# ABSTRACTS

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72nd Annual
Shellfish Growers Conference and Tradeshow

Pacific Coast Shellfish Growers Association
National Shellfisheries Association Pacific Coast Section

Blaine, WA, September 18-20, 2018

ESTIMATING TOTAL ESTUARY FILTRATION FROM OBSERVATIONS OF IN SITU CLEARANCE RATES BY THE OLYMPIA OYSTER (OSTREA LURIDA) IN PUGET SOUND

**ALLEN*, Brian[1], Matthew W. GRAY[2], Holly HAGENSON[1]**

**[1]Puget Sound Restoration Fund**

**[2]University of Maryland, Horn Point Laboratory**

Oyster clearance rates can be measured in situ, using novel methods developed by M. Gray, and applied for estimates of Total Estuary Filtration when calculated using data on population and hydrodynamics. We developed a simple apparatus and protocol to collect samples and measure size-related clearance rates in fall 2015; we will present results and discuss how residence time, season, and population structure impact how this oyster can modulate seston and therefore water quality in the context of Puget Sound and often rich bivalve assemblages.

USING BIOTECHNOLOGY AND PHYSIOLOGY TO PREDICT FUTURE IMPACTS OF CLIMATE CHANGE ON TWO IMPORTANT SHELLFISH SPECIES

**ALMA*, Lindsay, Jacqueline PADILLA-GAMINO**

**School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA**

Seventy percent of our planet's surface is covered by the upper ocean boundary layer (OBL), an extremely energetic and variable layer of water that is affected by wind, waves, atmospheric, and land input. Climate change associated stressors such as ocean acidification, thermal stress, and hypoxia can affect the growth and performance of marine organisms living in the OBL with important ecological and economic implications for the communities that depend on them. Currently, little is known about the temporal and spatial variation of pH, dissolved oxygen temperature, and potential contaminants near the coastal zone, and how these oceanographic variables may interact (or not) to affect the performance, reproduction, and survival of local species. By placing bivalves in their habitat we can use the ocean as a natural lab to quantify physiological changes within the organism, which can serve as biomarkers to monitor water quality and predict the fate of the organism as global change progresses. Adult Olympia oysters and Mediterranean mussels were placed at 3 locations and two depths within Puget Sound, Washington where they experienced different levels of nutrients, food sources, chemicals, pCO2, temperatures, and dissolved oxygen levels across a range of temporal and spatial scales. Shellfish were mounted directly to mooring lines of Oceanic Remote Chemical Analyzers (ORCA) buoys which monitor real-time oceanic water quality profiles. Conducting a full gamut of physiological

tests and pairing their results with oceanographic conditions can assist the shellfish industry in predicting ideal growing conditions in the present and future as climate change progresses.

RISING TIDES FLOATS ALL BOATS: WORKING TOGETHER FOR A HEALTHY PUGET SOUND

**ATTEMANN*, Rein**

**Washington Environmental Council**

Achieving a healthy Salish Sea from the many threats/pressures that exist will require partnerships, collaboration, and trust among stakeholders at different levels at opportune times. Over the past several years, the shellfish industry and the environmental community, along with other interests, have successfully advocated for clean water that is critical for a vibrant economy and healthy ecosystems. Find out how we have built strong voices in addressing stormwater pollution, oil spill prevention, preparedness and response, and most recently the establishment of the Puget Sound No Discharge Zone.

QUANTIFYING PARAMETERS OF ECOLOGICAL CHANGE BEFORE AND AFTER OLYMPIA OYSTER RESTORATION

**BARBER[1]*, Julie S., Sarah K. GROSSMAN[1], Jeffery R. CORDELL[2], James T. McARDLE[1], Lindy L. HUNTER[1], and Courtney M. GREINER[1]**

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Restoration of oyster beds is important for both rebuilding populations of native species and for the reestablishment of biological communities that co-evolved with these ecosystem engineers. Research investigating the biology and ecology of Olympia oysters, Ostrea lurida, has increased over the last decade, but little information exists on how the reintroduction of this species affects local biological communities. To address this gap, the Swinomish Indian Tribal Community developed a long-term monitoring program to quantify ecological change before and after Olympia oyster restoration efforts in northern Puget Sound. It was hypothesized that the restoration effort would change habitat complexity, resulting in changes in species abundance and diversity within tidal lagoons. Epifaunal, sessile, and mobile invertebrate surveys were conducted in the spring for two years prior to the reintroduction of Olympia oysters and for two years following oyster reintroduction; post-oyster restoration data collection is planned for the

next decade. Sites were located within tidal lagoons in Skagit and Similk Bays such that two lagoons served as the treatment sites (oysters reintroduced) and one served as the control site (no oyster reintroduction). Prior to oyster restoration, epibenthic results show that all three lagoons have distinct biological communities despite relative proximity. These results highlight the importance of collecting ecological data before beginning restoration efforts and will serve as a baseline for post-restoration data comparisons.

## THE CRAB TRACKER: ULTRASONIC TELEMETRY TO TRACK ESTUARINE CRUSTACEANS

**BARNES*, Patrick, John LUND, Noah STRONG, Margot MAXWELL, Lizzy SCHOEN, Chloe YUGAWA**

**Western Washington University**

Ultrasonic telemetry is a method using sound to relocate tagged underwater animals that yields high-resolution spatiotemporal data on aquatic animals in their natural habitats. This method has proven to be highly effective at improving quantification of activity patterns, diel movements, migrations, habitat utilization, and home ranges of individuals and populations over traditional techniques such as baited trapping. However, this technology has not been widely applied because of its high cost. Our group has developed emitter and receiver prototypes that cost 20 times less than currently available technology. Our design includes a touchscreen user interface that will improve the relocation accuracy and efficiency of current technology while being more user-friendly than analog microphones currently used to relocate tagged animals.

## SHELLFISH IN THE 2018 SUSTAINABLE SEAFOOD LANDSCAPE

**BOEVERS*, Justin**

**FishChoice**

The sustainable seafood landscape is becoming more dynamic and it is important for shellfish producers to stay up-to-date with both sustainable seafood assessments and certifications as well as how businesses are engaging and participating in sustainable seafood efforts to remain competitive in 2018 and beyond. With assessment and restaurant programs such as Monterey Bay Aquarium’s Seafood Watch program, Vancouver Aquarium’s Ocean Wise program, and the James Beard Foundation Smart Catch program, it presents both an opportunity and a challenge for shellfish producers to market the sustainability of their shellfish as well as knowing how their products fit within different sustainability requirements of restaurants that participate in these

respective programs. This session will provide an update on how bivalves such as mussels and oysters are being evaluated by various assessment programs, a sustainability breakdown of bivalves currently by both ratings and certifications, and a primer on how shellfish producers can position their products to show how they meet the sustainability standards of sustainable seafood restaurant programs.

MATERNAL PROVISIONING DIFFERENTIALLY AFFECTS SURVIVAL OF TWO POPULATIONS OF RED ABALONE (Haliotis rufescens)

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Absorption of anthropogenic CO2 emissions is leading to a decline in the pH of global oceans, a process termed ocean acidification (OA). The effects of OA have been documented in many species of marine molluscs and include decreased rates of calcification, growth and survival among other impacts. We tested the hypothesis that alternate maternal provisioning strategies favoured by natural selection in different oceanographic regions of the California coast may contribute to OA resilience in the red abalone (Haliotis rufescens). As free-swimming, lecithotrophic larvae, red abalone rely on maternally provisioned nutrients, such as lipids, for successful growth and settlement metamorphosis until they are capable of feeding as post-settlement juveniles. Exposure to additional stress, such as OA during this phase may lead to a reduction of lipids available for successful growth and survival during these sensitive early life history phases. We analysed the total lipid content of larval and post settlement abalone generated from broodstock sourced from two populations; the Mendocino coast, a region that

experiences low annual pH values driven by seasonal upwelling, and animals sourced from the Santa Barbara Channel, which experiences higher annual pH values. Larvae from Mendocino exhibited a 16.5 fold increase in post-hatch lipid content compared to larvae from Southern CA; however, no differences in survival were observed between the two populations during the larval phase. Differences in lipid content persisted throughout the post-settlement phase and during this phase, under low-pH conditions, significant increases in mortality were observed in the Southern California population, correlated with the significantly lower lipid content of these animals. These data suggest that maternal provisioning may be critical process in mediating the response of abalone to future OA.

