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OYSTER FILTRATION OF *Labyrinthula zosterae* IN CHANGING ENVIRONMENTAL CONDITIONS

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The effects of climate change, such as increased pCO2 and sea surface temperatures, are current and future threats on our oceans and are likely to cause increases in marine disease prevalence and severity. Mitigation strategies are therefore becoming increasingly important to protect marine ecosystems. Filter feeders, such as oysters, actively filter seawater through their gills to capture particles as food. These food particles include planktonic species, such as algae and diatoms, and may also include pathogens. Specifically, Pacific oysters, *Crassostrea gigas*, have demonstrated the ability to filter out *Labyrinthula zosterae*, the known causative agent of wasting disease in eelgrass, *Zostera marina*. These effects of climate change, however, are also anticipated to have an effect on the filtration capabilities of oysters. The objective of this study is to investigate the relationship between oysters, eelgrass, and L. zosterae under changing environmental conditions. Various numbers of oyster seed will be co-inhabited with Z. marina shoots and infectious doses of *L. zosterae* to determine the optimal number of *C. gigas* seed needed to minimize wasting disease. Follow-up experiments will focus on how increased pCO2 and temperature alter oyster bio filtration and progression of eelgrass wasting disease. Data presented will include changes in water concentration of *L. zosterae* over time and final prevalence and severity of wasting disease in *Z. marina* in the presence and absence of oysters in multiple conditions.

OLYMPIA OYSTER (*Ostrea lurida*) RECRUITMENT BEHAVIOR IN PUGET SOUND

Brian Allen*

The intent of this monitoring effort is to align actions for monitoring Olympia oyster cohorts and to facilitate a collaborative and shared data archive from across Puget Sound; the program is now in its 5th year. We collectively benefit from annual observations of recruitment from the historic range in Puget Sound, where variations in magnitude and spat survival are the rule. I am presenting results from this monitoring collaborative through 2018. Our strategy was to employ a practical, low cost method to collect quality information on cohort recruitment behavior (abundance, size, mortality). The vision is to maintain a long-term monitoring effort for multiple, priority water bodies for Olympia oyster bed habitat conservation and restoration in Puget Sound.

DOES IT MATTER WHERE MY PARENTS GREW UP? TRANSGENERATIONAL EFFECTS OF OLYMPIA OYSTER LARVAE

Lindsay Alma*, Ryan Crim, Eileen Bates, Jacqueline Padilla Gamino

It is important to understand if in situ oceanographic stressors experienced by broodstock have the potential to affect the success and fitness of offspring. Puget Sound, Washington is

experiencing rapid change due to increased carbon dioxide levels in the atmosphere. It is also home to countless shellfish aquaculture operations who are already beginning to notice declining success in shellfish spat due to change in seawater chemistry. This makes Puget Sound an ideal location to test shellfish broodstock acclimatization potential in a natural setting while taking advantage of the seawater's spatial and temporal variability. We acclimatized sibling Olympia oysters (*Ostrea lurida*) to four locations within Puget Sound for six months. Precise oceanographic and carbonate chemistry conditions were recorded throughout the adult acclimatization period due to the strategic placement of shellfish cages onto the mooring line of Oceanic Remote Chemical Analyzer (ORCA) buoys. Adult oysters were pulled from the study sites and stimulated to spawn in the lab to test parental carryover effects. Larval families from each study site were kept at either 14 or 20°C and were monitored for growth, survival, and development until settlement. At the pediveliger stage, larvae were subjected to five acute thermal stressors and performance was measured using respirometry techniques. Results from this study may assist shellfish restoration or aquaculture practices to make informed decisions and determine which oceanographic stressors may have the most influence on larval performance. Furthermore, understanding thresholds of broodstock and larval tolerances may help design a breeding program for the future which takes advantage of transgenerational plasticity through generations.

2019 *Vibrio parahaemolyticus* ENVIRONMENTAL SAMPLING REVIEW

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Vibrio parahaemolyticus is a leading cause of foodborne illness following the consumption of raw shellfish. It is a native bacterium present in Washington coastal waters and more prevalent during summer months. Humans who consume raw or undercooked shellfish, most commonly oysters, containing V. parahaemolyticus can develop a gastrointestinal illness called vibriosis. One of the ways the Washington State Department of Health (DOH) manages for *V. parahaemolyticus* through the analysis of regular environmental sampling during summer months. This presentation will review changes made to the sampling program for the 2019 V. parahaemolyticus control months and analyze the environmental results and trends identified to date. Additionally, this talk will seek to identify correlations between environmental results and confirmed *V. parahaemolyticus* illness cases received by the department.

IMPACTS OF OCEAN ACIDIFICATION AND WARMING ON EARLY LIFE STAGES OF PINTO ABALONE (*Haliotis kamtschatkana*) IN WASHINGTON STATE

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From 1992 to 2017 pinto abalone (*Haliotis kamtschatkana*) experienced a 97% decline in Washington waters. Pinto abalone are the only abalone species native to Washington, and their decline is a loss for indigenous tribes, recreational divers, and for the health of rocky reefs and kelp beds that benefitted from their persistent grazing. Efforts by Puget Sound Restoration Fund and Washington Department of Fish and Wildlife are underway to restore populations in the San Juan Islands. However, as this restoration occurs, global climate change continues to

cause ocean acidification and warming in the northeast Pacific at a rate outpacing many other marine ecosystems, and these factors may further threaten our native pinto abalone. In this study, we investigated the responses of three early life stages of pinto abalone: eggs, larvae, and post-settlement juveniles, to ocean acidification and warming. We exposed abalone beginning immediately post-fertilization to four treatments: 1) ambient pH and hatchery rearing temperature, 2) low pH and hatchery rearing temperature, 3) ambient pH and high temperature, and 4) low pH and high temperature. We measured survival, hatching rate, settlement rate, and growth. Subsamples from each life stage were preserved for further analysis. Results from this study will reveal the interacting effects of increasing temperature and ocean acidification on the vulnerable early life stages of this species. This research will inform restoration efforts by providing more information both on hatchery rearing success and on likelihood of wild population survival under future climate change scenarios.

OCEAN ACIDIFICATION NEGATIVELY AFFECTS EARLY DEVELOPMENT IN ENDANGERED WHITE ABALONE (*Haliotis sorenseni*)

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Recovery of endangered white abalone (*Haliotis sorenseni*) depends on understanding the effects of climate change on this iconic species. With a historic range from southern California, USA to Baja California, MEX, overharvesting of white abalone led to the listing of the species as endangered in the early 2000's. In response, the White Abalone Restoration Consortium was formed to expand scientific knowledge of white abalone and spearhead restoration efforts. Ocean acidification (OA), a decline in pH due to the absorption of anthropogenic CO2, is known to affect shellfish populations throughout the world; however, the effect of this change on white abalone is unclear. To test the sensitivity of white abalone to OA, we reared white abalone from embryos to post settlement juveniles under both contemporary pH values (pH 8.1) and acidic conditions (pH 7.6) that will be common mid-century. In addition to pH manipulation, white abalone were settled on two different diets, wild crustose coralline algae (CCA) and commercially produced diatoms (*Navicula* sp.). White abalone mortality increased under low pH conditions, and animals settled in CCA environments had 28.6% higher post-settlement survival compared to abalone settled on diatoms. Under low pH, white abalone exhibited a 53% increase in survival if raised on CCA as compared to diatoms. Ongoing results from these experiments will inform the management of this species in the face of changing ocean chemistry as well as inform conservation and commercial aquaculture production of closely related red abalone (*H. rufescens*).

EFFECTS OF OFF-BOTTOM AQUACULTURE AND DEVELOPMENT OF BEST MANAGEMENT PRACTICES

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Objectives: 1) Address specific effects on: a) oyster food, b) current velocity and direction, c) sediment transport/deposition, and overall bed elevation, d) the intensity and distribution of light/shade, and e) contributions to marine debris at multiple sites and varying culture conditions. 2) Using results from Objective 1, plus additional inputs of typical estuarine parameters, use models to examine and predict the effects of off-bottom culture on farm operations and the adjacent environment under various scenarios, particular different spatial scales. 3) Based on site specific observations (Objective 1) and model predictions (Objective 2) collaborate with regional shellfish farmers to prepare best management practices (BMPs) which optimize farm development and operation and reflect environmental effects both on-site and off-site. So far, we have established study sites at Willapa Bay (Taylor Shellfish), Samish Bay (Taylor Shellfish), and Eld Inlet (Chelsea Farms). Preliminary results show that the deployed instruments were able to discriminate differences in water quality parameters at a very fine scale. At Chelsea: During one 6 day instrument deployment, temperature, DO and salinity were the same both up-current and down-current from a single array of double flip bags, but pH, Chl, and salinity were all higher down-current. During each of 4 multiple deployments, averages were higher for 4 of 5 on the in-coming tide but salinity was higher on the out-going tide. At Samish Bay, the rate of elevation change was higher inside a flip bag array compared to outside after 6 months of measurements.
We also explain the modeling strategy.

THE RECOVERY OF HARVESTED GEODUCK TRACTS IN THE PUGET SOUND

Henry Carson*, Bethany Stevick, Ocean Working, Robert Sizemore

Geoduck clam (*Panopea generosa*) harvest in Washington State is managed using serial, intensive harvest of discrete "tracts" ranging in size from less than 20 to over 900 acres. After harvest, tracts are left to recover over decades, with occasional surveys to monitor the progress toward attaining the original, pre-harvest density of geoducks. Regional harvest rate options are provided by an equilibrium yield model with key parameters derived from sampled age distribution, however tract recovery rates do not inform the model. At the time of model development, average tract recovery time was estimated to be 39 years, adding qualitative support to managers ' choice of a 2.7% annual harvest rate. However, more recent data shows that average tract recovery time is considerably longer, suggesting that a reevaluation of harvest strategy is needed to ensure the long-term sustainability of the fishery.

TRACKING LARVAL AND JUVENILE DUNGENESS CRAB IN THE SOUTHERN SALISH SEA: TWO YEARS OF RESULTS AND PLANS FOR FUTURE RESEARCH

Claire COOK*, Sarah GROSSMAN, Julie BARBER

The Dungeness crab (*Metacarcinus magister*) is one of the most highly-valued marine species in the Pacific Northwest. Throughout the region, the species forms the basis for many local fishing economies and is prized for its cultural and recreational significance. Although the biology and

ecology of M. magister is relatively well-understood compared to other marine invertebrates, fundamental gaps still exist, notably in crab populations within the southern Salish Sea. In 2018, Swinomish began monitoring the abundance of larval Dungeness crab at sites in Whidbey and San Juan Basins to improve our understanding of crab population dynamics and ecosystem services. The scope of this monitoring work was broadened in 2019 as part of a collaborative effort throughout Washington to include participation from 12 agencies representing tribal, state, federal, and academic entities. Results from two years of Swinomish larval Dungeness crab monitoring via light traps will be presented along with results from intertidal monitoring aimed at quantifying juvenile recruitment, settlement, and survival in Swinomish management regions. Understanding larval supply and juvenile settlement could have important implications for continued successful management of this fishery and provide essential baseline data to inform future management practices as environmental conditions change.

