cells mL^-1 C. polykrikoides/R. salina mixtures were not significantly different than zero unlike clearance of those at 1,000 cells mL^-1 C. polykrikoides/R. salina mixtures indicating a density dependent effect of blooms. Collectively, the results demonstrate that hard clams can actively clear C. polykrikoides cells, including moderate (<1,000 cells mL^-1) but not elevated (> 1,000 cells mL^-1) bloom densities. M. mercenaria may be an ideal candidate for aquaculture and restoration in regions prone to HABs caused by this species.

AGENCY UPDATES AND LISTINING SESSIONS – BREEDING AND HEALTH MANAGEMENT PROGRAMS

Pacific Room

USDA Pacific Shellfish Research Unit Engagement Session - POGS Breeding Program Update and Listening Session

USDA-ARS Pacific Shellfish Research Unit

The USDA-ARS Pacific Shellfish Research Unit (PSRU) will summarize the ongoing activities of our new unit and hear from shellfish industry and stakeholders. We will present our current and projected capabilities in terms of infrastructure, personnel, and research capacity. A synopsis of the Pacific Oyster Genomic Selection (POGS) projects 2023 year class hatchery production, current research with the 2023 year class, and a summary of the first USDA PSRU oyster release to industry will be presented.

Workshop: Strengthening Research Support for Shellfish Health Management - OsHV-1 and The West Coast Shellfish Industry

NOAA Fisheries Northeast Fisheries Science Center and CA Department of Public Health

Ostreid herpesvirus 1 (OsHV-1) is an economically devastating disease affecting oysters globally. OsHV-1 and its variants affect all life stages of the Pacific oyster, as well as other oyster species, making this virus an emerging threat to the West Coast's $270M shellfish industry. Significant investments are being made to support research aimed at better understanding OsHV-1 infections in US cultivated oysters, as well as the implications and mitigation strategies for the industry. Recognizing that industry priorities and practices shift in response to evolving environmental threats and regulatory landscapes, this workshop aims to create a dialogue between researchers, growers, and shellfish managers to understand the state of the science and refine future research objectives for application to health management practices.

BEYOND BIVALVES: CRAB, SEAWEED, AND MORE

Pacific Room

Effects of climate change (warming and acidification) on bull kelp (Nereocystis leutekana) microscopic stages

Miranda Roethler (University of Washington), Jacqueline Padilla-Gamino, Cinde Donoghue*

Kelp forests are some of the most iconic and critical marine habitats in the Pacific Northwest, but both local and global kelp populations have been declining. These declines are likely linked to warming waters. Ocean warming will co-occur with ocean acidification (OA), particularly in Puget Sound, which has naturally acidic water. While the negative effects of OA on many marine organisms (e.g., calcifiers) are well-studied, the effect of OA on kelps is less well-understood. Understanding the effects of multiple stressors is particularly critical, as stressors can interact in unexpected ways. Bull kelp (*Nereocystis luetkeana*), the primary canopy-forming kelp species in Puget Sound, has a biphasic life history with macroscopic (sporophyte) and microscopic (gametophyte) stages. We still know very little about how the microscopic stages will be impacted by multiple stressors in Puget Sound. This study aims to better characterize the effects of warming and OA on Puget Sound bull kelp throughout its microscopic life stages. We challenged kelp gametophytes from two different, genetically distinct populations to elevated levels of temperature and pCO2 in the lab and tracked survival, growth, development, and reproductive success from spore settlement through the juvenile sporophyte stage. We also developed a method to measure photosynthesis and respiration of gametophytes using a Mini-PAM-II fluorometer. Our collection sites differed in the overall temperature, urbanization level, and state of the kelp forest. Understanding local adaptability is critical in predicting future population responses to climate change, to elucidate potential range shifts or local extinctions that will happen in Puget Sound kelp beds and to plan for conservation, restoration, and recovery of healthy kelp forests.