DIFFERENTIAL PERFORMANCE OF OYSTERS TO MULTIPLE STRAINS OF OSHV-1

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The Ostreid herpesvirus 1 (OsHV-1) and its variants, particularly the OsHV-1 µvars are virulent and emerging viruses known to infect and kill Crassostrea gigas, globally. Prior to the detection of OsHV-1 µvar in France, OsHV-1 killed primarily larval and seed oysters and can be referred to as Summer Oyster Mortality Syndrome or SOMS. OsHV-1 µvars that cause Pacific Oyster Mortality Syndrome or POMS kill oysters of all life stages. In the US, SOMS causes severe (50-60%) losses of oyster seed in Tomales Bay most summers. Given the emergence and rapid spread of POMS and its impact on Pacific oyster culture, a proactive approach is necessary. Breeding programs have met with success in France, New Zealand, and Australia following

outbreaks of POMS indicating resistant oysters may be widespread in Pacific oyster populations. Twenty families from the Molluscan Broodstock Program (previously determined to be low and high survivors in experiments conducted in France) were exposed to two POMS variants, OsHV-1 µvar FRA, OsHV-1 µvar AUS and one SOMS variant: OsHV-1 CA. Survivorship analysis indicates variability of response across families. Additionally, families that were highly susceptible to one virus were also susceptible to other viruses; correlation in cumulative survival ranged from 0.44-0.66 between virus strains ($p=0.05$; $p \geqslant 0.01$, respectively). qPCR analysis of high and low families is underway to determine whether families resistant to POMS were also more resistant to OsHV-1 infection. Importantly, data from this study indicates that variation in susceptibility exists in MBP families.

MICROPLASTIC CONCENTRATIONS IN WILD AND CULTURED CLAMS AND OYSTERS IN BRITISH COLUMBIA, CANADA

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Microplastic contamination is an emerging threat to marine ecosystems. Many aquatic animals – ranging from mammals to invertebrates – have been shown to ingest microplastic particles (MPs). These particles can disrupt digestive and reproductive processes, act as vectors for harmful chemical pollutants, and reduce overall animal health. As relatively non-specific filter feeders, bivalves are susceptible to ingesting MPs from the water column. In southern British Columbia (BC), shellfish aquaculture is an important industry, and Manila clams (Venerupis philippinarum) and Pacific oysters (Crassostrea gigas) are the dominant culture species. Shellfish aquaculture often uses plastic infrastructure (anti-predator netting, fencing, rope, cages, trays, floats) that may degrade and release secondary MPs. We quantified the microplastic content of these two species in southern BC by transplanting an initial population of adult individuals to shellfish farms and nearby non-aquaculture intertidal areas in 6 regions important for shellfish aquaculture with varying degrees of farming intensity. The bivalves were collected after 2-3 months, chemically digested with 10% KOH to remove tissue, filtered, and their microplastic content visually quantified against procedural blanks using a compound microscope. Water

samples were also collected and analyzed for MPs. Results suggest that shellfish grown on aquaculture sites do not contain significantly more MPs (majority microfibres) than those grown at non-aquaculture sites. The average number of microplastic particles found in all shellfish after accounting for identification error (0.60 ± 0.72 and 0.09 ± 0.11 MPs/g dry tissue weight [SD] or 0.45 ± 0.52 and 0.42 ± 0.54 MPs/individual, for clams and oysters respectively) are similar to or lower than MP concentrations reported for these species by other studies.

I'LL TAKE A SLICE AND PLEASE PASS THE SALT

**DENNEY*, Rose A., C.J. CHRISTENSEN, S.M. COLOSIMO, K.E. CRAMER, A.C DEKERLEGAND, R.H. KITTLE, K.N. LEAZER, J.R. MCCOY, T.T. MIKOMBORIRAK, A.I MOOSMILLER, W.R. ROSTOMILY, A.C. SAWYER, R. TORRES, M. WATOWICH, M. HINTZ, C.E GRUE**

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For several years, we have studied the toxicity of imidacloprid (IMI) on juvenile and adult burrowing shrimp (ghost shrimp, Neotropea californiensis) in the laboratory in an effort to improve operational efficacy 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). In addition, we have investigated alternatives to IMI in response to concerns over its use to control the shrimp. Our tests with IMI indicate adult ghost shrimp are overtly affected (immobilized) when exposed to IMI at concentrations up to 1 million ppb active ingredient (a.i.) in artificial seawater (SW), but not killed and subsequently recover – likely because their primary neurophysiology does not match the mode of action of IMI. Subsequently, we have studied emamectin benzoate (EB) and non-iodized table salt (TS) as alternatives to IMI. We targeted juvenile shrimp because they are likely more sensitive than adults and reside within the upper 10-15 cm of the sediment facilitating control. EB, the active ingredient in Slice®, is currently registered for use in marine waters for the control of sea lice on farmed salmon. In a 96-h test (static 48-h renewal), we exposed juveniles (mean carapace length = 2.1 mm) to concentrations of EB ranging from 10 to 100 ppb a.i. to determine the median lethal concentration (LC50). All shrimp exposed to 100 ppb died within 24 h. The 96-h LC50 was 18.8 ppb compared to >12,000 ppb for IMI. EB may provide more effective control than IMI because it targets the primary neurophysiology of the shrimp. For TS, we exposed juveniles (mean carapace length = 2.5 mm) to 19 ppt (ambient salinity, control) or 25, 30, 36, 43, 52, and

62 ppt in natural SW for 6 h (duration of a low tide) and then transferred survivors to 19 ppt for 42 h. All shrimp at 43 ppt died within 6 h. Although promising, further tests are planned with EB and TS to determine effective concentrations within sediment, assess potential non-target effects, and evaluate environmental fate.

TIME TEMPERATURE INDICATORS (TTIs) – VIBRIO PREDICTIVE GROWTH DATA WAS USED TO CALIBRATE A TTI FORMULATION; NOW THIS TTI HAS THE SUPPORT OF THE FRESHTAG SYSTEM

**DESROSIERS*, Jeff**

**Vitsab International AB**

Vitsab was approached by the FDA and asked if their technology could be adapted to monitor Vibrio growth. The FDA provided predictive growth data for Vibrio vulnificus and Vibrio parahaemolyticus, enabling Vitsab to develop TTI labels that mirror these growth data. Conducting focus groups on 3 continents, Vitsab upgraded the product name to Freshtag. Freshtag more accurately delivers the message behind their function, the safety and freshness of oysters. Working with current Freshtag Shell Safe Shipping TTI users, Vitsab created the Freshtag System. This system validates eCommerce/direct to consumer deliveries plus confirms transportation to wholesalers/distributors; resulting in a decrease in returns and credits.
About the presenter: Jeff Desrosiers, EVP for Vitsab International AB, has over 25 years of senior level global experience within the technology, pharmaceutical, and seafood industries.

BREEDING PACIFIC OYSTERS FOR RESISTANCE TO MULTIPLE STRAINS OF OSHV-1

**DIVILOV*[1], Konstantin, Blaine SCHOOLFIELD[1], Benjamin MORGA[2], M. Victoria AGNEW[3], Colleen BURGE[3], Lionel DEGREMONT[2], Carolyn FRIEDMAN[4], Evan DURLAND[1], Claudio DE MELO[5], Brett DUMBAULD[1], Chris LANGDON[1],**

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**[4]School of Aquatic & Fishery Sciences, University of Washington**

**[5]Laboratory of Marine Mollusks, Department of Aquaculture, Federal University of Santa Catarina**

Since 2008, Pacific oyster mortality syndrome (POMS), attributable to a new strain of herpesvirus (OsHv-1 µvar), has caused massive mortalities in oyster growing regions in Europe, Australia, and New Zealand. Although West Coast oyster populations remain free of this pathogen, the rapid spread of OsHv-1 µvar across hemispheres represents a looming threat to U.S. oyster aquaculture. The best strategy to ensure sustainable production of this vital shellfish species is the pre-emptive development of resistant Pacific oyster broodstock on the West Coast. In furtherance of this goal, 70 breeding families from the Molluscan Broodstock Program (MBP) were sent to France as three-month old spat to be evaluated for resistance to the French strain of OsHv-1 µvar at IFREMER, La Tremblade. A substantial amount of variation in resistance was observed in the families and resistance was found to be highly heritable (>0.9), suggesting that selection on genetic breeding values will be effective in producing disease-resistant broodstock. Validation of the model used to obtain these breeding values by prediction of untested families using the pedigree resulted in a moderate (approx. ~0.3) correlation between predicted and true breeding values. From these 70 families, the most resistant and susceptible families were sent to Arizona to be tested against a reference OsHv-1 strain endemic to Tomales Bay, CA and the Australian OsHv-1 µvar. This coordinated strategy will help to determine if oysters bred for resistance to one strain will be resistant to other strains as well. The results from these experiments will inform oyster breeding programs on how to best optimize time and money to achieve disease-resistant broodstock.