EFFECTS OF BITTER CRAB DISEASE ON THE GENE EXPRESSION OF ALASKAN TANNER CRABS

G. CRANDALL*, P. JENSEN, S. WHITE, S. ROBERTS

Alaskan Tanner crabs (*Chionoecetes bairdi*) are a coldwater crab species found in the Bering Sea, along the Gulf of Alaska, and southeastern Alaska. The southern stocks supported a $21 million fishery in 2014, but warming waters and disease have been threatening their numbers as well as the industry's profits. Bitter crab disease is caused by a parasitic dinoflagellate of the genus Hematodinium, and is considered to be the "principal threat" to crab stocks by the Alaska Department of Fish and Game. Aside from its causing the crabs to become lethargic, among other signs, it renders their meat bitter and chalky. Due to this, the crab industry has been suffering from the loss of marketable product. It is not known how the disease is transmitted, or if it is fatal. It would be useful to have a better grasp of how the parasite affects its host on a molecular level, which is what our study set out to do. We held infected and uninfected crabs in tanks over the course of 2.5 weeks at ambient (6˚C), cold (4˚C), and warm (10˚C) temperatures, sampling their hemolymph at three time points. From these samples, we identified crab genes involved in immune response and temperature response. We were also able to characterize the parasite's transcriptome. These data will provide important insight into the linkages between bitter crab disease, climate change, and pathogenicity.

GONAD MATURATION OF THE MEDITERRANEAN MUSSEL *Mytilus galloprovincialis* AND OLYMPIA OYSTER Ostrea lurida IN THREE LOCATIONS WITHIN THE PUGET SOUND, WA

Trevor Derie*, Lindsay Alma

Bivalves often use environmental cues for spawning times throughout the year, such as rising ocean temperature in the spring and summer months. The Olympia oyster (*Ostrea lurida*) and Mediterranean mussel (*Mytilus galloprovincialis*) are two bivalve species found throughout the Puget Sound of Washington State. The Puget Sound offers a wide range of environments in a relatively small area, providing ample opportunities to investigate different water qualities affecting reproductive health of these species. Using samples of the initially same grown population placed at three separate locations in the Puget Sound, this study investigates environmental factors influencing gonad health and maturation of these two shellfish species.

The results found variable maturation stages and sex ratios between sites of both species, both in specific sexes and seasons when comparing throughout the Puget Sound. The results suggest differing environmental factors (temperature, oxygen and chlorophyll in this case) can lead to various maturation and sex ratios of the same initial population. Future studies should focus on sex and maturation ratios on a monthly basis to see any trends throughout the year, as well other environmental parameters not investigated in this study.

MBP OsHV-1 RESISTANCE BREEDING PROGRESS

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OsHV-1 (oyster herpesvirus) currently causes massive moralities in Pacific oysters in California and has the potential to spread to estuaries in the Pacific Northwest. In 2018, field and in vivo laboratory trials identified superior OsHV-1-resistant oyster families from the Molluscan Broodstock Program (MBP), a Pacific oyster breeding program at the Hatfield Marine Science Center in Newport, OR. In 2019, crosses among these families were made, and the resulting progeny were tested in the field and in laboratory trials (in vitro and in vivo) to determine the efficacy of selection to OsHV-1 resistance. The results from this year ’s trials will guide selection in 2020 and will provide a better estimate of when resistant broodstock (>90% survival) will be available to MBP stakeholders.

PERMITTING SHELLFISH HATCHERIES UNDER THE CWA, AKA THE COSTANZA NEXUS

Rich DOENGES*, Laurie NIEWOLNY

Permitting shellfish hatcheries in Washington

CLIMATE AND SKINNY OYSTERS: ANOTHER LOOK AT OYSTER CONDITION AND SPAWNING IN WILLAPA BAY, WASHINGTON

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Pacific *oysters Crassostrea gigas* were introduced to the US west coast in the early 1900’s where they have become the mainstay for the shellfish aquaculture industry replacing the native oyster *Ostrea lurida*. Pacific oysters only regularly spawned and became "naturalized" in several discrete estuarine locations where conditions allowed for both adult oyster conditioning and spawning and larval survival, retention and settlement. The shellfish industry relied on "natural" set at these locations and/or continued to import seed from Japan until the advent of hatchery technology in the late 1970’s. Since that time the industry has gradually shifted to hatchery production of oyster larvae with large operators establishing their own in-house hatcheries and smaller companies incorporating remote setting facilities and purchasing product from hatcheries that specialize in producing late stage eyed larvae. Most operators continued to take advantage of "wild" set until a prolonged set of failures in larval production

termed the seed crisis occurred in both hatcheries and in these estuaries like Willapa Bay, Washington where wild set was and continues to be a feature of management on state established oyster reserves. The failures at hatcheries have been clearly linked to water chemistry and ocean acidification where aragonite saturation state is reduced and larval oysters are unable to deposit shell, but evidence for direct effects of carbonate chemistry in estuaries like Willapa Bay is more equivocal due to complex interactions with other factors. Variables like temperature, salinity, and phytoplankton also influence gametogenesis and spawning in adult oysters.and a fattening line linked to proximity of the ocean and cold upwelled water nutrient rich water. We summarize long term historical records for oyster condition and spawning in this naturalized Pacific oyster population and propose a new effort to evaluate some of these additional factors and compare these records with data from locations in Japan where these oysters were originally in order to understand and potentially mitigate for the effects of anthropogenic changes to these systems and an uncertain future climate.

EYE IN THE SKY: THE POTENTIAL OF UNMANNED AERIAL SYSTEMS (UAS) AS A TOOL TO MAP EELGRASS HABITAT IN OREGON ESTUARIES

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Recent technological advances have made Unmanned Aircraft Systems (UAS) increasingly efficient and cost-effective tools for coastal mapping and inventory of natural resources. Present methods employed by the Oregon Department of Fish & Wildlife (ODFW)'s Shellfish and Estuarine Assessment of Coastal Oregon (SEACOR) project to assess shellfish populations and their habitats in Oregon's estuaries involve extensive field surveys that take more than one year to complete and are evaluated on a decadal scale. Combining these field surveys with UAS mounted with digital camera systems has the potential to improve the resolution of resource and habitat distribution maps, and increase the capacity of the agency to conduct more frequent resource monitoring. Since 2016, SEACOR has been using small quadcopter UAS to map small-scale eelgrass beds in Netarts Bay. These systems are capable of high resolution (3-6mm/pixel) but can only cover smaller areas. In 2018 and 2019, ODFW has also used fixed wing systems for mapping eelgrass through a collaboration with the Career Tech Charter High School Coastal Drone Academy (Lincoln City). Fixed wing systems have longer flight times and cover greater areas per flight but the imagery is at a lower resolution (16mm/pixel) relative to quadcopter UAS. A comparison of these two UAS systems for mapping eelgrass will be discussed including lessons learned, recommendations to avoid common pitfalls, and limitations of the technology.

SHELLFISH HEALTH AND DISEASE UPDATE – WEST COAST

Ralph A. ELSTON*, Colleen BURGE, Stephanie PORTER

Following our detection of OsHV-1 on the west coast of N. America in October 2019, we have conducted a range of testing to determine if any other locations are positive for this oyster disease agent. All locations tested up until June 1, 2019 (date of this abstract submission) were negative, including triploid Pacific oysters deployed to the October 2018 positive site. These oysters were deployed in February 2019. We have scheduled additional testing during summer 2019 and will update findings from these tests, all using a validated qPCR test. In addition, we have consolidated and organized all AquaTechnics health and disease examinations from 1995 to the present. A summary of these findings, as formatted for publication, will be presented. Status of health and condition in hatchery and nursery production sites, as determined by 2019 season examinations will also be summarized.

CHARACTERIZING THE HABITAT FUNCTION OF BIVALVE AQUACULTURE USING UNDERWATER VIDEO

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Bivalve aquaculture is an expanding coastal industry, with the potential to replace, augment, or diminish habitat for the nearshore marine community. The presence of cultured Pacific oysters (*Crassostrea gigas*) and Manila clams (*Venerupis philippinarum*), sometimes with associated grow-out gear, has can provide refuge from predation, provide feeding opportunities, or impede movement and foraging in an area. Underwater video was used to observe fish and crab species' use of oyster (on-bottom and flip bags) and clam (under anti-predation nets) aquaculture sites along with natural reference sediment and eelgrass habitats. Sites were monitored in 10 locations around Puget Sound, WA in the summers of 2017 and 2018. Local environmental conditions, species distributions, and the structure provided by shellfish and grow-out gear, all contribute to the habitat function of bivalve aquaculture in Puget Sound. The presence of fish and crab species on aquaculture farms varied sub-regionally, on a scale of approximately 150km. Results of aquaculture habitat use show evidence of species attraction (e.g., surf perch; Embiotocidae), deterrence (e.g., flatfish; Pleuronectiformes) and preference by life history stage (e.g., crabs). Understanding the ecological mechanisms explaining these habitat relationships (foraging, refuge, etc.) is the next step in predicting how an expansion of bivalve aquaculture will interact with the nearshore marine community in this region. A habitat portfolio approach is one suggestion in accounting for this suite of aquaculture habitat functions across the marine fish and crab community.

USING SCIENTIFIC COLLABORATION TO BUILD RESILIENCY AT A CA SHELLFISH FARM

Gary FLEENER*, et al.

We will take a look at how collaboration with the academic community is helping Hog Island Oyster Co. develop policies and practices that we hope will build resilience in the face of environmental and regulatory uncertainty.

2020 SHELLFISH ACREAGE GOAL: SUCCESSFUL WATER QUALITY RESTORATION

Jean FROST*, Washington State Department of Health

The Washington State Department of Health evaluates and classifies all commercial shellfish harvesting areas. Identified water quality issues result in the development of partnerships and implementation of actions to protect and restore impacted areas. Beginning in 2007, the Department developed a stretch-goal of a net water quality improvement to 10,000 harvestable shellfish acres in Puget Sound by 2020. This presentation will highlight the successful water quality restoration efforts and partnerships that led to increased shellfish harvestable acres from 2007-2020. It will discuss the status of the acreage goal as we approach 2020 and next steps beyond 2020. Lastly, it will demonstrate the opportunity for commercial shellfish harvesters to engage and support pollution prevention activities and programs in growing areas.