The Impact of Temperature on the Nutritional Composition of Dulse (Devaleraea mollis) and its Influence on Juvenile Red Abalone (Haliotis rufescens)

Jackson Gross (Univeristy of California, Davis), Natalie Rizzo, and Sara Boles

This study investigates the direct effect of temperature on the nutritional makeup of dulse (*Devaleraea mollis)* and its subsequent indirect effects on the growth of two size classes of juvenile red abalone (*Haliotis rufescens)*. As climate change alters primary producers' nutritional profiles, consequential effects may ripple up the food chain, potentially stressing and impairing ecosystem health. Dulse was cultured at 13°C, 15°C, and 17°C, then fed to two size classes of red abalone—small (15.6±1.76mm) and large (42.86±4.65mm)—kept in ambient seawater. In total, 288 small abalone were divided into 24 troughs (12 per trough), and 63 large abalone were divided into 21 troughs (3 per trough), with each group receiving a randomly assigned diet twice weekly for 13 weeks. The study assessed the abalone's health via condition factor (CF) and change in body weight ratio (BWR) derived from initial and final measurements. Concurrently, dulse samples underwent nutritional analysis at the UC Davis Analytical Laboratory.

A year in the life: Tracking post-larval cohorts of Dungeness crab in an estuarine system

Sarah Grossman (Swinomish Indian Tribal Community), Claire Cook, Julie Barber

Improved understanding of population supply, and recruitment of Dungeness crab (Metacarcinus magister) in Puget Sound is a priority to ensure sustainable management of the largest commercial fishery in Washington State. Recent studies have provided evidence for multiple year-class cohorts of Dungeness crab based on spatial patterns of timing and size at settlement. We conducted paired larval flux and intertidal surveys at several sites across northern Puget Sound to quantify the intra- and interannual patterns of M. magister post-larval (megalopal) supply and subsequent settlement and growth of young-of-the-year (YOY) crabs. Additionally, we examined how the annual relative contributions of phenotypically-distinct settlement cohorts relates to site-specific YOY population dynamics. From 2018 to 2022, the total number of megalopae delivered to the study region varied significantly between sites, seasons, and years. The magnitude of larval flux was not consistently correlated with the abundance of J1 instars (recent settlers) in the intertidal nursery habitats. Nor was the relationship of J1 instar abundance consistently indicative of total recruits (J2+ instars) present in August, indicating local factors likely affect YOY survival. Carapace dimensions of megalopae and J1 instars decreased significantly over the April to August delivery period in all years, confirming the presence of multiple larval inputs to the study region. The larval and settlement cohorts, differentiated by seasonality and size, were observed at all of the study sites though the relative proportions varied on annual and spatial scales. Sites north of the Rosario-Haro complex likely receive significantly fewer early-season settlers relative to sites near the eastern Juan de Fuca Strait. By the end of the settlement season, the structure of size classes on beaches was reflective of the relative proportion of the larval delivery cohorts. Our results highlight that the relative annual magnitudes of larval delivery and growth of cohorts are not uniform across northern Puget Sound beaches and the underlying processes controlling growth and survival at a beach level are complex. Given the declines in Dungeness crab populations in

southern Puget Sound, it is important to further examine the oceanographic processes controlling larval delivery, as well as factors influencing post-settlement survival. We hypothesize that the presence of multiple settlement cohorts provides for an increased population resilience as ocean conditions and land-use change.

Return of the Green: An update on the development of a seaweed recycling network

Emily Buckner (Puget Sound Restoration Fund), Hannah Garfield, Jodie Toft, Joth Davis, Bill Dewey, Duane Fagergren, Evie Fagergren, Betsy Peabody

Intertidal shellfish operations in Puget Sound can be burdened by native seaweed that accumulates on cultivation gear throughout the growing season, oftentimes suffocating clams, oysters and other farmed shellfish. Seaweeds, including sea lettuce, grow quickly and abundantly during warm months, fueled by nutrients from upland sources, the ocean, and nutrients excreted by the shellfish themselves.