BURROWING SHRIMP: A 2019 POPULATION FORECAST FOR COASTAL ESTUARIES INCLUDING WILLAPA BAY, WASHINGTON

**DUMBAULD, Brett R.*[1], Kim PATTEN[2], Katelyn BOSLEY[3]**

**[1]USDA-ARS**

**[2]Washington State University**

**[3]NOAA**

The ghost shrimp, Neotrypaea californiensis, is an important member of estuarine intertidal communities along the US Pacific Coast, but its burrowing behavior causes significant problems for shellfish culture. We have monitored populations of these shrimp in Willapa Bay, Washington for three decades and in other Washington and Oregon coastal estuaries since 2005. Ghost shrimp density increased dramatically in the 1990's in Willapa Bay, then declined almost as precipitously through 2010. Similar, though less dramatic declines occurred in other estuaries from 2005-2010. These shrimp have pelagic larval stages which develop in the coastal ocean, so

we asked whether the observed population changes were related to estuarine recruitment which we have also monitored. We found significant relationships between recruitment and the number of larger 1-year-old shrimp present in both Willapa Bay and Yaquina Bay, Oregon. Population increases have since occurred in all of the coastal estuaries we have studied, due to consistent recruitment since about 2011. We used more detailed monthly data collected in Willapa Bay during 2017-18 to refine first year mortality estimates for these shrimp and applied an age structured population model to examine the influence of recruitment events on shrimp populations. Data collected in 2018 surveys were included to develop a forecast for shellfish bed management in 2019.

ADVANCING SHELLFISH DISEASE PREVENTION FOR WASHINGTON: A PROGRESS REPORT FROM WDFW.

**EARDLEY*, Christopher, Brady BLAKE, Robert SIZEMORE, Camille SPECK**

**Washington Department of Fish and Wildlife**

The WDFW Shellfish Program has been investing in updating its approach to shellfish disease control to protect the state's cultured and wildstock resources. From improvements in permitting to monitoring, response, and education, the program has been active in 2017-18. The program is eager to continue engaging with the shellfish aquaculture industry and program news and updates will be presented.

RESULTS FROM THE BAYNES SOUND ENVIRONMENTAL INTELLIGENCE COLLABORATION (BaSEIC)

**EVANS*[1], Wiley, Darlene WINTERBURN[2], Katie POCOCK[1], Carrie WEEKES[1], Alex HARE[1]**

**[1]Hakai Institute**

**[2]BC Shellfish Grower's Association**

Baynes Sound, in the northern Salish Sea, hosts approximately 50% of the BC shellfish aquaculture industry with Pacific oyster (Magallana gigas) as the dominant production species. The known vulnerability of this species to ocean acidification (OA) driven changes in seawater chemistry, specifically through alteration in calcium carbonate (CaCO3) mineral stability, combined with periodic production problems in Baynes Sound, have led to a growing concern regarding possible contemporaneous impacts of OA in spite of lacking environmental intelligence detailing baseline conditions. In order to build-out our understanding of current

biogeochemical patterns in this key Salish Sea setting, a research initiative known as the Baynes Sound Environmental Intelligence Collaboration (BaSEIC), was formed in early 2016 between the BC Shellfish Growers Association and partnering shellfish growers in Baynes Sound and the Hakai Institute, with support from the Province of British Columbia and the Tula Foundation. Seasonally-resolved and spatially-distributed discrete seawater samples were collected by shellfish growers and an independent citizen science group operating in the area. Discrete measurements were used to add spatial context to a high-frequency data stream produced by instrumentation installed at a shore-side facility for continuous observing of in situ (8 m) CO2 chemistry. Taken together, the discretely-collected and continuously-measured seawater CO2 data provide a dynamic picture of the baseline conditions in Baynes Sound, including: (1) a pronounced seasonal cycle with surface-focused favorable conditions for CaCO3 mineral precipitation between spring and early autumn, (2) a sharp decrease in mineral stability of sub-surface water with excursions toward CaCO3 undersaturated conditions during the winter season and summer neap tide cycles, (3) a north-south gradient in mineral stability with the northern region exhibiting a greater prevalence toward lower mineral stability. These stake-holder generated results illustrate the current CO2 system patterns in Baynes Sound that are now being considered in shellfish industry management discussions.

## A NEW FLOATING FARM APPROACH FOR OPEN-WATER GROW-OUT OF OYSTER COLONIES

**FINN*, Arnold A.**

**MSE Coastal Engineering, PE, CGC**; **President, Global Dock and Marina Systems, LLC.**

This unique approach to Oyster Aquaculture provides extreme densification of open water oyster colonies and an engineered process for faster growth and more efficient harvesting.

The system can provide more than 7,000 oysters per square meter of structure surface area. The oysters are grown in 2-meter high basket columns, each containing 18 baskets with 150 oysters per basket. Each basket location is uniquely identified and tracked during grow-out.

The basket columns are lifted with a solar-powered, electric A-frame gantry and delivered to a service boat by rubber-tired work cart. With newly evolved Triplets, and up-weller feeding, grow-out to market can be achieved in less than one year.

THE ECONOMIC BURDEN OF VIBRIO PARAHAEMOLYTICUS ON PACIFIC NORTHWEST AQUACULTURE

**FREITAG*, Amy, John Jacobs**

An interactive session to help determine the many ways Vibrio costs the Aquaculture industry. We want to include costs to managers, growers, and restaurants. Hear about our project and how you can help! Help build our model of costs.

ECONOMIC RISKS & BENEFITS TO CALIFORNIA AQUACULTURE EXPANSION INFORMED BY OCEAN ACIDIFICATION AND HYPOXIA MONITORING

**HARPER*[1], Alex, HENRY Ruhl[1], CLARISSA Anderson[2], EMILY Bockman[3], LUKE Gardner[4], SCOTT Hamilton[5], CHARLES Colgan[6],**

**[1]Central and Northern California Ocean Observing System, Monterey Bay Aquarium Research Institute**

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In 2015, the U.S. West Coast aquaculture industry produced $468 million in revenue accounting for 36% of aquaculture seafood revenue nationwide. California is currently a small player in U.S. aquaculture, accounting in 2013 for only 4% of aquaculture farms and 6% of the value of output (National Agricultural Statistics Service 2014), highlighting potential for growth. Shellfish aquaculture is a growing industry in California and provides a sustainable alternative to wild caught seafood (National Agricultural Statistics Service 2014). However, the expansion of aquaculture is occurring in a changing ocean where ocean acidification (OA) and increasing hypoxia (H) are altering seawater conditions. To meet the growing demand, aquaculture producers will need to adapt to and/or mitigate the impacts of OAH. Monitoring is a cornerstone of effective environmental and resource management, highlighting spatial differences and revealing the trajectory of conditions while providing a means for adapting to, or mitigating, changing conditions. We aim to build upon recent successes of improved aquaculture operations enabled by the co-location of OAH and other monitoring with aquaculture operations and furthers the recommendations of the Washington State Blue Ribbon Panel to expand and

integrate knowledge about OAH and to meet societal needs for monitoring information. This interdisciplinary socioeconomic vulnerability assessment provides actionable information for policy-makers and industry representatives to adapt to OAH in the future. Through understanding and mitigating vulnerabilities, we can quantify what is at stake without strategic action improve the industry's adaptive capacity and identify opportunities to expand shellfish aquaculture in California.

MICROPLASTIC CONTAMINATION ACROSS AN URBAN GRADIENT

**HARRIS*, Lyda, Emily CARRINGTON**

**University of Washington**

Intertidal habitats are routinely exposed to varying levels of biotic and abiotic particles. As microscopic plastic (MP, plastic < 5mm) and sediment from runoff become more prevalent in our waters, it is important to determine the concentration of MP in the Salish Sea and the quantity of MP shellfish ingest. We focused on mussels (Mytilus spp.), well-known filter feeder and bioindicator species that are essential in Washington's aquaculture industry. Mussels are known to ingest MP both in natural and laboratory settings around the world, however, the local extent of ingestion is unknown. Here we investigated mussel and environmental MP contamination across an urban gradient in the Salish Sea. I hypothesized mussel MP contamination reflect water and sediment MP concentrations and that sites closer to Seattle's urban center contain more MP. Additionally, we hypothesized that sites closest to water treatment facilities contain the most MP particles. Preliminary results demonstrate all mussels at each site contain MP particles and MP fibers are among the most prevalent. 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.