UNRAVELLING THE TROPHIC ECOLOGY OF WILD AND CAPTIVE JUVENILE DUNGENESS CRAB (*Metacarcinus magister*) USING FATTY ACID BIOMARKERS

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Juvenile Dungeness crabs are voracious consumers of a wide variety of taxa and their feeding habits likely affect the ecology of their nursery habitats. The annual abundance of young-of-the-year (0+) Dungeness crabs fluctuates dramatically and they are periodically observed in high densities in coastal nearshore and estuarine habitats. We used laboratory feeding trials to investigate the utility of fatty acids as trophic biomarkers in juvenile Dungeness crabs. We compared the fatty acids of juvenile crabs collected in the field to those fed controlled diets. We found that juvenile crabs fed mono-specific diets rapidly assimilate dietary fatty acids into their tissues and their fatty acid composition is readily distinguished by multivariate analyses. Crabs fed fish, bivalve, and conspecific megalopae grew faster than crabs fed algal-based foods. The fatty acid profiles of juvenile crabs collected in the field were distinct from those fed in the laboratory, but were closest to those fed bivalve diets. Wild crab fatty acids were separated from experimental crabs by elevated levels of bacterial and copepod biomarkers. Wild 0+ crabs were collected during a year of exceptionally high Dungeness crab settlement in the Coos Bay, OR, estuary (2018), and had slower growth than the previous three years when settlement was much lower. The proportion of the nutritionally valuable long-chain poly-unsaturated fatty acid DHA (22:6ω3) in wild crab lipids was lower than in all experimental crabs. Slow growing 0+ crabs in 2018 may be the result of a limitation in the availability of high-quality foods rich in DHA. The ratio of ω3/ω6 fatty acids in crab lipids was significantly higher in faster growing crabs and may be a useful metric to assess crab condition and diet quality in future field studies.

HAS OCEAN ACIDIFICATION A REAL EFFECT ALONG THE WASHINGTON COAST? AN ISOTOPIC INVESTIGATION

Y GAO and Russell SVEC

Marine bivalve shells are composed of calcium carbonate (CaCO3) and exist in polymorphism as calcite and aragonite. When the anthropogenic CO2 sinks into ocean, it will produce HCO3- and CO32- and this affects the carbonate saturation state (Ω). In this study we report the results of stable isotope analyses on carbonate shells of Pacific razor clam (*Siliqua patula*), Pacific geoduck (*Panopea abrupta*), and Pacific sea scallop (*Patinopectin caurinus*) along the Washington coast, and using d13C values in detecting the effects of ocean acidification. Among a large number of samples analyzed the d13C values of the clam shells ranged from -2.9 to -0.3‰, whereas d18O values of the same samples ranged from -2.2 to +1.4‰. As compared with the carbon isotope indicators reported previously, data from our study did not show a steady decrease in d13C patterns. The d18O values of the clam shells clearly showed life history that was consistent with the annual growth lines on the outside of the shell. Overall the isotopic results suggest that the carbonate shell is a good proxy for reconstructing the life history and environmental changes that a clam experienced, but the signatures of ocean acidification along the Washington coast (mainly in d13C) are open to question.

APPLYING CUTTING-EDGE TECHNOLOGY FOR REPRODUCTIVE CONTROL IN BIVALVES

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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 formation and development. The power of this biotechnological approach has been realized recently in some finfish species, where suppression of the germ-cell specific gene, dead end (dnd), results in fish with no detectable germ cells. Given the recent advances in finfishes, the shellfish industry is now poised to adopt these technological advances. Unfortunately, the development of this technology is hampered by the lack of knowledge of the genes essential for primordial germ cell (PGC) specification in bivalves. Here, I will introduce an approach to identify genes involved in PGC specification in bivalves using single-cell RNA-Seq (scRNA-Seq). This cutting-edge approach will allow us to transcriptionally profile single cells in developing bivalve embryos. scRNA-Seq is particularly suited to identify PGC markers in bivalves, as germ cell precursors represent only a small number of cells at these early developmental stages. An introduction to scRNA-Seq technology and methodology and preliminary steps we have taken to adapt this technology to bivalves will be presented.

COMPACT PHOTOBIOREACTORS FOR LIVE MICROALGAE PRODUCTION IN AQUACULTURE HATCHERIES

S. GLOVER*, R. Roulston, J. LONG

Availability of high quality microalgae is a bottleneck in aquaculture hatcheries. Numerous species of nutritious microalgae are used to feed bivalve and crustacean larvae. In any facility, algae contaminated with pathogens (i.e. Vibrio spp.) can result in high larval mortality and

lower growth rates. Traditional methods of microalgal production are unreliable and labor intensive, while substitutes such as concentrates and dried algae can degrade water quality as they decompose, increasing the organic load in the system and creating a substrate for pathogenic bacteria. Automated photobioreactors offer a compact and easier method of producing live algae onsite compared to traditional methods (e.g. figure 1). They are often more cost effective than substitutes and contribute less to the organic load in the water. Closed photobioreactors provide a biosecure culture environment and reduce the chance of culture contamination. This control over the microbial environment is of paramount importance since pathogenic or probiotic organisms introduced into algae cultures will be transferred downstream to livestock, impacting survivability and ultimately profits.

IS TABLE SALT A VIABLE ALTERNATIVE FOR THE CONTROL OF BURROWING SHRIMP ON SHELLFISH BEDS IN WASHINGTON STATE?

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Imidacloprid (IMI), a neonicotinoid insecticide, is being sought by shellfish growers to control burrowing shrimp (ghost shrimp, *Neotropea californiensis*) in Willapa Bay and Grays Harbor, Washington. The shrimp destabilize sediments resulting in poor survival and low yields of the commercially harvested Pacific oyster (Crassostrea gigas), threatening the local shellfish industry. A permit for the use of IMI has been denied by the State, Pacific County has declared an economic emergency, and the outcome of an appeal by the growers remains uncertain. We have undertaken studies to determine if un-iodized table salt may be an alternative to IMI, specifically targeting juvenile shrimp (recruits) inhabiting the upper 10-15 cm of the sediment. Studies in 2018 indicated that a 2-3-fold increase in salinity resulted in 100% mortality when juveniles were exposed in artificial seawater. In 2019, we exposed juveniles (3 replicates, 5 shrimp each) within 10 cm of native sediment to five different salt solutions to achieve sediment pore water salinities of 25 (ambient, control), 35, 50, 70, and 100 ppt. Salt solutions were prepared with native seawater, added on top of the sediment (depth = 2 cm), and allowed to percolate through the sediment column for 6 h (low tide). At 6 h, 2 cm of ambient seawater (25 ppt) were added to simulate tidal inundation and allowed to remain on the surface for 12 h (low-high + high low tide) with two subsequent drawdowns and tidal inundations at 25 ppt (total test duration = 48 h). The sediment was then sieved to remove the shrimp and determine mortality. Average survival of controls (25 ppt) was 73.3% whereas none of the shrimp exposed to elevated salinities survived. Additional tests are underway to examine different exposure scenarios. Results to date suggest table salt may be a viable and greener alternative to IMI.

METABOLIC RECOVERY AND COMPENSATORY SHELL GROWTH OF JUVENILE PACIFIC GEODUCK *Panopea generosa* FOLLOWING SHORT-TERM EXPOSURE TO ACIDIFIED SEAWATER

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While acute stressors can be detrimental, environmental stress conditioning can improve performance. To test the hypothesis that physiological status is altered by stress conditioning, we subjected juvenile Pacific geoduck, *Panopea generosa*, to repeated exposures of elevated pCO2 in a commercial hatchery setting followed by a period in ambient common garden. Metabolic rate and shell length were measured for juvenile geoduck periodically throughout short-term repeated reciprocal exposure periods in ambient (~550 µatm) or elevated (~2400 µatm) pCO2 treatments and in common, ambient conditions, five months after exposure. Short-term exposure periods comprised an initial 10-day exposure followed by 14 days in ambient before a secondary 6-day reciprocal exposure. The initial exposure to elevated pCO2 significantly reduced metabolic rate by 25% relative to ambient conditions, but no effect on shell growth was detected. Following 14 days in common, ambient conditions, reciprocal exposure to elevated or ambient pCO2 did not alter juvenile metabolic rates, indicating ability for metabolic recovery under subsequent conditions. Shell growth was negatively affected during the reciprocal treatment in both exposure histories, however clams exposed to the initial elevated pCO2 showed compensatory growth with 5.8% greater shell growth (on average between the two secondary exposures) after five months in ambient conditions. Additionally, clams exposed to the secondary elevated pCO2 showed 52.4% increase in respiration rate after five months in ambient conditions. Early exposure to low pH appears to trigger carry over effects suggesting bioenergetic re-allocation facilitates growth compensation. Life stage-specific exposures to stress can determine when it may be especially detrimental, or advantageous, to apply stress conditioning for commercial production of this long-lived burrowing clam.

MICROPLASTIC CONTAMINATION ACROSS AN URBAN GRADIENT

Lyda Harris,* University of Washington, Jacqueline Padilla-Gamino, University of Washington, Emily Carrington, University of Washington

Intertidal habitats are routinely exposed to varying levels of biotic and abiotic particles. As microscopic plastic (MP, plastic ≧ 5mm) become more prevalent in our waters, it is important to determine the concentration of MP in the Salish Sea and the quantity of MP that shellfish ingest. We focused on mussels (*Mytilus trossulus*), which are well-known filter feeders and bioindicators that are essential in Washington's aquaculture industry. Mussels are known to ingest MP both in natural and laboratory settings around the world, and provide insight to water contamination levels. Here we investigated mussel MP contamination across an urban gradient in the Salish Sea. We hypothesized mussel MP contamination correlates to human population and that sites closest to urban centers contain the most MP particles. We collected mussels from 11 different sites, chemically digested them in a sterile lab environment, and visually identified MP under a microscope. We found no evidence of MP concentrations increasing along an urban gradient, however, we did find a difference in MP composition between sites. These results indicate that perhaps factors such as basin residency times, currents, or distance from waste water treatment plants may influence MP contamination rather than solely urban population size. It is important to assess the damage already done to

marine organisms and water quality to foresee the future health of oceans in the presence of anthropogenic perturbations and changing climate.