Tuesday, September 19, 2023

LABOR ISSUES

Riverside A

wafla Update

Enrique Gastelum (wafla)

Struggling to secure and retain employees for your short-term seasonal requirements? Join us for an essential presentation addressing your labor force stability concerns. Discover the game-changing potential of the H-2A guestworker visa program—a solution tailored to your labor demands. With its 40-year history, this program is gaining momentum among shellfish farmers and packers, offering a legal avenue to access skilled international workers precisely when you need them. Enrique Gastelum, CEO of wafla, the largest association of H-2A agricultural employers on the west coast, will be your guide. Gain insights into the H-2A program's core elements and explore how wafla has been instrumental in helping shellfish growers fill critical roles. Don't miss this opportunity to enhance your labor strategy and ensure seamless productivity during peak employment periods.

Tide's Out: Proposed Washington Shellfish Crew and Manager Training

Teri King (Washington Sea Grant), Ashleigh Epps, Nicole Naar

The Washington shellfish industry has been hit hard by climate change, with unprecedented heatwaves and rainfall over the past two years (Raymond et al. 2022). On top of these ecological stressors, pandemic-related disruptions (e.g., supply chain disruptions, inflation, and limited housing) have exacerbated workforce shortages. Those in rural communities – where the workforce pool is limited, and unemployment rate is high – have been the hardest hit.

Though shellfish growers in rural areas struggled to find and retain workers for their operations prior to the pandemic, both inflation and worsening housing availability and affordability crises have made it even more difficult to find and retain workers.

The results of a Sea Grant needs assessment for Oregon/Washington aquaculture emphasized difficult working conditions – such as extreme weather, unpredictable work schedules, physical demands of workers, low wages and limited benefits. Shifting workplace culture and generational attitudes about manual labor, work ethic, company loyalty, credentials and compensation have created divergent expectations between employers and potential employees that also contribute to poor worker retention and high turnover. Farms are working with fewer crew than needed and dealing with unprecedented rates of employee turnover. This lack of workforce capacity creates declining working conditions for the remaining employees, which then feeds back into high turnover rates.

To begin addressing the challenges and meeting the identified needs, our proposal is to revive a previously successful WSG crew training program by updating it to reflect current shellfish industry needs and adding a manager training component to equip employers with the necessary tools for recruiting and retaining a diverse next-generation workforce. Our talk will outline the proposed workforce development trainings, curricula, instructors, timeline and participant recruitment.

THE NATURE CONSERVANCY UPDATES

Riverside A

TNC's Restorative Aquaculture Program, Stories, Updates, and New Tools

Tiffany Waters, Molly Bogeberg, and SOAR grant recipients

Join TNC staff and grant recipients to learn more about:

- The Supporting Oyster Aquaculture and Restoration (SOAR) Program (30min)
- The Shellfish Growers Climate Coalition's Carbon Footprint Calculator (15 min)
- Seaweed Aquaculture Novel Markets and Carbon Crediting Analysis (15 min)

POLICY AND ECOSYSTEM MANAGEMENT

Riverside B

Taylor Shellfish Farms - Habitat Conservation Plan

Jesse DeNike (Plauche & Carr), Samuel W. (Billy) Plauche, Phil Bloch, Kelly McDonald, and Chris Cziesla

Taylor Shellfish is currently developing a habitat conservation plan (HCP) under the federal Endangered Species Act (ESA) for its shellfish farming activities in Washington State. Taylor Shellfish's farming activities are currently covered by the programmatic consultation that was completed between the U.S. Army Corps of Engineers, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service in 2016 for shellfish activities in Washington State inland marine waters and, to a lesser extent, by project-specific individual consultations.

Taylor Shellfish is pursuing an HCP as an alternative means of complying with the ESA. Taylor hopes and expects that a company-specific HCP will allow for the development of unique conservation measures that are better suited to Taylor's farming practices, land holdings, and business needs. Additionally, a key goal of an HCP is to conserve the ecosystems upon which listed species depend, ultimately leading to their recovery. Accordingly, Taylor believes that the HCP will result in improved outcomes for both the company and sensitive species.

This presentation will include an overview of Taylor Shellfish's anticipated HCP, including its geographic scope, covered activities, covered species, and potential conservation measures. It will also discuss the status of the HCP, additional steps to be completed before finalization, and opportunities for engagement.

his presentation is expected to provide useful information for individuals interested in the scope and timeline of the HCP. Finally, as Taylor is developing impact analyses and some alternative conservation strategies for addressing sensitive species and habitat, the HCP could prove helpful information for other growers that may want or need to utilize practices that are not fully covered by the Programmatic Consultation in the future.