THE GENETIC AND PHYSIOLOGICAL BASES OF HYBRID VIGOR

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Hybrid vigor, the superior performance of hybrids produced by crosses between inbred parents, underlies much of the increases in agricultural production that have helped keep a global Malthusian catastrophe at bay for over a century. Nearly 25 years ago, we demonstrated that the Pacific oyster, and likely other shellfish species, show hybrid vigor for yield, implying that

shellfish production should be amenable to the kinds of dramatic improvements seen in terrestrial agriculture. Unfortunately, such improvements have yet to occur, a situation that our new company, Pacific Hybreed, Inc., seeks to rectify.

Crossbreeding—a systematic method for selecting inbred parent lines that can repeatedly produce high-yielding hybrids—utilizes special and general combining ability of parents and differs from selective breeding, which depends strictly on general combining ability. Crossbreeding requires no sophisticated technology or even a clear understanding of the mechanisms of hybrid vigor, which have remained elusive for over a century. However, recent breakthroughs in our understanding of the genetic and physiological bases of hybrid vigor in the Pacific oyster offer several promising avenues for increasing the efficiency of crossbreeding. Specifically, biomarkers for hybrid vigor enable identification of elite hybrids at very early life stages, within a few days post-fertilization, eliminating the need for lengthy and expensive field tests. Owing to their superior metabolic efficiency, elite hybrids not only show increased yield but also show resilience to environmental stresses, such as increasing temperatures, ocean acidification, and emerging diseases. Pacific Hybreed is actively implementing these advanced technologies in its crossbreeding programs.

## COMPARING OFF-BOTTOM OYSTER CULTURE AND EELGRASS (Z. MARINA) BEDS USING A HABITAT SUITABILITY INDEX

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Considerable effort is directed at studies of ecosystem functions in shellfish culture and associated aquatic vegetation. It is challenging, however, to establish fixed measures of those functions, particularly in complex or mixed habitat types. This is due partly to their variability and difficulty in accurately measuring change and usage of those habitats. Here, we describe the application of the Habitat Suitability Index (HSI) as a simplified tool to quantify and map aspects of ecosystem functions in mixed off-bottom oyster culture and seagrass habitats. This tool applies two general measures: 1) indices of epibenthic taxa richness, abundance and suites of prey taxa targeted by salmonid species and other predators; and 2) index modifiers or Relative

Value Indices that characterize environmental conditions that may vary spatially across strata and influence the overall habitat suitability for fish and crab species of interest. Methodology, rationale for parameter selection and final HSI values for measured strata from four West Coast estuaries will be presented. HSI values are informed by field and lab data collected and analyzed by our project team in 2016-2017 supported by NOAA Saltonstall-Kennedy Grant # NA15NMF4270318.

ALASKA MARICULTURE DIVERSIFICATION: NEW OYSTER GEAR TRIALS

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Shellfish aquaculture in Alaska is a relatively small but growing industry. Farm gate value finally surpassed $1M in 2016, after fits and starts of limited growth since 1990. Currently, Pacific oysters (*Crassostrea gigas*) dominate farmed production, and are the sole exception to Alaska's strict restriction for cultivating only indigenous species. Shellfish farmers cite seed availability, slow growth rates, labor costs, outdated technology, shipping costs and harmful algal bloom closures as factors limiting profitability and growth of the industry. The Pacific Shellfish Institute (PSI), Alaska Sea Grant, and Maine R+D collaborated with shellfish farmers and the Alaska Shellfish Growers Association (ASGA) to provide technical assistance and advisement on best culture practices of oyster and kelp species through a NOAA grant (NA14OAR4170079). PSI coordinated distribution of new oyster grow-out gear. This presentation will focus on results and lessons learned from the oyster grow-out gear trials. Participating shellfish farms (8) agreed to collect and record oyster growth and environmental condition data at their farm sites. Monthly measurements of oyster length (mm) and weight (g) of 30 oysters from each gear type were used to assess the performance of different gear types. Results revealed differences in oyster growth among sites, but not between gear types. The most valuable aspect of the gear trials were lessons learned by participating shellfish farms, then shared with attendees of the ASGA annual meetings between 2015-2018. In general, the oyster gear floats were the weakest link to successful use. At one farm, the Zapco bag with floats were abandoned immediately due to sea otter vandalism of the attached polystyrene. Multiple farms experienced issues with another floating basket because the plastic floats had a tendency to leak.

In contrast, SEAPA 35L containers performed extremely well for one participating farm. The farm reported that baskets are very easy to work and result in an excellent meat to shell ratio.

MATURATION SCHEDULES AND DISTRIBUTION OF REPRODUCTIVE SUCCESS IN PURPLE HINGED ROCK SCALLOPS (Crassadoma gigantea)

**JACKSON*[1], Molly, Natalie LOWELL[2], Jonathan DAVIS[3], Brent VADOPALAS[1], Lorenz HAUSER[1]**

**[1]Taylor Shellfish Farms and University of Washington**

**[2]University of Washington**

**[3]Puget Sound Restoration Fund**

Native species are commonly chosen for aquaculture expansion to avoid negative environmental impacts associated with the introduction of foreign species. However, the culture of native species is not without risks, as interbreeding with wild populations and can impact naturally occurring genetic diversity and population structure. The risk of adverse impacts depends, among other factors, on the frequency of interbreeding and genetic diversity of hatchery produced animals. Here, we evaluated both factors, first by establishing age and size at maturity and second, by determining the distribution of reproductive success in a voluntary mass spawn of rock scallops Crassadoma gigantea. Cultured scallops were deployed in Dabob Bay, WA, when they were eight months old and sampled every two weeks to monitor reproductive development and growth. Scallops reached 50% sexual maturity around 24 months post spawn or at 54mm shell height. To estimate reproductive success, 1350 individuals were produced by mass spawn of up to 52 broodstock animals, deployed in three growout sites. After a ten-month deployment, tissue samples were used to determine the effective number of breeders (Nb) at each growout site. Survival at the three growout sites differed markedly, with 98% survival in Totten Inlet, 66% in Dabob Bay and 14% in Neah Bay, and corresponded to a reduction in Nb, (Nb=17.3, Totten Inlet; Nb=14.9, Dabob Bay; Nb=8.6, Neah Bay). Our results show that with a projected harvest age of three to four years, cultured C. gigantea will mature prior to commercial harvest, and thus potentially interbreed with wild individuals. Compared to other shellfish, reproductive success of individual parents was relatively even, but Nb was reduced considerably when mortality was high. Genetic risks to wild populations are therefore possible, but could be reduced by modifying hatchery and farm management practices.

TEMPERATURE CONTROL AND PERFORMANCE OF COLD CHAINS FOR HALF-SHELL OYSTERS FARMED IN WASHINGTON STATE

**KUEHL*[2], Lillian, Bobbi HUDSON[1], , Kate CLANCY[2], Jillian FRY[2], James HARDING[2], Dave LOVE[2], Bob LANE[3]**

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**[3]Virginia Tech Agricultural Research and Extension Centers, Hampton, VA 23669.**

Temperature controlled supply chains (cold chains) require an unbroken chain of refrigeration to maintain product quality and safety. This study assessed the performance of cold chains for oysters produced in Washington State and sold live to the half-shell market within the state, nationally, and internationally. Study goals were to use temperature as a predictor of Vibrio parahaemolyticus growth in oysters after harvest, and to describe the diversity and structure of Washington oyster cold chains. We deployed temperature data loggers inside of oysters and on oyster packaging on farms, then removed the data loggers once the products reached food retailers and restaurants. Approximately 120 data loggers were deployed on 8 farms between April and July 2018, and each logged temperature every 10 minutes. We also performed interviews with producers, freight carriers, wholesalers, food retailers, and restaurants to further understand how cold chains function and the levels of traceability within the Washington oyster industry. This work follows similar work in 2017 on the Chesapeake Bay oyster industry. Results will be discussed.

UPDATE ON PROGRESS AND ENSURING LONG-TERM SUPPORT FOR THE MOLLUSCAN BROODSTOCK PROGRAM (iMBP)

**LANGDON*, Chris, Blaine SCHOOLFIELD, Marilyn LEARY, Claudio DE MELO, Evan DURLAND, Konstantin DIVILOV.**

**Coastal Marine Experiment Station, Department of Fisheries and Wildlife, Oregon State University, Newport, Oregon 97365.**

The Molluscan Broodstock Program (iMBP) was initiated in 1996 and has primarily focused on improving yields of Pacific oysters through selection; however, MBP has also recently included selection for larval tolerance to acidified seawater and resistance to oyster herpes virus. iMBP works closely with West coast hatcheries and farmers in transferring selected broodstock and knowledge in order to improve production. Currently, the State of Oregon is the principal

funding source for iMBP but alternative funding mechanisms need to be developed in order to ensure the long-term viability of program.