BLOOMING LARGE: TACKLING THE HEALTH RISKS OF HARMFUL ALGAE

Megan HINTZ*

One increasing climate related health threat to coastal and tribal communities is increased Harmful Algae Blooms (HABs). Warming sea temperatures have contributed to increased frequency, duration, and severity of naturally occurring HABs events which produce biotoxins that accumulate in filter feeding shellfish making them unsafe for human consumption. Last year levels of Paralytic Shellfish Poisoning reached lethal levels within important shellfish harvest areas for the Lummi Nation and biotoxins are predicted to continue to increase with a warming climate. In response to the increased health risk, we have increased sampling monitoring of biotoxin levels on the Lummi Reservation, improved education and outreach, and enhanced the distribution of shellfish biotoxin levels to the community. Furthermore, we analyzed data from 1991-2018 to better understand the spatial and temporal trends of biotoxins within Whatcom County. This analysis of biotoxin levels will show trends determining if HABs events are occurring earlier or later in the year, lasting longer and how the risk of biotoxins is changing.

BIOTOXIN ACCUMULATION AND DEPURATION IN FIELD EXPOSED ROCK SCALLOPS Crassadoma gigantea: A PREREQUISITE FOR CULTURE

Katie HOULE*, Bobbi HUDSON, Pacific Shellfish Institute, Joth DAVIS, Baywater Shellfish, Sandra SHUMWAY, University of Connecticut, Steve MORTON, NOAA/NOS, Jerry BORCHERT, WA Dept. of Health, and Brent VADOPALAS, University of Washington

The rock scallop Crassadoma gigantea is a promising new species for culture on the U.S. west coast. Due to the expansive range of the species, culture potential exists from Baja California to southeastern Alaska. After two to four years of grow-out, a high quality shellfish can be produced to supply both domestic and export markets. One serious, unresolved issue, however, is the lack of information on accumulation and retention of algal toxins in rock scallops that can cause paralytic shellfish poisoning (PSP) in humans. To address this issue, scallops were deployed at three locations prone to PSP closures in Puget Sound, WA from 2017-2018. Scallops (n=10) were sampled when a closure occurred and weekly thereafter until the closure was lifted. Results from PSP exposures in Sequim Bay revealed that concentrations of PSP toxins in the digestive glands (687±27 μg/100g tissue) of rock scallops were significantly higher ($p \geqslant 0.05$; n=144 for both) than concentrations in adductor muscle tissue (32±2.9 μg/100g tissue). These results support previous reports for rock scallops in Sequim Bay by the WA Department of Health. Data from the current study also show that PSP concentrations and depuration rates are variable among individuals. In a single sample period, some scallops tested had toxin levels over the FDA approved limit for PSP (80μg/100g tissue), while the toxin was not detected (NTD) in others. This information will be used to inform effective biotoxin monitoring and regulation of this species for human consumption, supporting public health agencies, the shellfish industry and the future commercial production of this species.

WEST COAST SHELLFISH RESEARCH GOALS & 2020 PRIORITIES

N/A

In the late 1990s the West Coast shellfish industry was heading into a new millennium. Advances in hatchery and nursery technology were significantly enhancing and diversifying production, but Endangered Species Act listings and other measures were creating new levels of regulatory scrutiny and oversight. Challenges to the industry were coming from many directions. To help position the industry to address these challenges, the Pacific Shellfish Institute took the initiative to establish the West Coast Shellfish Research and Education Goals and Priorities. At the 1998 Annual Shellfish Conference in Nanaimo, Canada, goals—and research priorities needed to achieve those goals—were established. Since then, the "Goals and Priorities" document has evolved, along with the shellfish industry's information needs. This has lead to a substantial infusion of public and private dollars directed at supporting shellfish research in response to the documented ranking of priorities. Today, new challenges have surfaced, while others remain. This session will review, edit, prioritize and generally discuss research priorities to strengthen the West Coast shellfish industry. Outcomes will represent what the shellfish producing community has established as priorities for the next decade of shellfish research and information collection.

COLD CHAIN PERFORMANCE FOR WASHINGTON STATE AND CHESAPEAKE BAY FARMED OYSTERS

Bobbi Hudson,* David C. Love, Lillian Kuehl, Robert M. Lane, Jillian P. Fry, Jamie Harding, Benjamin J.K. Davis, Kate Clancy

In this study, we tracked the performance of the cold chain for U.S. farmed oysters distributed nationally and internationally using temperature sensors. Boxes and bags of oysters (n = 125) were shipped from farms in Washington State and the Chesapeake Bay to 143 unique businesses in 20 U.S. states, Washington D.C, and Hong Kong, China. Eighty-one percent of the temperature sensors were returned with usable data. The average product temperature among all participants was 4.4 +/- 2.7 deg C (40 +/- 5 deg F), which is 5.6 deg C (10 deg F) cooler than the 10 deg C (50 deg F) guidance criterium established by the U.S. government. There were spikes in temperature in some shipments: 18% of shipments (16/91) experienced oyster temperatures above 10 deg C for one hour or more, and the median time spent out of temperature control was 2.5 hours. We modeled V. parahaemolyticus abundance using temperature sensor data, and 75% (68/91) of shipments had a net decrease in V. parahaemolyticus abundance in the cold chain. There are opportunities for improvements in cold chain performance in the shellfish industry and related businesses. In the discussion we provide recommendations for oyster producers related to product cooling, for businesses that handle shellfish to make sure they are following HACCP guidelines, and for government and industry groups to develop guidance for shipping by air, among other issues.

GENETIC IDENTIFICATION OF PARASTICHOPUS CALIFORNICUS IN THE CLASSROOM: USING PLACE-BASED RESEARCH TO ADVANCE GENOMICS LITERACY AT TRIBAL COLLEGES

Destinee HUTCHINSON*, Rachel ARNOLD. Northwest Indian College.

Research-based pedagogy and active learning in the classroom have been shown to increase student engagement and understanding of science. However, less attention may be given to place-based pedagogy and its effects on the engagement of students, particularly Indigenous students that may not travel far from home for higher education. At Northwest Indian College, students typically enter the Native Environmental Science program with the desire to help their tribes and may be strongly connected to their homelands. With this in mind, classes at NWIC are designed to take a "place-based" approach to provide grounding for students. For an introductory genetics course, students learned how to use genetic tools to answer a question concerning the identification of the California Sea Cucumber (Parastichopus californicus), a culturally important fishery that is co-managed by western Washington treaty tribes and the Washington Department of Fish and Wildlife. Staff at Lummi Natural Resources also directly contributed to this project by donating tissue samples and giving presentations on current management practices and knowledge gaps. In addition, this project was taken further by using MinION technology, as it allows real-time sequencing, cutting out the need to send samples out to a third party for sequencing. This is an essential aspect of data sovereignty for Indigenous nations, and learning how to do genetic research with this tool is a step toward empowering young Indigenous researchers to practice their sovereign rights.

MODERNIZING LABORATORY ANALYTICAL METHODS FOR AMNESIC SHELLFISH POISONS (ASP) AND DIARRHETIC SHELLFISH POISONS (DSP)

David IKEDA *

Washington State Public Health Laboratory analyzes shellfish samples for Paralytic Shellfish Poison (PSP); Amnesic Shellfish Poisons (ASP); and Diarrhetic Shellfish Poisons (DSP). The PSP method has been used for over 40 years and is still considered the preferential method by the ISSC. The ISSC has recently added the ASP and DSP analytical methods to their approval list. The Laboratory has had to update their analytical methods to meet the new ISSC methodology.

SWEATING THE SMALL STUFF: POTENTIAL FOR BITTER CRAB DISEASE IN THE PACIFIC NORTHWEST

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The parasitic dinoflagellate, Hematodinium, is an emerging disease of decapod crustaceans that in Alaska infects Tanner, snow, Pacific lyre and Arctic lyre crabs, and in Russia, red, blue, and golden king crabs. In North Atlantic waters, Norway lobster, blue crab, and edible crab are among the infected, and in Asia, Hematodinium was first found in aquacultured shrimp and crab and then several years later in wild populations. The parasite is most likely eventually fatal to its hosts, and while not harmful to humans, imparts a bitter aspirin-like flavor to the meat that impacts wild fisheries and aquaculture products and can lead to large economic losses. First described in 1931 as a parasite of two crab species, since 1985 Hematodinium has undergone an almost explosive expansion – increasing in prevalence (rate of infection in a population), spreading to new geographical areas and new hosts (currently over 40 species of decapods). Disease dynamics, including within- and cross-species transmission, are not well understood, but Hematodinium expansion has tended to follow warming waters. Known host

species extend from Alaska into Puget Sound and Oregon providing a possible Hematodinium conduit from heavily infected Alaskan populations to the Pacific Northwest. The only 2 reports of infected hosts in the Pacific Northwest were from Vancouver Island, in 2003 (4% of a surveyed population of grooved Tanner crab) and 2004 (1 scarlet king crab), but U.S. west coast crab populations are not monitored for Hematodinium outside Alaska. In addition to an overview of Hematodinium, this talk will discuss the potential for an increase in its occurrence in the Pacific Northwest, describe signs of Hematodinium infection, and how to effectively document and report a suspected occurrence.

ASSESSING VULNERABILITY OF PACIFIC NORTHWEST SHELLFISHERIES TO OCEAN ACIDIFICATION: A HYBRID APPROACH TOWARD SCALABLE RISK COMMUNICATION

Brian G. Katz*

The Pacific Northwest is well-understood to be the global frontline for ocean acidification impacts, having already experienced the first adverse impacts to regional shellfisheries as early as 2006. As ocean acidification continues to intensify throughout the 21st century, key gaps remain in understanding how vulnerability to ocean acidification manifests within the Pacific Northwest and which watersheds are most vulnerable to experiencing harm. The purpose of this study is to characterize Pacific Northwest watersheds by their differential vulnerability to ocean acidification. A spatial clustering approach was performed to group watersheds by similar combinations of factors related to exposure, sensitivity, and adaptive capacity to ocean acidification. Four watersheds of differential vulnerability were then selected for qualitative fieldwork validation. Participatory mapping exercises and small group discussions were performed in each watershed to analyze how risk factors and barriers to adaptation varied between vulnerability clusters and latitudinal gradients. The results of spatial clustering revealed a north-south divide in hot spots of vulnerability to ocean acidification, with northern watersheds appearing highly sensitivity (e.g. Salish Sea) and southern watersheds appearing highly exposed (e.g. Humboldt Bay, CA); watersheds in the mid-latitudes of the region (e.g. the Oregon Coast) appeared to be less vulnerable to ocean acidification due to relatively higher adaptive capacity. The results of participatory mapping and small group discussions reveal nuances of each local watershed and suggest implications for the development of local adaptation pathways through hybrid approaches to assessing vulnerability from both the top-down and bottom-up.