INTEGRATED PEST MANAGEMENT

Riverside B

Ecological impacts of the invasive European green crab (Carcinus maenas) in Washington

Ben Rubinoff (WA Sea Grant), Jeff Adams, Emily Grason, Kate Litle, P. Sean McDonald, Alex Stote

The European green crab (EGC) was first detected in Washington, USA in 1998, and since then, has expanded in numbers and spatial extent across coastal and inland waters. Ecological impacts of EGC have not yet been recorded at this early stage of invasion, but as populations continue to grow, they are likely to become increasingly detectable/apparent. We analyzed Washington Sea Grant's Crab Team monitoring data to determine how EGC populations vary over space and time and to identify species showing negative population correlations with green crab abundance. Native hairy shore crab (*Hemigrapsus oregonensis*) showed the strongest negative relationship with green crab abundance, aligning with documented impacts in other locations. We then conducted a tethering experiment during the summer of 2023 to investigate whether green crab abundance across multiple invaded sites show a positive correlation with the number of tethered hairy shore crab consumed. In this talk, we will present the results of our tethering experiment and discuss how they align with documented impacts of EGC in other locations. We will conclude by suggesting how our monitoring and experimental results can best be utilized by managers in coastal Washington.

What's Eating You: an Overview of Known Interactions and Impacts of The Invasive European Green Crab on Pacific Coast Shellfish Species

Brian Turner (WA Dept. of Fish and Wildlife)

The European green crab (EGC), Carcinus maenas, is a prolific invasive species and voracious predator that threatens shellfisheries in North America. While there are documented impacts of EGC on shellfisheries (e.g., soft-shell clams) and predation on fishery species (e.g., oysters,

mussels) on the Atlantic Coast, far less is known of the impacts of EGC on commercial shellfish of the Pacific Coast. This presentation will serve as an overview of known interactions and potential effects of EGC on Pacific Coast shellfish species. In addition, this presentation will address gaps in our understanding of EGC/shellfish interactions and highlight research priorities.

Monitoring Recent Shifts in Burrowing Shrimp Populations in Coastal Estuaries: Are They Really New and Should a Shellfish Grower be Concerned?

Brett R Dumbauld (USDA-ARS), Brooke McIntyre, Nathaniel Lewis, Jennifer Ruesink, and Wesley Hull

Ghost shrimp, Neotrypaea californiensis, are important components of estuarine intertidal communities along the US Pacific coast, but are of significant concern to shellfish growers, especially in Willapa Bay where a program to control these shrimp on shellfish beds was recently suspended. Populations of these shrimp have been monitored in Willapa Bay, Washington for three decades and in Yaquina Bay, Oregon since 2005. Ghost shrimp density at individual monitoring locations increased dramatically in the 1990s in Willapa Bay, declined almost as precipitously from 2000 through 2010, and has since increased again. Similar though less dramatic population fluctuations have occurred in Yaquina Bay since 2005. These shrimp have pelagic larvae that develop in the adjacent coastal ocean and then “recruit” as postlarvae back to estuaries. Significant relationships between the number of recruits and the number of larger 1 year-old shrimp present have been documented for both of these estuaries, but some precipitous population declines have recently been observed at several locations in Willapa Bay, where larger/older shrimp have either moved/receded or suffered mortality. Results from surveys suggest that shrimp continue to recruit to areas where larger adults have disappeared, but small juveniles are then also subject to mortality or move from these areas. It is important to understand the mechanisms that influence post-recruitment shrimp survival due to these shrimps impacts on shellfish aquaculture, but also their broader role and influence on other habitats at the estuarine ecosystem scale.

IPM Update from WA Department of Agriculture

Laura Butler (WA Department of Agriculture)

Since 2020, the Washington State Legislature has provided $3.94 million for research to assist with the development of an Integrated Pest Management Plan to address burrowing shrimp in Willapa Bay and Grays Harbor. This panel will provide high-level overview of the research that has been funded to-date and next steps for the Integrated Pest Management Workgroup.