PRESENCE AND PREVALENCE OF SHELL-BORING MUDWORMS (Polychaeta: Spionidae) IN WASHINGTON STATE

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Some spionid polychaetes can burrow into the shells of bivalves, creating unsightly mud blisters. Because they are unappealing to consumers and can burst, fouling oyster flesh, these blisters are an economic burden on affected oyster half-shell industries. Historical invasions by the spionid Polydora websteri have resulted in the collapse of aquaculture operations in Australia, New Zealand, and Hawaii, USA. Recent sightings of mud blisters on Pacific oysters (Crassostrea gigas) in Puget Sound, Washington, suggest that the area might be experiencing a spionid polychaete invasion. To determine whether P. websteri is the polychaete creating the mud blisters, we obtained 170 Pacific oysters from seven locations in Washington and examined them for blisters and burrows associated with spionid polychaete infection. Four of seven sites showed infection, with a range from 20 - 53% infection. Polychaetes were then extracted from the shells and vouchered for molecular analyses. We used mitochondrial (cytochrome c oxidase I [COI] and cytochrome b) and nuclear (18S rRNA) genes for species-level identification for a subset of polychaetes (n = 24). Our results confirm a positive identification of P. websteri in mud blisters of Puget Sound oysters, the first documented sighting in Washington, USA. This study is the foundation for advising the Washington shellfish industry on strategies for mitigating the economic impacts of this invasive polychaete.

GENETIC RISK EVALUATION OF NATIVE SHELLFISH AQUACULTURE: EMPIRICAL DATA, STAKEHOLDER INPUT, AND INITIAL RESULTS FROM A POPULATION MODEL

**LOWELL*[1], Natalie, Brent VADOPALAS, Eric WARD[2], Bobbi HUDSON[3], Benoit EUDELINE[4], Robert SIZEMORE[5], Lorenz HAUSER[1]**

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**[4]Taylor Shellfish**

**[5]Washington Department of Fish and Wildlife**

Native shellfish aquaculture has many benefits, but interbreeding of hatchery and wild populations may pose genetic risks to wild populations. The type and magnitude of these risks depends in part on the genetic population structure of native shellfish species as well as hatchery management practices. Early genetic studies on marine shellfish provided little evidence for such structure. However, recent population genetic studies provide higher resolution, make use of both neutral and non-neutral molecular markers, and suggest some marine shellfish can exhibit population structure and even local adaptation. Here, we present preliminary results on genetic differentiation among populations of Crassadoma gigantea (the purple-hinged rock scallop) and Parastichopus californicus (the giant California sea cucumber), two native species that are currently being developed for aquaculture production in Puget Sound. Data for both species demonstrate high levels of genetic diversity and indications for population structuring by geography. Results will be used in a genetic risk model to quantify risk under multiple management scenarios, which will provide decision support to resource managers and other stakeholders. We will present preliminary results of the genetic risk assessment, including model simulation results and a synthesis of stakeholder input data. Our study shows the importance of population structure for genetic risk assessment and the power of combining empirical data, computer modeling, and end-user input.

HAWAII: HAVE YOUR CLAMS AND EAT THEM TOO

**LOWREY*, Amanda R.K.**

**Hawaii Department of Health Sanitation Branch**

Hawaii has been recognized by the United States Food and Drug Administration (US FDA) as a producing state for many years thanks to the participation of dealers on the Interstate Certified

Shellfish Shippers List (ICSSL). However, no locally grown product has been legally shipped out of state since the inception of the Interstate Shellfish Sanitation Conference (ISSC). The local growing industry was recently revived after two decades without production. The progress and challenges of the exciting growth and expansion of the Hawaii State Shellfish Program will be discussed.

BACTERIOPHAGES PREVENT LARVAL Crassostrea gigas MORTALITY FROM Vibrio coralliilyticus RE98 INFECTION

**MADISON*[1], David, Chris LANGDON, Claudia HASE, Gary RICHARDS[2], Mike WATSON[2], Nitzan SOFFER[3], Manrong LI[3], Alexander SULAKVELIDZE[3],**

**[1]Oregon State University,**

**[2]USDA ARS**

**[3]Intralytix, Inc.**

The oyster industry in the Pacific Northwest of the United States has been plagued by severe and frequent larval mortality events associated with blooms of the pathogenic bacterium Vibrio coralliilyticus RE98 (Vcor). There is a clear need to be able to control Vcor populations in the shellfish industry. Bacteriophages (phages) are viruses that specifically infect bacteria and are known to play a major role in controlling bacterial populations in nature. Phages have been used to control pathogens in a number of aquaculturally important species, but never in larval oysters. This study found that adding 2 x 107 PFU/ml of a cocktail of three Vcor specific phages to the Pacific Oyster (C. gigas) culture water could eliminate mortality of two day post fertilization (dpf) larvae from simultaneous exposure to 6.4 x 104 CFU/ml of Vcor, a concentration of Vcor that caused >99% mortality in the absence of phages. This study also found that the single addition of phages to two dpf larvae improved C. gigas settlement rate more than sixteen days later. The ability to improve settlement and reduce larval mortality from Vcor infection has the potential to benefit the shellfish industry by allowing for the production of higher and more consistent yields of seed oysters.

PRESENCE OF MICROPLASTIC CONTAMINANTS IN PACIFIC OYSTERS FROM PUGET SOUND

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Marine plastic pollution is a serious threat to marine life with long term impacts to ecosystems and organisms. Over time, plastics in marine environments break into smaller pieces, or microplastics (< 5 mm). These particles float in the ocean, flow through rivers and accumulate in sand. Washington state is home to Puget Sound, the third largest estuary in the United States. Puget Sound supports populations of filter feeders such as oysters, that easily capture and accumulate microplastics from the surrounding water. In this research, we quantified the abundance and type of microplastics in Pacific oysters Crassostrea gigas (n = 200) from 10 wild populations in Puget Sound. Bivalve tissue was digested with 30% H2O2, incorporated to a 25% NaCl solution, and lastly filtered with a 5µm membrane. The filter membrane was examined under a microscope to count and visually identify the microplastics retained. Preliminary data from two sites indicates that the mean number of microplastics per oyster ranges from 1.6 to 3, with a maximum of six. Larger oysters did not have more microplastics, suggesting pollution might be size-independent and site-specific. Microfibers were the dominant type of microplastics found, and a subset of these were analyzed with a micro-Fourier transformed infrared spectroscope to determine their composition and possible sources of origin. These findings will help to better understand the abundance and distribution of microplastics in ecological and commercial important species in Washington state and introduce mitigation strategies to ensure shellfish health for current and future generations.

## CONSERVATION PALEOBIOLOGY AS A TOOL TO SUPPORT OLYMPIA OYSTER RESTORATION

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Historical baselines are fundamental to inform and monitor restoration efforts, and to interpret long-term changes in marine ecosystems. However, the validity and reliability of historical baselines can be compromised if the ecosystem has already been degraded and/or modified by anthropogenic activities. In Washington state, restoration of native oysters is limited by shifting

baselines and the lack of information of Olympia oyster populations before they collapsed in the late 1800s due to over-exploitation. Conservation Paleobiology is an emerging multidisciplinary field that aims to use recent fossil and archeological records to develop historical baselines and support conservation and restoration strategies. For this study, I will compile information from historical assemblages to increase our understanding on what healthy oyster beds looked like in the past. Preserved oyster beds can help us learn about species diversity in a community, biotic interactions, and habitat provision to other organisms. Furthermore, important metrics for oyster restoration such as reef height, oyster density per m2 and size frequency distributions can also be quantified from preserved oyster beds. At the individual level, oyster shells function as archives of proxies such as water temperature, salinity and pH at the time organisms were alive and depositing their shells. These proxies can be quantified through δ18O, Ba-Ca isotope ratios and radiocarbon dating. Better integration of historical baselines and ecological studies, together with increased collaboration between paleobiologists, ecologists and restoration managers and practitioners will help improve the planning, design and implementation of conservation and restoration efforts of Olympia oysters.