INVASIVE TUNICATES AS BIOFOULING AGENTS OF LONGLINE BIVALVE AQUACULTURE

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Didemnum vexillum, a globally invasive ascidian, was first observed in Oregon in 2010, and has since fouled the Umpqua Aquaculture subtidal longline oyster (*Crassostrea gigas*) farm in Winchester Bay. Divers monitored the extent of *D. vexillum*'s cover biannually in spring and fall from 2011 to 2016. Here, we characterize the seasonal dynamics of this population. We observed significant differences in percent cover between fall and spring. The shallowest

portions of the lines generally lacked *D. vexillum* cover, and colonies were most concentrated at ~4.5-6.5 m depth. Percent cover per line varied erratically over the course of the survey period. Our proxy for salinity and sea surface temperature both failed to predict the variance in percent cover per line ($p = 0.789$ and $p = 0.886$, respectively), though season was significant ($p = 0.028$). We remained curious as to what impacts colonial ascidian have on the bivalves they foul in an aquaculture context. Thus, we set up a manipulative field experiment in the Charleston, OR Boat Basin, where we grew oysters (*C. gigas*) and mussels (*Mytilus trossulus*) under three treatments: fouled with *Botrylloides violaceus*, ambient fouling, and control (i.e., epibionts removed). We used B. violaceus instead of *D. vexillum* for the fouling treatment because the *D. vexillum* population in the Boat Basin was dwindling and we wanted to avoid adding propagule pressure to it. At the end of the four-month experiment, we found that B. violaceus had no significant impacts on the growth, condition index, and organic composition of the oysters and mussels. We recommend continued investigation of invasive ascidian-bivalve epibiont-basibiont relationships, especially considering the erratic fluctuations some invasive ascidian populations exhibit. Moreover, we recommend continued monitoring of the two *D. vexillum* populations in Oregon, as well as determining empirically what, if any, economic effects *D. vexillum* has on aquaculture operations along the Pacific Coast.

UPDATE ON PROGRESS OF MBP AND ENSURING LONG-TERM SUPPORT FOR PACIFIC OYSTER BREEDING AND GENETICS ON THE US WEST COAST

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The Molluscan Broodstock Program (MBP) was initiated in 1996 and has primarily focused on improving yields of Pacific oysters through selection. Due to emerging environmental and disease challenges, MBP has also recently included selection for larval tolerance to acidified seawater and resistance to oyster herpes virus. Results are encouraging, suggesting that some MBP families show resistance to both the French OsHV-1 microvariant and the Californian "standard", less pathogenic OsHV-1 strain. Currently, the State of Oregon is the principal funding source for MBP but there are plans that USDA/ARS will increase funding for its Shellfish Genetics program based at the Hatfield Marine Science Center, Oregon State University. This USDA/ARS initiative could potentially include funding for an ambitious program consisting of three scientists and funding for collaborative research with other research institutions and programs, to ensure long-term breeding and improvement of Pacific oysters on the US West coast.

BIG FISHERY, BIG DATA, AND LITTLE CRABS: USING A GENOMIC APPROACH TO EXAMINE LARVAL RECRUITMENT PATTERNS OF DUNGENESS CRAB (CANCER MAGISTER) IN THE CALIFORNIA CURRENT ECOSYSTEM

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The California Current Ecosystem (CCE) is a dynamic marine environment from which many socioeconomically important fisheries species are harvested. Dungeness crab (*Cancer magister*) is the most lucrative single-species commercial fishery within the CCE. Historically, the annual harvest of Dungeness crab has fluctuated by an order of magnitude. Survival and dispersal during the larval stage is influenced by ocean conditions, and successful recruitment of larval megalopae has been used to predict CCE harvest abundance four years later. Variation in the abundance and timing of megalopae recruitment has been extensively studied for over two decades in Coos Bay, Oregon. Here, we used a genotyping-by-sequencing (GBS) approach to examine genetic variation in megalopae of the Dungeness crab (Cancer magister). Larval megalopae recruits were monitored daily and collected from light traps at two sites along the Oregon coast (Coos Bay and Yaquina Bay) throughout three recruitment seasons (2014, 2017, and 2018). Based on variation at neutral and putatively adaptive genetic markers, evidence was found for intra-annual and inter-annual genetic differentiation among recruiting megalopae. These findings suggest that Dungeness crab megalopae recruiting in coastal Oregon may be originating from both within and outside the CCE. This study improves our understanding of how ocean conditions influence larval dispersal and population connectivity of Dungeness crab.

POPULATION GENETICS OF *Apostichopus californicus* ACROSS THE PACIFIC COAST OF NORTH AMERICA

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Commercial aquaculture production methods for the California sea cucumber (*Apostichopus californicus*) are being developed in response to high demand in overseas markets and wild stock declines. Because interbreeding of wild and farmed animals can lead to genetic risks, patterns in population structure in the wild is important to inform aquaculture practices, such as the site choice for collection of broodstock and transfer of seed across geographic areas. Here, we quantify population structure (1) at a small-scale, within Puget Sound, and (2) at a broad-scale, from Alaska to California. We used single-digest restriction site associated DNA (RAD) sequencing, the dDocent software package, and custom filtering scripts to identify 1680 single nucleotide polymorphisms (SNPs) across nine collection sites of *A. apostichopus*. Using these SNPs, we estimated population structure to be significant yet low, consistent with previous results. Additionally, we found strong evidence for isolation by distance, suggesting that dispersal is geographically limited and drives population differentiation. We detected population structure at both small and large geographic scales; even within Puget sound, the majority of pairwise population comparisons were significantly differentiated. We recommend that these estimates of population differentiation be considered in management decisions concerning movement of broodstock and seed, to limit gene flow among differentiated populations.

USING PROBIOTIC BACTERIA TO REDUCE LARVAL MORTALITY OF *Crassostrea gigas* DUE TO THE BACTERIAL PATHOGEN *Vibrio coralliilyticus*

David Madison* Oregon State University, Chris Langdon Oregon State University, Carla Schubiger Oregon State University, Claudia Häse Oregon State University, Ryan Mueller Oregon State University

The West coast oyster industry often suffers severe mortalities of Pacific oyster larvae and spat associated with an increase in the abundance of the pathogenic bacterium *Vibrio coralliilyticus* (Vcor). Vcor is present in low concentrations in most hatcheries, but does not have any discernable effect on the oyster larvae or spat until it reaches concentrations greater than about 1000 cells ml-1. This study examined the potential use of probiotic bacteria isolated from Yaquina Bay, Oregon, to determine if they could reduce mortality in Pacific oyster larvae due to exposure to high concentrations of Vcor. We have identified three bacterial strains that, when added together to the culture water of larvae 24 hours after egg fertilization, eliminated mortality from a subsequent exposure to a concentration of Vcor that resulted in greater than 99% mortality in the absence of the probiotics. The ability to reduce larval oyster mortality by controlling Vcor populations in shellfish hatcheries could greatly benefit the industry by providing a more consistent production of seed oysters.

IN SITU FILTRATION RATES OF OLYMPIA OYSTER *Ostrea lurida* HABITAT AND PACIFIC OYSTER *Crassostrea gigas* AQUACULTURE

Althea MARKS* and Danielle ZACHERL, California State University Fullerton

The filtration services of Olympia oyster (*Ostrea lurida*) habitat and Pacific oyster (*Crassostrea gigas*) aquaculture operations along the North American west coast have been little explored. In situ filtration studies can incorporate variable environmental conditions important to filtration as well as the contributions of other filter feeders living among oysters (i.e. mussels, tunicates, scallops, and sponges). This ongoing study is quantifying in situ filtration rates of two restored Olympia oyster habitats in Newport Bay, CA and San Francisco Bay, CA, a Pacific oyster aquaculture operation in Morro Bay, CA. Questions are: 1) How do filter feeder community composition and density affect filtration rates of oyster habitat? 2) How do water quality parameters affect oyster habitat filtration rates? 3) What are the filtration rates of *C. gigas* floating long lines operated by Morro Bay Oyster Company in Morro Bay, CA? Two identical instruments are deployed upstream and downstream of the oyster habitat to measure temperature, salinity, turbidity, chlorophyll, and water velocity; filter feeder density and ambient total particulate organic matter are also measured. Each site at least 5 times over twelve months. Filtration rates are expressed in Lhr-1g-1 to compare to previous filtration studies and Lhr-1m-2 to calculate habitat level filtration. This research ground truths pervious oyster-centric filtration estimates with aquaculture and restored oyster habitat into filtration service estimates.

POPULATION TRENDS AND REPRODUCTIVE CYCLES OF THE PISMO CLAM, *Tivela stultorum*, IN CALIFORNIA

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Pismo clams (*Tivela stultorum*) are an iconic fishery species in California, and once supported a thriving fishery. Overharvest led to the closure of the commercial fishery in 1947 and a decline in recreational harvest. There is limited life history information for Pismo clams and despite numerous management actions by the state, Pismo clam populations have continued to decline throughout California. Our project expands the amount of available life history information by; investigating the relationship between statewide clam abundance and a variety of abiotic and biotic factors, and examining annual clam reproductive patterns on Pismo Beach, CA. We quantified Pismo clam presence, abundance, biotic, and abiotic factors along their range in California from Monterey, CA to the US-Mexico border. We evaluated the role of biotic and abiotic factors using a mixed model framework. Our results suggest that clam presence is more strongly correlated to local beach conditions than human or predator presence. Additionally, it is likely that several factors interact to drive clam abundance. We collected Pismo clams monthly from Pismo Beach, CA to determine gonadal stage with histological analysis and a body condition index (BCI). Work from the 1950's identified June through August as the primary reproductive period, however our 2018 data indicated no spawning had occurred before August. BCI showed a steep decline in clam condition in September and October, suggesting a delay in spawning period potentially related to shifts in ocean conditions. Combined these investigations will aid in management of Pismo clams, elucidate barriers to their recovery, and help us understand factors required for successful spawning and recruitment.

AN ANALYSIS OF ENVIRONMENTAL FACTORS INFLUENCING SPATIAL CLUSTERING OF SALISH SEA CLAM SPECIES

James McARDLE*, Julie BARBER, Lindy HUNTER. Swinomish Indian Tribal Community - Fisheries Department

Mapping bivalve biomass through the use of GIS can be a valuable tool for managers of commercially and recreationally-important clam species. The Swinomish Indian Tribal Community has been conducting intertidal clam surveys on reservation beaches since the early 2000s with the goal of managing their bivalve fisheries sustainably. These data, however, can also be used to investigate how environmental factors may influence spatial clustering of target species. We mapped biomass data of *Leukoma staminea*, *Saxidomus gigantea*, *Clinocardium nuttallii*, and *Tresus sp*. on a culturally-valuable beach located on the reservation. Statistically significant clusters of biomass polygons were identified using a Getis-Ord Gi* Hotspot Analysis. Results give a pronounced and distinct picture of distribution and clustering of specific clam species for a given period of time. In an attempt to identify potential driving factors of spatial clusters, multiple "variable" datasets, including elevation, distance from harvester access, slope, aspect (as a proxy for fetch), distance from seeps/beach drainages, and substrate were compared with the biomass hotspot layer of each clam species. In order to validate correlations, each resulting dataset comparing a clam species to a variable was run through a

regression. This process was then duplicated, separating out early and late timeframes in order to view and analyze temporal and spatial patterns of change. This type of analysis can assist managers by identifying important variables related to the generation of clam hotspots.