FARMING DOWN UNDER - AN AUSTRALIAN STORY

**MCASH*, Ewan, Colin BRIDGES***

**SmartOysters**

Much of the industry around the world still relies on paper, farmer memory & the whiteboard in the shed to capture data &manage the farm. However, unless this information is captured in digital form, the farmer's knowledge & records of activity are extremely vulnerable. Furthermore, as other agricultural sectors continue to digitise their practices, they are increasingly able to access new capital & manage risk through detailed & verified systems. This leaves the shellfish industry at risk of being left behind. For many oyster farmers, the whiteboard represents an easy to use, low cost tool. It has remained in use even though more technically advanced and efficient alternatives have become available. The low cost & familiarity of the whiteboard means that often superior & cost-effective technology is frequently overlooked or rejected. For all their benefits, whiteboards, paper & farmer memory have significant limitations. They have no back-up. They are not secure. Manual entry of data can be time-consuming & must be laboriously transferred to an electronic format if stock & financial reports are required. All data collected out on the lease must either be written down or memorised prior to being entered on the board. This increases the risk of mistakes being made. In short; real-time monitoring &

reporting is not practicable using these methods. All is not lost though! The good news is that easy to use, cost-effective digital alternatives, specifically designed for the shellfish industry are now readily available. For example, the team at SmartOysters has achieved just that. Rather than starting with complex database design or sensors, SmartOysters commenced with a very simple concept; make it easier for a shellfish farmer to do their job & as a by-product capture what they do digitally. What has emerged from the collaboration of SmartOysters' founders is a world first. An industry specific farming tool in a simple to use mobile app with an elegant map interface. This enables the farmer to do their work, capture what they do in seconds, & then use that information to readily visualise their farm & activities. Like single seed cultivation & long-line production, the digitisation of farm practice & stock is a significant moment in the industry's evolution. Adoption of new technology will assist in future proofing the industry & ensuring that shellfish growers are not left behind.

## TRANSLATIONAL SCIENCE IN THE MANAGEMENT OF EUROPEAN GREEN CRAB (CARCINUS MAENAS) IN THE SALISH SEA

**MCDONALD*[1], P. Sean, Emily GRASON[1], Jeffrey ADAMS[2], Kate LITLE[2]**

**[1]University of Washington, Seattle, WA 98195**

**[2]Washington Sea Grant**

The European green crab (*Carcinus maenas*) was first detected in Washington waters in 1998 after warm El Niño currents spread larvae of California populations as far north as Vancouver Island. Because of perceived risks to coastal resources, the green crab was designated a deleterious species in Washington State, which among other actions, mandated monitoring and control of the species in state waters but none were found in inland waters of Puget Sound. In 2012, Canadian wildlife officials discovered a population of green crab in Sooke basin near Victoria, British Columbia, well within the Strait of Juan de Fuca. Green crab spread is currently being tracked by a citizen science network of early detection sites along Washington's inland shorelines: Washington Sea Grant (WSG) Crab Team. Crab Team's network of volunteer, tribal, and agency partners monitors 52 sites across Puget Sound, the San Juan Islands and the Strait of Juan de Fuca, with the goals of assessing the status and impacts of the nascent invasion. In 2016, volunteers captured the first confirmed green crab on Washington's inland shorelines. Green crab populations are currently extremely small, but have the potential to grow rapidly without swift intervention. The present rarity of the crab, infrequent dispersal and relative isolation of Salish Sea populations, sets up a promising scenario for effective intervention. A collaborative,

coordinated and rapid response is required to offer the greatest changes for successful protection of natural, economic, and cultural resources. Ongoing efforts, including an update on the 2018 field season is discussed.

CRACKING CRAB: IMPROVING OUR UNDERSTANDING OF POPULATION DYNAMICS AND ECOSYSTEM SERVICES OF DUNGENESS CRAB IN THE SALISH SEA

**MCDONALD, P. Sean, Julie BARBER (moderators)**

**Presenters:**

**Alan SHANKS, Evelyn BROWN, Sarah GROSSMAN, and more.**

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. This session will begin a discussion on the development of a collaborative monitoring effort through Washington inland marine waters to improve our understanding of Dungeness crab population dynamics, its ecosystem services, and management of fisheries targeting the species. Dr. Alan Shanks will present on his light trap monitoring research, focusing on how these data can be used to predict commercial crab catch in Oregon. Data from Lummi and Swinomish light trap and intertidal monitoring efforts will also be presented. These talks and others will be followed by a panel discussion where we plan on (1) determining who is interested in participating in this collaborative research effort, and (2) outlining group hypotheses and goals. Results from this session will include a research agenda with priorities and recommendations. Other speakers and panels to be determined.

SHELLFISH GROWERS AS ADVOCATES FOR CLIMATE ACTION: WHAT YOU NEED TO KNOW

**MCGEE[1], Sally, Jodie TOFT*[1], Joth DAVIS[2]**

**[1]The Nature Conservancy**

**[2]Baywater Shellfish Company**

Shellfish growers throughout the U.S. are seeing impacts of climate change on their businesses. So, last year, seven growers joined together to begin to figure out how they could impact climate policy. They reached out to The Nature Conservancy and together have formed the Shellfish

Growers Climate Coalition. The Coalition now totals 18 members from the East and West Coasts and the Gulf of Mexico. Coalition members agree that:

• Human impact on the Earth's climate system is well documented, scientifically understood and profound.

• Taking action to address climate change is imperative to secure the viability of our businesses, our communities, and the natural resources they depend upon.

• Improving people's understanding of climate change and its impact on our businesses represent an important way to promote and enact climate policies that guide America to a low carbon future.

This session will explore the reasons the Coalition formed and actions the Coalition has taken to promote understanding of the impacts of climate change on shellfish and to advance proactive climate policies at the state and federal level. It will also explore the potential for future Coalition activities to advance the sustainability of members' businesses.

## COMPARATIVE HABITAT USE OF ESTUARINE HABITATS WITH AND WITHOUT OYSTER AQUACULTURE: CHALLENGES, PARTNERSHIPS, AND PENULTIMATE LESSONS LEARNED

**MEADERS*, Marlene, Phil BLOCH*, and Chris CZIESLA**

**Confluence Environmental Company, 146 N. Canal St, Suite 111, Seattle, WA**

Shellfish aquaculture, native eelgrass, and mudflat habitats have co-existed in Humboldt Bay, California, for at least the last 60 years of commercial shellfish production, and for more than 100 years since the first attempts to introduce shellfish in 1896. The goal of this project was to provide research on the environmental impacts of shellfish aquaculture by furthering the understanding of how fish and invertebrate communities are affected by the presence of cultch-on-longline oyster aquaculture in comparison to areas without oyster aquaculture in Humboldt Bay.

There were three objectives established for this project:

1. Does oyster culture alter fish and/or macroinvertebrate assemblages in Humboldt Bay?
2. Does oyster culture alter invertebrate assemblages (prey resources) in Humboldt Bay?
3. Does oyster culture alter the food web in Humboldt Bay?

Sampling for fish and invertebrates were conducted in four areas: (1) oyster longline culture in mudflat habitat, (2) oyster longline culture in eelgrass habitat, (3) mudflat habitat without oyster longline culture, and (4) eelgrass habitat without oyster longline culture. Four sampling events

occurred between June 2017 and June 2018 documenting fish assemblages. Invertebrate assemblages were sampled during the same timeframe, although all samples were from 2017. Results from the invertebrate data collection will be finalized at the end of the year. This presentation will provide the major preliminary results of the fish and invertebrate sampling in Humboldt Bay, approach to a fall workshop that will discuss the use of Ecopath with Ecosim (EwE) modeling, and lessons learned throughout the project.

Overall, the data indicate that differences in fish assemblages and abundance are correlated with both presence of vegetation (eelgrass habitat vs. mudflat habitat) and presence of aquaculture (habitats with aquaculture vs. habitats without aquaculture present). Specifically, the results suggest that fish abundance and species richness are higher in areas with vegetation present (eelgrass) and in areas with aquaculture gear present. Conversely, fish abundance and species richness are lower in areas without eelgrass or aquaculture. There are also unique species within each habitat that prefer the type of structure (or lack of structure) provided. Similar observations for the invertebrate community are also predicated on presence of structured habitat. These results support the conclusion that the environmental impacts due to aquaculture presence do not result in a major shift in prey or species use of Humboldt Bay. This microcosm study shows that shellfish aquaculture can be conducted in an estuary without significant risk of changing the biological resources. Future work will improve our understanding of how adding aquaculture to an estuary could affect the food web within Humboldt Bay.

ON THE EDGE: ASSESSING FISH HABITAT USE ACROSS THE BOUNDARY BETWEEN PACIFIC OYSTER AQUACULTURE AND EELGRASS IN WILLAPA BAY, WA

**MUETHING*[1], Kelly, Brett DUMBAULD[2], Fiona TOMAS-NASH[1]**

**[1]Oregon State University**

**[2]USDA-ARS**

Estuaries are an important ecological link between terrestrial, freshwater, and marine systems, but are also subject to a variety of human pressures. Pacific oyster (Crassostrea gigas) aquaculture commonly occurs in intertidal areas in US West Coast estuaries where native eelgrass (Zostera marina) is also present. In these locations, eelgrass provides valuable nursery habitat for many commercially-harvested species, including salmonids, Dungeness crab, and English sole. Because of this, eelgrass has attracted conservation attention and is currently protected as "essential fish habitat" under federal legislation. This protection restricts oyster aquaculture within or near eelgrass, creating a stakeholder conflict. To help inform management

decisions around this issue, questions were addressed regarding the use of both oyster aquaculture and eelgrass as habitat by fish. Specifically, we were interested in whether the edge between these two habitats supported different abundances of fish from each respective habitat. Due to a recent shift towards off-bottom culture methods, this comparison was made in both long-line and on-bottom aquaculture. Direct (underwater video) and indirect (e.g. predation tethering units) measures of fish community composition and behavior were used to quantify differences along a transect between aquaculture and eelgrass for each aquaculture method. Results suggest that long-line oyster aquaculture and eelgrass provide similar habitats for fish, with minimal effect of the edge. However, habitat use of the on-bottom aquaculture was less than that for both long-line aquaculture and eelgrass beds. These results are consistent with an expected positive relationship between fish abundance and three-dimensional habitat structure, and provide valuable information to managers and permitting agencies as they consider requests to expand culture operations.

## SOCIOECONOMIC IMPACTS OF OYSTER-BORNE NOROVIRUS OUTBREAKS ON HAMMERSLEY INLET SHELLFISH GROWERS

**NIXON*, Marisa**

**Washington State Department of Health**

In 2014 and 2017, the Hammersley Inlet shellfish growing area in Washington State was linked to a series of shellfish-borne norovirus outbreaks. These outbreaks resulted in closures, costly recalls and on-going economic impacts. This presentation shares selected findings from a 2018 survey of shellfish growers in the area, which sought to quantify the socioeconomic impacts of the outbreaks. Additionally, the data collected from the survey highlights growers' concerns about future illness events and ways in which they are trying to mitigate these concerns. This research underscores the harm that fecal pollution can do to Washington's shellfish industry and the need for sustainable work on pollution identification and correction in Puget Sound.

## IS IT FEASIBLE TO MANAGE THE ON-SITE POPULATION OF NEWLY RECRUITED BURROWING SHRIMP?

**PATTEN*, Kim**

**Washington State University**

There has been an upward trend in the settlement of new ghost shrimp in recent years. These new populations pose a major threat to the shellfish industry. Mechanical control of juvenile ghost

population is more feasible than it is for adults. Studies were conducted on juvenile ghost shrimp to investigate the duration of their recruitment time period, their growth rate, their natural over-winter mortality rate, and their distribution profile in the sediment by size class. Addition research was also conducted on the effectiveness of clean-up dredging, barging harrowing, and deep raking as a management tool for new recruits.

A HOPEFUL HUB FOR OFFSHORE SHELLFISH FARMERS

**RACINE*, Phoebe, Josh GRAYBIEL, Sutara NITENSON**

**University of California Santa Barbara**

A recent series of marine spatial planning projects highlighted Santa Barbara as one of the best places for offshore aquaculture growth, spurring the development of new offshore shellfish projects. While this industry has minimal impact especially in offshore environments, state government and local community concerns remain. To ensure the industry minimizes their impact on marine ecosystems and plays a positive role in the Santa Barbara community, this project developed an easy-to-use resources hub that explores Best Management Practices for offshore aquaculture, makes sense of state and federal permitting, breaks down the science around farming, and identifies areas where further research is in need. This tool can be especially useful for Southern California shellfish farmers, aspiring offshore farmers, and interested stakeholders.

FEED THE MUSSEL: EXPLORING THRESHOLDS OF OFFSHORE MUSSEL FARMING IN THE SOUTHERN CALIFORNIA BIGHT

**RACINE*, Phoebe**

**University of California Santa Barbara**

The scientific community largely agrees that shellfish minimally, and most often negligibly, impact the abundance of the base of the marine food web, phytoplankton. While seen across most of the world as ecosystem builders and biofilters, within California, stakeholders routinely demand information on the shellfish impact on phytoplankton abundance. While this has caused a social cost to farmers, there have also been a few cases of financial cost through required reporting and monitoring. To facilitate public understanding, an interactive tool was developed as a public interface to assess the impact on phytoplankton abundance using the Santa Barbara Channel as a case study. This is a first step in understanding the potential cumulative impacts, and threshold, of a robust offshore aquaculture industry.

FILLING KNOWLEDGE GAPS: PARTNERING TO SEE UNDERWATER AND BEYOND

**SANDERSON*[1], Beth, Jackson BLALOCK, Molly BOGEBERG, Tish CONWAY-CRANOS, Bill DEWEY, Bridget FERRISS, Peter KIFFNEY, Kate LITLE, Jodie TOFT, Laura HOBERECHT, Karl VEGGERBY**

**[1]NOAA Northwest Fisheries Science Center**

Nearshore habitats, including seagrass beds and natural and cultivated shellfish beds, provide a host of ecosystem functions including serving as habitat for fish and invertebrates where they forage, shelter, and reproduce. Using a unique combination of industry partnership and emerging technology, we are working to characterize nearshore fish and invertebrate communities associated with shellfish aquaculture habitat relative to adjacent eelgrass meadows or mudflats, thereby improving our understanding of the ecological functions provided by these habitats. Video cameras function much like an underwater periscopes that stealthily capture glimpses of species occupying these underwater habitats. More than 1000 hours of underwater video we have collected from nearshore sites around Puget Sound is now revealing the underwater life of species occupying these habitats. As our understanding of species' use of these habitats unfolds, these partnerships also offer opportunities to identify and investigate new questions about ecological functions of nearshore ecosystems and more.

KELP; HARVEST, PROCESSING, & PACKAGING

**SCHRECK*, Stephen**

**Puget Sound Restoration Fund**

The kelp farming industry in the United States is on the rise. This type of aquaculture is sustainable as it requires no fertilizers, pesticides, herbicides or freshwater inputs. Over the past ten years, several dozen farms on the East Coast and start-ups in California, Oregon, and Washington have sprung up.

As interest in this industry gains momentum, the hurdles of harvesting, processing, and packaging must be addressed. In order to streamline distribution to restaurants, health food stores, and culinary institutions the mechanics of these processes must be evaluated. This presentation focuses on possible routes harvest, processing, and packaging of the fresh/raw product might take in the near future.

## SURVIVAL AND GROWTH OF THE GOOSENECK BARNACLE (POLLICIPES POLYMERUS, SOWERBY) IN A LOW FLOW MARICULTURE SYSTEM UNDER DIFFERENT DIETS

**SHANKS*, Alan, Mike THOMAS, Alexa RAMORSA, Julia BINGHAM**

**U of Oregon, Oregon Inst of Marine Biology**

Pollicipes pollicipes (Gmelin), an Atlantic gooseneck barnacle, are a highly-prized delicacy on the Iberian Peninsula. They have suffered from declining harvest as a result of high demand and a life history, which makes the organism slow to reestablish harvested stock. Pollicipes polymerus (Sowerby), a northeast Pacific gooseneck barnacle, is currently minimally fished, but there is growing interest for the development of a fishery in Oregon. Laboratory cultures have shown barnacles will survive in culture, but only under high flow conditions. Here we test a novel method of mariculture, which uses low water flow (~0.3 cm sec-1) coupled with strong aeration. Juvenile P. polymerus transplanted into the system from wild populations were given three different diets (unfiltered sea water, micro-algae, and de-capsulated Artemia spp. cysts). We monitored settlement and growth of larval barnacles onto the juveniles. Barnacle survival was high (88%, n=95/108) across all treatments. Average growth rates were highest in barnacles fed Artemia spp. cysts (0.31 mm RC wk-1) and significantly lower in those given micro-algae (0.15 mm RC wk-1) and unfiltered seawater (0.17 mm RC · wk-1). Within the first weeks, transplanted barnacles cemented themselves to the substrate and new recruits were observed on the peduncles of the transplants; recruits grew as much as 4-5 mm RC length by the experiment end. This experiment has demonstrated the ability to mariculture gooseneck barnacles in low flow systems and to successfully induce clump formation within culture.

## U.S. V. WASHINGTON LITIGATION UPDATE

**SMITH, Robert**

There have been significant developments in the U.S. v. Washington litigation over the past year that will affect both Treaty Tribes and shellfish companies. The presentation will provide an update regarding the status of the litigation, any reportable outcomes of ongoing negotiations, and the next steps in dispute resolution proceedings.