GROWING OYSTERS IN THE CONTEXT OF ECOSYSTEM RESTORATION: CHALLENGES AND OPPORTUNITIES

Phil BLOCH*, Confluence Environmental Company, Marlene MEADERS, Confluence Environmental Company, Chris CZIESLA, Confluence Environmental Company

Ecosystem restoration efforts are occurring in major estuaries throughout the USA in areas that were historically used for oyster aquaculture, currently being used for oyster aquaculture, and in areas that have historic native oyster populations. Restoration efforts to improve habitat conditions for mobile species (e.g., fish, birds, shrimp) can positively or negatively affect growing conditions for bivalves. Restoration efforts have also used native oysters to improve habitat conditions for mobile aquatic species, but have run into conflicts when larger habitat restoration projects change ecosystem processes that result in a loss of suitable habitat for bivalves. Finally, restoration efforts occur at many different scales from local stream habitat projects all the way up to changing land forming processes throughout an estuary. As projects get larger, and include more of a habitat mosaic, potential conflicts between user groups and focused restoration efforts in the nearshore are becoming evident. By exploring case studies in the Chesapeake Bay, Coastal Louisiana, Tomales Bay, Humboldt Bay, and Puget Sound, we explore how the interactions between oyster aquaculture and ecosystem restoration are affecting both commercial operations, landowners, restoration efforts, and other stakeholders. Ecosystem restoration is sometimes viewed as a partner to aquaculture, while at other times the efforts are perceived by the public or regulatory scientists as incompatible. Through case studies, we identify common themes and opportunities for aquaculture to contribute to, or demonstrate compatibility with, restoration and protection efforts.

NOAA Seafood Inspection’s Oil Spill Response System

Whitney MOORE*

The United States Department of Commerce (USDC) National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Seafood Inspection Program (SIP) has developed an Oil Spill Response (OSR) Program to evaluate fishery products for petroleum or chemical taint. The NOAA SIP National Sensory Program has developed a Petroleum Taint Sensory Course (PTSC) to train assessors to evaluate petroleum or chemical taint in seafood products. These trained assessors are members of NOAA’s Oil Spill Response (OSR) Team. When a petroleum or chemical spill incident results in the contamination of harvest waters, the Oil Spill Response Team is deployed as part of NOAA’s overarching response protocol to assess the impact of a contamination incident and to manage closures and subsequent reopenings of harvest water areas to fishing. The Oil Spill Response team’s responsibility in this larger process is to evaluate fishery products using sensory techniques to determine whether fishery products are free from taint odors to allow the reopening of fishery and recreational waters. The Oil Spill Response Plan, which is a framework of information,

procedures and forms required for oil spill response, has been developed and can be tailored to fit the response situation. Seafood quality assessments are made using sensory evaluation. To ensure uniform and harmonized approaches, NOAA SIP Sensory Team has developed courses to teach Consumer Safety Officers and Inspectors (CSO/Is) to classify seafood quality by relating odors to quality levels. CSO/Is who have developed proficient basic sensory skills attend the more advanced Petroleum Taint Sensory Course (PTSC) offered by NOAA. The PTSC provides a skills-building process by which CSO/Is learn to identify very low concentrations of chemicals and petroleum contaminants. Expert assessors can consistently identify contaminants in the 1 ppm to 5 ppm range. The Petroleum Taint Sensory Course combines sensory science and spiked samples to lead CSO/Is through a series of exercises and quizzes to develop, harmonize, and then test their sensory abilities. Four National Marine Fisheries Service (NMFS) SIP labs have been specially equipped to facilitate these classes, and are available for sensory use in the event of an oil spill response. The OSR team's sensory evaluation results are used by the site command team to determine if affected waters can be reopened to fishing and recreation.

IMPROVING WATER QUALITY BY BUILDING PROGRAMMATIC CAPACITY AND IMPROVING COORDINATION FOR PUGET SOUND'S POLLUTION IDENTIFICATION AND CORRECTION (PIC) PROGRAMS.

Henry L PETERSON*

The Washington State Department of Health started funding Pollution, Identification, and Correction (PIC) Programs in the Puget Sound region in 2011 through the EPA's National Estuary Program (NEP). In this presentation, I will review the history of the program and work being done to improve state oversight for PIC work. I will discuss my approach to assessing barriers to success through interviews with counties and share my results and recommendations. As a result of this work, I aim to provide better state oversight, increase inter-agency knowledge and communication, and discuss the future of PIC programs.

SALISH SEA TRANSBOUNDARY ACTION PLAN UPDATE

Allen PLEUS*, Joan DRINKWIN, Jeff ADAMS, Emily GRASON, Todd HASS, Kate LITLE, P. Sean MCDONALD, Renny TALBOT, and Thomas THERRIAULT

The Salish Sea Transboundary Action Plan for Invasive European Green Crab (Plan) establishes a coordinated and collaborative response to incursions of European green crab (EGC) that pose a risk of harming or threatening the environmental, economic, or human resources within the shared Washington State and British Columbia waters of the Salish Sea. The current response to early detections of EGC in the Salish Sea is a success story seldom seen in the world of aquatic invasive species management. Rather than playing 'catch up', we still appear to be ahead of the curve and are working proactively to understand, identify and prevent further incursions of EGC before they take hold and cause the dramatic impacts to the Salish Sea ecology and shellfish industry that have been seen on the East Coast of the United States and elsewhere around the globe.

OCEAN ACIDIFICATION MONITORING IN ALASKAN VILLAGES AND SHELLFISH ENHANCEMENT EFFORTS ON THE KENAI PENINSULA.

Jacqueline RAMSAY*, Jeff HETRICK

Chugach Regional Resources Commission (CRRC) has been supporting an Ocean Acidification monitoring program in the Chugach region for almost five years. Initially, we monitored the Alutiiq Pride Shellfish Hatchery seawater in-take in Seward, Alaska. After discovering levels of acidification that seemed of concern, we expanded the sampling effort region-wide under a Bureau of Indian Affairs grant. We now hope to continue and expand our monitoring program through Indian General Assistance Program (IGAP). The proposed near shore sampling program is the first of its kind and has provided valuable information linking off-shore monitoring to the near-shore environment. Ocean acidification, especially in colder waters which absorb more CO2, is becoming an increasing threat in Alaska. Understanding the patterns and impacts will greatly influence how coastal communities adapt to this threat. Maintaining a monitoring program is essential to understanding the effects and trends in our communities and facilitate efforts for shellfish enhancement and management projects.

OREGON'S COORDINATING COUNCIL ON OCEAN ACIDIFICATION AND HYPOXIA: WHY WE NEED IT, WHERE WE ARE

Charlotte R.WHITEFIELD , Oregon Department of Fish and Wildlife, Newport, Oregon *; Caren BRABY, Oregon Department of Fish and Wildlife, Newport, Oregon, Jack BARTH, Oregon State University, Corvallis, Oregon

In 2006, Oregon was one of the first places in the world to observe direct impacts of ocean acidification, hitting the shellfish growing industry through larval failure to thrive and mortality. Also since the early 2000s, low-oxygen or hypoxia has been observed increasing in Oregon's coastal waters and is correlated with seasonal upwelling and ocean acidification. Since then, all along our west coast, Ocean Acidification and Hypoxia (OAH) events have continued to intensify and there are now signs that OAH is undermining the rich ocean and estuarine ecosystems' food webs. Oregon's iconic shellfish and the coastal communities that depend on them are at risk. The emergence of OAH represents new challenges for the translation of scientific understanding into ocean policies. In 2017, in response to growing concerns, the passage of Oregon Senate Bill 1039 created the Oregon Coordinating Council on OAH to provide guidance and recommendations to the State on how to respond to this issue. The OAH Council consists of State agencies, shellfish industry, academic experts, and Tribal interests, who collaboratively advise and develop recommendations for the State on the implementation of actions to support the sustainability of Oregon's ocean and estuaries as the frequency and magnitude of OAH events intensify. The Council submitted their first report to the State Legislative Assembly in September 2018. The work of Oregon's OAH Council will continue to be part of the west-coast regional strategy, through the creation of Oregon's OAH Action plan. This Action Plan will be presented to the International Ocean Acidification Alliance by the summer of this year. Here, we will update the shellfish community on Oregon's OAH Council efforts moving forward and our goals to incorporate and facilitate regional scientific data and collaborations with the shellfish industry.

ESTUARINE HABITAT USE BY HIGHER TROPHIC-LEVEL FISH AND DECAPODS

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Habitat structure typically increases the densities of mobile species that respond to food, protection, or surface area for attachment, but is also expected to reduce densities of species that find structure an impediment to movement. From 2015-2017 we sampled fish, crabs and shrimp in low intertidal habitat mosaics throughout Washington State, by means of hundreds of samples with a circular beach seine. Our goal was to determine the spatial scale of differences in nekton communities, seasonal changes, and species-specific habitat associations with eelgrass or mudflat. All space and time scales in the study showed significant differences in nekton communities but had consistent rankings in terms of the relative amount of variation: Season > Site > Habitat > Day-Night. We also discovered interactions among these factors, for instance, more seasonal variation at sites with eelgrass of a smaller morphotype, and more habitat effect for fringing, patchy eelgrass mosaics than in extensive meadows. For 21 common species, we calculated their degree of habitat association. Eelgrass-associated species were pelagic, schooling fishes (shiner perch, stickleback), those cryptic in eelgrass (pipefish, grass shrimp), and some eel-like body plans (gunnels). Brownish, benthic species such as flatfish, Crangonid shrimp, and graceful and Dungeness crabs were mudflat-associated or more evenly distributed across habitats. These habitat associations provide a State-wide baseline for comparison as estuarine habitats are modified by a variety of human activities.

PARENTAL EXPOSURES PRIOR TO SPAWNING INFLUENCE LARVAL GENE EXPRESSION IN THE OLYMPIA OYSTER (*Ostrea lurida*)

Laura SPENCER*, University of Washington, School of Aquatic and Fishery Sciences, Steven ROBERTS, University of Washington School of Aquatic and Fishery Sciences, Katherine SILLIMAN, University of Chicago, Committee on Evolutionary Biology

The Olympia oyster, *Ostrea lurida*, is the only oyster species native to the Pacific coast of North America. Over-harvest, pollution, and competition from introduced species devastated populations in the early 1900's. *O. lurida* is being actively restored, but there are concerns that changing ocean conditions will damage populations and impede successful restoration. Ocean acidification and warming threaten calcifying and ectothermic marine organisms, particularly in the vulnerable larval stages, however positive intergenerational carryover is a hypothesized mechanisms for one generation to impart a beneficial "memory" of environmental stressors to the next. Here, we investigate whether adult-only exposure to low pH and warming affects gonad and offspring physiology in *O. lurida*. Gene expression was measured in adult gonad and in newly released larvae, where adults were exposed to pH and temperature treatments prior to reproductive conditioning. We will present effects on gonad development, sex ratios, fecundity, larval size upon release, and on gonad and larval gene expression. Preliminary results indicate that, counter to the prediction, typical stress-related genes were not heavily upregulated in gonad from stress-exposed adults, however larval gene expression differed by parental exposure in functional categories known to respond to direct exposure.

RELATIVE RECRUITMENT RECONSTRUCTIONS OF WASHINGTON STATE GEODUCK POPULATIONS

Bethany STEVICK*, Henry CARSON and Ocean WORKING, Washington Department of Fish and Wildlife, 1111 Washington St. SE, Olympia, WA, 98501 USA.

A new, large-scale geoduck age study was initiated in 2012 and was motivated by the desire to update growth and natural mortality parameters for the equilibrium yield model which is currently being used for the commercial geoduck fishery. We aged nearly 3,000 geoducks collected from four sites in Washington during 2012-2017. Using age frequency distributions, relative recruitment was reconstructed for the 1954-2006 age classes for each site, as well as for all sites combined. Overall, peak recruitment years were different across sites, and all sites can be characterized by different recruitment "shapes" across the timeframe analyzed with respect to having recent, mid or old recruitment peaks, or a combination thereof. Also, three of the four sites had years with no recruitment detected. When combined to show an overall picture of Washington, the recruitment data show a maximum recruitment in 1960, low levels persisting until the 1970s, high recruitment years through the early 1980s, low levels for the mid 1980s to 1990s with levels picking back up to higher levels in the early 2000s. We also examined recruitment at an additional three sites from previous age collections and compared them with those of the current study. It appears that closely located sites, and even sites co-located by region, show similar recruitment trends within a pair. These site or regional recruitment patterns do not persist across the State as a whole, but rather sites from other regions show a characteristically different picture. Washington geoduck populations exhibit pulse recruitment events that are highly variable with respect to both time and space. A next step for expanding our understanding of Washington geoduck recruitment is to explore what is driving these recruitment patterns. Factors such as large-scale climatic forces, local conditions such as temperature and primary production as well as larval dynamics all likely influence recruitment patterns.

SEA CUCUMBER CO-CULTURE TRIALS IN WASHINGTON STATE, FROM NURSERY TO GROWOUT

Andrew SUHRBIER* (Pacific Shellfish Institute), ryan CRIM (Puget Sound Restoration Fund), katie HOULE (PSI), diane BORATYN (SOLSEA), isabel PLATTEN (PSI)

Summary of the current state of sea cucumber aquaculture in Washington State. The Giant Red Sea Cucumber (*Apostichopus californicus* or *Parastichopus californicus*) is a west coast species known for its demand in Asia. Project partners are exploring ways to increase efficiencies on growth and survival utilizing co-culture settings on land and in the water.

DIALING IN SUCCESS: WHAT ARE THE KEY PERFORMANCE INDICATORS FOR A SHELLFISH FARM?

Chip TERRY*

Shellfish farming is essentially a big data challenge. Lots of moving pieces in a dynamic environment. There is lots you could track, but what are the key things to track for success? And what are your options for tracking? Having visited over 50 farms over the last 2 years, we have seen what farms from Canada to Florida and in Europe have been tracking. Not all farms need a digital system. However you track there are certain things that really matter for your success over time. We'll explore those data points and why they matter.

GROWTH AND ABUNDANCE OF JUVENILE AND SUB-ADULT DUNGENESS CRABS IN THE SOUTH SLOUGH ESTUARY

Michael THOMAS*, University of Oregon; Bree YEDNOCK, SSNERR; Alan SHANKS, University of Oregon; Aaron GALLOWAY, University of Oregon

Estuaries serve as important nursery habitat for young Dungeness crabs throughout their range in the northeastern Pacific and many studies have demonstrated this within large estuarine systems. Less is known, however, about how the abundant, small estuaries on this coast contribute to the life history of this commercially and ecologically important species. To better understand the function of small estuaries as nursery habitat for juvenile and sub-adult Dungeness crabs, we sampled juvenile crabs using monthly beach seines between July 2015 and November 2018 at six sites within the South Slough National Estuarine Research Reserve on the southern Oregon coast. We also used a light trap at the mouth of the estuary to collect larval crabs as an index of settlement to compare with observations of juvenile densities in the estuary. Settlement, as measured by number of megalopae caught daily in the light trap throughout the settlement season, varied annually by almost three orders of magnitude. Juvenile young-of-the-year crabs (0+) in the estuary grew rapidly in their first year in the estuary and were rarely caught after fall of their second year, ~ 1.5 years post-settlement. Between 2015 and 2017, average summer/fall catch per unit effort (CPUE) ranged from 119 – 314 / ha, but CPUE was significantly higher in 2018, when massive settlement of larvae increased density almost ten-fold (2,071/ha). Growth of 0+ crabs were similar in all years except in 2018, when crab sizes were significantly smaller six months after settlement. Our study indicates the South Slough serves as important nursey habitat for young Dungeness crabs and in years when larval settlement is high, density dependent effects may reduce 0+ growth.

THE GREAT EXPERIMENT: A COLLABORATIVE COMMUNICATION STRATEGY TO IMPROVE PUBLIC PERCEPTIONS ABOUT US MARINE AQUACULTURE

Kimberly THOMPSON*, Jerry R. SCHUBEL, Seafood for the Future, Aquarium of the Pacific, Long Beach, California, 90802

There is great potential (ecological and economic) to grow nutritious protein in U.S. waters to complement land-based agriculture and support a more climate resilient food supply. Despite this, the growth of the sector in U.S. waters, particularly on the West Coast, is negligible relative to its capacity for responsible growth. One of the barriers to growth is a lack of "social license" from the public. Negative perceptions among small, but politically powerful public stakeholder groups can greatly complicate, and even prevent the growth and expansion of marine aquaculture projects. The Aquarium of the Pacific's Seafood for the Future program hosted a forum in 2018 to discuss these perception challenges and identify potential solutions to address them. Based on these conversations, Seafood for the Future developed the US Marine Aquaculture Communication Toolkit to support and facilitate collaborative action to disseminate scientifically accurate about marine aquaculture more consistently across diverse stakeholder groups. The information in the Toolkit is rooted in science, but also highlights stories and perspectives from the farmers who apply and are impacted by science and policy decisions. It also provides a platform for more cross-sector collaboration and strategic

development of proactive and reactive messaging about responsible marine aquaculture in the U.S. This effort is a great experiment and its success greatly depends on quality and diversity of participation. We will need all hands on deck!

"NOOCS" AND CRANNIES OF OLYMPIA OYSTER RESTORATION: AN UPDATE ON THE NATIVE OLYMPIA OYSTER COLLABORATIVE'S ACTIVITIES FROM BAJA CALIFORNIA TO BRITISH COLUMBIA

Jodie TOFT*

From a new story map to a new name, the Native Olympia Oyster Collaborative (NOOC; formerly the Coastwide Olympia Oyster Network) has been weaving together restoration practices across our group of oyster scientists, practitioners, educators and aquaculturists. Our vision? Resilient native oyster populations in a network of bays and estuaries from British Columbia to Baja California, valued by people and forming an integral part of healthy coastal ecosystems. In this talk, we will highlight progress in each of our focal areas: community engagement, restoration/conservation, aquaculture, and science. Using our multi-pronged approach with collaboration at the core, we continue to learn from one another to conserve and rebuild our native oyster through place-based work happening along our coast.

A PROTEIN INVENTORY REVEALS MECHANISMS OF TEMPERATURE IMPACT ON OYSTER DEVELOPMENT

Shelly A. TRIGG*1, Kaitlyn R. MITCHELL1, Rhonda ELLIOT1, Benoit EUDELINE2, Brent VADOPALAS1, Emma B. TIMMINS-SCHIFFMAN3, and Steven B. ROBERTS1, 1School of Aquatic and Fishery Sciences, University of Washington, Seattle, Washington, USA, 2Taylor Shellfish Hatchery, Quilcene, Washington, USA, 3Department of Genome Sciences, University of Washington, Seattle, Washington, USA

The Pacific oyster importantly serves as a biofilter and habitat in coastal ecosystems, and contributes over $190M to annual marine aquaculture revenue. However, little is known about the landscape of protein expression during early development, a time when mass mortality is common which can negatively impact industry and ecosystems. To better characterize physiological pathways active during oyster development we performed a developmental time series proteomics analysis of larval cultures reared at 23°C and 29°C. These temperatures were selected based on aquaculture industry reported observations of differential performance in oysters reared at 23°C and 29°C. While we observed no difference in survival, larvae reared at 29°C were larger in size. Protein inventories revealed differentially abundant proteins related to transport and metabolic processes among larvae reared at different temperatures. These results provide deeper insight into mechanisms underlying fundamental developmental processes and how temperature may render larvae more equip to deal with biotic stress.

NOT JUST FOR OYSTERS ANYMORE: STRIP-SPAWNING GEODUCKS FOR HATCHERY PRODUCTION

Matt HENDERSON*, Jamestown S'Klallam Tribe, Sam GURR, University of Rhode Island, Brent VADOPALAS, Washington Sea Grant, University of Washington, Grace CRANDALL, School of Aquatic and Fishery Sciences, University of Washington, Benoit Eudeline, Taylor Shellfish Co.

The ability to strip spawn oysters provides many benefits by giving hatchery operators control over timing, production, and breeding. In contrast to oysters, geoducks require spawn induction via increased algal rations and temperature, because their oocytes require release from meiotic prophase I via an unknown neurohormone produced by the female upon spawning. This prophase I arrest precludes strip spawning oocytes in geoduck, making it difficult for hatchery operators to control the spawning process. This study focused on testing the ability of KCl (potassium chloride) to release geoduck oocyte arrest at prophase I. Ripe geoducks of both sexes were shucked to expose the ripe gonads. For males and females, gametes were 'dry stripped': the surface epithelium of the gonad was cross-hatched with a scalpel to expose genital canals and breach follicles/acini. Gametes were collected via scraping of gonads into liter beakers. Oocytes were exposed to specific dosages of KCl (potassium chloride) and durations of treatments alongside controls in replicate before fertilization. Approximately 900 degree-hours post-fertilization, treatment efficacy was assessed by enumerating veligers to obtain proportions of stripped oocytes that successfully developed. Proportions of veliger larvae were compared to determine the optimal treatment concentration and duration. The results of commercial geoduck seed production using strip-spawned gametes will be presented.

THE ECONOMIC EFFECT OF PERMITTING DELAYS ON PACIFIC COAST SHELLFISH AQUACULTURE.

Dr. Jonathan VAN SENTEN*, Dr. Carole R. ENGLE

A survey to assess the costs and impacts of regulations at the farm level for shellfish aquaculture in Washington, Oregon, and California was initiated in the fall of 2016. The survey measured an estimated total regulatory cost more than $225 million across the Pacific coast shellfish industry. An estimated 74% of the production value of the Pacific coast shellfish industry was captured in the dataset. The results of that survey revealed significant challenges and delays in obtaining licenses and permits for shellfish aquaculture on the Pacific coast. Delays and challenges in permitting have been demonstrated to be a barrier to entry to the industry and a barrier to expansion and diversification. The results also revealed that the total costs associated with obtaining permits and licenses were greater than the costs of ongoing monitoring and compliance on the farm. A follow up study conducted with this dataset investigates the effects of permitting delays on the financial outlook of a farm from an investment perspective. Shellfish aquaculture involves capital costs for equipment and infrastructure, in addition to operating costs for labor and operational activities. Delays in permitting have been documented to result in delays in the harvesting and sale of products; which means delays in returns to the farm. Scenarios such as this, where return on investment is delayed, are likely to affect the appetite for investment in shellfish aquaculture.

INFLUENCE OF OCEAN ACIDIFICATION ON PACIFIC OYSTER (*Crassostrea gigas*) DNA METHYLATION

Yaamini R. VENKATARAMAN*, University of Washington School of Aquatic and Fishery Sciences, Steven B. ROBERTS, University of Washington School of Aquatic and Fishery Sciences

As negative effects of ocean acidification are experienced by coastal ecosystems, there is a growing trend to investigate the effect of ocean acidification has on multiple generations. For example, temporarily exposing adult Pacific oysters (Crassostrea gigas) to low pH prior to gametogenesis affects larval abundance. The documented effect on Pacific oyster larval abundance indicates a potential role for epigenetic modifications, specifically DNA methylation, in response to ocean acidification. To assess how ocean acidification affects the Pacific oyster epigenome, DNA was extracted from adult oysters exposed to either low pH (7.31 ± 0.02) or ambient pH (7.82 ± 0.02) conditions for seven weeks. Pooled samples were created for each pH treatment using DNA from two individuals. Whole genome bisulfite sequencing was used to identify methylated regions. The predicted function of genes containing differentially methylated loci location suggests a role for DNA methylation in acclimating to adverse conditions. Understanding a possible mechanism for phenotypic plasticity and acclimation across generations is valuable when considering organismal ability to persist in the face of environmental change.

DIXIE CHICKS: WOMEN AND THE NEW SOUTHERN OYSTER

Beth WALTON*, Bryan T. RACKLEY, William C. WALTON.

Oyster aquaculture is an opportunity in the southern United States (from North Carolina around to Texas) for a viable near-shore domestic aquaculture industry that can provide a large economic boon to the coastal communities in the region (both to producers as well as local supporting industries). Oyster aquaculture may help watermen maintain traditional ways of life, keeping them working on the water. Oyster South, a non-profit 501(c)(3), is dedicated to supporting the sustainable development of oyster aquaculture in the southern US, to help the region's economy, improve the coastal environment, and preserve the coastal culture and traditions. Our membership consists of both oyster consumers and industry members. Our industry members draw from a broad base, including growers, wholesalers, restaurateurs, chefs, media and educators, all striving to advance oyster aquaculture in the southern US. We encourage this through information exchange, fund-raising, and highlighting the region's world-class oysters and oyster farmers in the media. We are proud of the women-led and women-owned businesses that we have as part of the Oyster South community.
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THERE IS AN APP FOR THAT - A SIMPLE APP FOR EVERYDAY TASKS ON THE OYSTER FARM

William C WALTON, Auburn University Shellfish Lab & Alabama Cooperative Extension System, Russell GRICE, Auburn University Shellfish Lab

To help with some of the common, repetitive tasks on an oyster farm, we developed the first version of a free smartphone app, 'Oyster Farming'. The app includes several customized calculators that 1) help producers determine the number of shellfish seed delivered (with a

record of that number within confidence intervals), 2) assist in achieving desired stocking densities and 3) help estimate current stock on a farm.Users can also track the latest news from the Auburn University Shellfish Lab Facebook, Twitter and Instagram feeds. The app features a section to submit questions to the Extension water resources team and the Auburn University Shellfish Lab. We hope the app will act like a Swiss Army Knife with a lot of useful tools that the farmer will always have in his or her pocket or on the dash of a boat. We would love to hear from farmers about how we can improve the app and what features should be added.

POPULATION GENETIC STRUCTURE AND CONNECTIVITY OF PARASTICHOPUS CALIFORNICUS IN THE NORTHEASTERN PACIFIC COASTAL REGION

Amanda XUEREB* (Department of Ecology and Evolutionary Biology, University of Toronto) , Laura BENESTAN (Institut de Biologie Intégrative et des Systèmes, Université Laval) , Eric NORMANDEAU (Institut de Biologie Intégrative et des Systèmes, Université Laval) , Janelle CURTIS (Pacific Biological Station, Ecosystems Sciences Division, Fisheries and Oceans Canada), Louis BERNATCHEZ (Institut de Biologie Intégrative et des Systèmes, Université Laval) , Marie-Josée FORTIN (Department of Ecology and Evolutionary Biology, University of Toronto)

Strong directional advection of water masses or retentive hydrodynamic forces can affect dispersal trajectories of marine organisms, thus influencing the degree of connectivity and genetic exchange among populations. In this study, we investigated the relative importance of asymmetric oceanographic processes as drivers of marine connectivity in a commercially harvested marine invertebrate – the giant California sea cucumber (*Parastichopus californicus*). We first tested for the presence of genetic discontinuities in the northeastern Pacific coastal region. Then, we tested two hypotheses regarding spatial drivers of population genetic structure: (i) isolation by distance (genetic structure is explained by geographic distance), and (ii) isolation by resistance (genetic structure is driven by ocean circulation). We integrated genomic data derived from restriction site associated DNA sequencing (RAD-sequencing) with biophysical modelling of larval dispersal and a spatially explicit approach based on asymmetric eigenvector maps (AEMs) to model the effect of directional ocean circulation. With a total of 3,699 single nucleotide polymorphisms (SNPs) from 717 individuals, we identified two distinct genetic clusters with restricted connectivity representing northern and southern regional groups, as well as significant, albeit weak, substructure within regions. We demonstrated that local oceanography is a better predictor of genetic variation across space compared to geographic distance, and that directional processes play an important role in shaping spatial patterns of genetic structure, especially at relatively fine spatial scales. Our study emphasizes the importance of accounting for directional flow in analyses of marine dispersal and contributes to the growing body of seascape genomics literature identifying significant population structure in marine systems despite the potential for widespread gene flow. Our findings have important implications for designing reserve networks as well as delineating transfer zones for a commercially important species in the northeastern Pacific coastal region.

RANGE EXPANSION OF EUROPEAN GREEN CRABS IN BRITISH COLUMBIA

Sylvia B. YAMADA*, Graham E. GILLESPIE, Tammy C. NORGARD and Richard E. THOMSON

An introduced population of European green crabs *Carcinus maenas* was established in San Francisco Bay prior to 1989. Subsequently, their northern range expansion is linked to larval transport in the Davidson Current to Northern California (~1995), Oregon (~1996), Washington coastal estuaries (1998), and to the west coast of British Columbia (1998). Range expansions through larval transport to the Central B.C. coast occurred around 2009 and into the Washington Salish Sea in 2014 - 2016. Range expansions on the Central B.C. coast and in the Salish Sea are continuing. Both the range expansion of green crabs, and their abundance are strongly linked to ocean indices. These include 1) warm surface water temperatures (>15°C for reproduction, and >10°C for larval development), and 2) coastal circulation patterns that keep larvae close to shore, where they can be carried by wind and tidal currents into estuaries and embayments to settle. Green crabs are especially successful following major El Niños. The strongest year classes and the largest range expansions occurred during the last two strong El Niño events. The 1997-1998 El Niño resulted in the colonization of coastal Washington estuaries and the west coast of Vancouver Island, while the 2014-2016 El Niño is linked to the range expansion into the Salish Sea.

OCEAN ECOSYSTEM INDICATORS FORECAST YEAR CLASS STRENGTH OF THE INVASIVE EUROPEAN GREEN CRAB (*Carcinus maenas*) IN OREGON ESTUARIES.

Sylvia B. YAMADA*, Jennifer L. FISHER, P Michael KOSRO

The annual abundance of the non-native European green crab, *Carcinus maenas*, in Oregon estuaries varies greatly with ocean conditions. Numbers were high following the 1997-1998 El Niño, decreased and remained low until they spiked again following the extended anomalous warming in 2014-2016. The year class strength of young crabs is strongly linked to ocean indicators during their planktonic larval development. Many of the same physical and biological ecosystem indicators used in salmon forecasting, also apply to green crabs, only in reverse. While cold ocean conditions benefit salmon, warm ocean indicators are positively linked to *C. maenas* year class strength. Among the best indicators for green crab year class strength are winter water temperatures, the sign of the Pacific Decadal Oscillation index, the day of physical and biological spring transitions, and copepod community structure. These correlations suggest that green crabs need (1) warm winters (temperature >10°C), which enable larvae to complete their development in the near-shore, (2) strong northward flow of coastal waters during winter, which allows larvae to be transported from established populations to the south and (3) coastal circulation patterns that keep larvae close to shore, where they can be carried by wind and tidal currents into estuaries to settle. By adapting Peterson's stoplight graph concept to these indicators, and using a metric of the combined indicators, we were able to explain 71% and 66% respectively of the interannual variability in green crab year class strength. This robust suite of indicators allows forecasts of green crab recruitment to Oregon estuaries in advance. However, local recruitment might break down this relationship thus, the possible role of additional larval sources from the north or from local estuaries is discussed.