LOW PH AND HIGH TEMPERATURE ADULT EXPOSURE AFFECTS LARVAL VIABILITY AND JUVENILE GROWTH IN O. LURIDA FROM PUGET SOUND, WA

**SPENCER*, Laura H., Steven ROBERTS**

**University of Washington School of Aquatic and Fishery Sciences**

A broadening body of work indicates that projected low pH and high temperatures negatively affect fertilization and early life stages of many marine invertebrates. Oysters may, however, contain a unique capacity to keep pace with rapidly shifting climate stressors via genetic variation. To examine the transgenerational carry-over affects of these exposures on Ostrea lurida, the only oyster native to the United States' west coast, larval production, larval survival, and juvenile growth were measured following adult-only exposures. First-generation hatchery reared broodstock from three sub-populations in the Puget Sound estuary in Washington State were exposed to elevated temperature and dissolved CO2, then conditioned and induced to spawn. We will present results on eight weeks of larval production data, as well as survival to metamorphosis and juvenile stages, and growth after ten months for a subset of the progeny. Results will include gonad histology, sampled after each treatment exposure.

INNOVATING KELP AQUACULTURE METHODS BY STUDYING THE LIFE CYCLE OF Saccharina latissima

**THOMSON *[1], Annie, Michael STEKOLL[2]**

**[1]University of Alaska Fairbanks**

**[2]University of Alaska Southeast**

Kelp farming has the potential to economically diversify coastal communities while offering potential ecosystem services including carbon sequestration and mitigating the effects of eutrophication. Our research is focused on identifying methods to control life stages of Saccharina latissima to optimize kelp aquaculture output. First, we are interested in understanding the natural fertility patterns of sporophytes, providing insights as to when the commercial kelp seeding process can be implemented. Preliminary observations from sporophyte fertility surveys show that S. latissima sporophytes are found most commonly in protected sandy habitats attached to shells of bivalves, small cobbles or rocks. There also appears to be site specific variation with respect to population abundance and whether the plants exist as annuals or perennials. Additionally, preliminary observations from sporophyte fertility surveys show S. latissima fertility patterns may vary between different regions in Alaska. Second, we are investigating how growth and development of gametophytes and juvenile sporophytes can be controlled by varying temperature, nutrients, light quality and light intensity. The ability to

control the life cycle at these stages will give more flexibility to future kelp hatchery operators and farmers. So far, we have evaluated different techniques of halting or delaying gametogenesis. Methods include removing iron from the gametophyte culture medium and filtering out blue light while gametophytes are in culture. Our preliminary results suggest removing iron from the gametophytes nutrient medium is a reliable method of halting gametogenesis. of S. latissima from Juneau. However, filtering out blue light does not appear effective in halting gametogenesis. We have also observed that kelp gametophytes and juvenile sporophytes grow differently under a range of light intensities. Current experiments are examining how gametophyte and juvenile sporophyte growth can be slowed by varying temperature and light intensity and duration. Results from current and upcoming experiments will help inform kelp aquaculture practices and give insight to the ecological life cycle strategy of S. latissima.

UNDERWATER VIDEO WORKSHOP: PROS, CONS AND PATHS FORWARD FOR COLLABORATIVE RESEARCH

**TOFT*[1], Jodie, Bridget FERRISS[2,3], Beth SANDERSON[2], Molly BOGEBERG[1]**

**[1]The Nature Conservancy**

**[2]NOAA Northwest Fisheries Science Center**

**[3]Washington Sea Grant**

NOAA, The Nature Conservancy, and Sea Grant will hold a 45-60 minute workshop to identify pathways for use of underwater video in permitting and to affect public perception. The team will discuss our work with shellfish growers in the region over the last year, in which we have deployed GoPro cameras to explore fish and crab use of shellfish growing areas. In the workshop, the team and workshop attendees will discuss pros and cons of the research, necessary improvements and future directions for collaborative research using underwater video and other emerging technology.

ECONOMIC EFFECTS OF REGULATIONS ON WEST COAST SHELLFISH FARMS.

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

A survey to assess the costs and impacts of regulations affecting shellfish aquaculture in Washington, Oregon, and California was conducted in the fall of 2016. The survey captured an estimated 74% of the production value of the west coast shellfish industry. Fifty-one percent of respondents acknowledged the importance of regulations, specifically with regards to environmental protection and food safety. Many producers reported indirect costs of regulatory

compliance in their business, such as lost opportunities, lost sales, changes on the farm for compliance, and manpower for permitting and compliance activities. Regulatory costs were broken into two broad categories; the cost of obtaining permits and licenses and the cost of monitoring and compliance. The total cost of obtaining permits and licenses was larger than the total cost of monitoring and compliance activities on farms. This was driven primarily by lost sales and lost opportunities resulting from permitting delays and lost production. The survey captured a total regulatory cost of $225 million across the west coast shellfish industry.

## INFLUENCE OF OCEAN ACIDIFICATION ON THE EPIGENOME OF OYSTER REPRODUCTIVE TISSUE

**VENKATARAMAN*[1], Yaamini R., Kathleen E. LOTTERHOS[2], Steven B. ROBERTS[1]**

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Epigenetic modification, specifically DNA methylation, is one possible mechanism for transgenerational plasticity. Before inheritance of methylation patterns can be characterized we need a better understanding of how environmental change modifies the parental epigenome. To examine the influence of experimental ocean acidification on Eastern oyster (Crassostrea virginica) gonad tissue, oysters were exposed to control (400 µatm) or high (2800 µatm) pCO2 conditions for four weeks. DNA from reproductive tissue was isolated from five oysters per treatment, then subjected to bisulfite treatment and DNA sequencing. Over 400 differentially methylated loci were identified primarily overlapping with gene bodies. A majority of these loci were in exons (93%). with little intron overlap (18%). The predicted function of genes containing differentially methylated loci location suggests a role for DNA methylation in acclimating to adverse conditions. Understanding how experimental ocean acidification conditions modify the oyster epigenome, and if these modifications are inherited, will allow for a better understanding of how ecosystems will response to environmental change.

ACCELERATING OCEAN CHANGE IN THE PNW: NEW RESEARCH, AND NEW POLICY TOOLS TO PROTECT HEALTHY WATERS

**WARREN*[1], Brad, Richard FEELY[2]**

**[1]Global Ocean Health**

**[2]Pacific Marine Environmental Laboratory**

New research indicates that Puget Sound is likely to get hit with accelerated acidification conditions, as the ocean burns through its buffering carbonates. Dr Richard Feely will present the problem, while Brad Warren will focus on policy tools that allow us to fight back to protect Pacific Northwest waters. In particular, Warren will discuss the potential for a carbon policy to provide new funding for shellfish aquaculture, ocean acidification research, and other carbon pollution reduction efforts. In a classic problem-solution format, they will work together to prepare the audience for what is to come.

AQUACULTURE BY DESIGN: ASSESSING ECOSYSTEM SERVICES OF RESTORATIVE AQUACULTURE

**WATERS*, Tiffany**

**The Nature Conservancy**

Shellfish and seaweed are nature's water purification systems - they clean and filter estuaries and bays and provide vital fish habitat. Yet, these species and the services they provide are fast disappearing due to a multitude of stressors. By farming shellfish and seaweed in the right way, we believe that we can leverage the potential of commercial aquaculture to provide a triple-bottom-line win: helping restore coastal ecosystems, while providing food and jobs.

The Nature Conservancy is collaborating with industry, government and academia to develop the science of aquaculture's ecosystem services and maximize the ecological benefits of shellfish and seaweed farms. We have Restorative Aquaculture by Design projects in Washington, California, Virginia, Belize, Indonesia, Australia, and Hong Kong. Our focus on restorative aquaculture compliments the more than 200 marine restoration projects we've invested in over the last two decades.

TEMPERATURE EFFECTS ON THE BIOENERGETICS OF DUNGENESS AND GRACEFUL CRABS

**WORKMAN*[1], G., S. MCDONALD[1], K. Holsman[2], D. ARMSTRONG[1]**

**[1]University of Washington**

**[2]NOAA Resource Ecology and Ecosystem Modeling Program**

Dungeness crabs (Cancer [Metacarcinus] magister) hold commercial and cultural value in Washington State, yet little is known about the effects of climate change on their population--even less is known about their competitor, the graceful crab (C. [M.] gracilis). To investigate the effects of temperature and size on feeding rate, we conducted consumption experiments in aquaria at multiple temperatures and across a range of sizes of Dungeness and graceful crabs. We investigated their weight-specific feeding rates, ingestion loss, and egestion via a mass balance bioenergetic equation from the Wisconsin bioenergetics model. We measured the ingestion loss and egestion components by collecting unconsumed food material and fecal material, respectively. This multi-species comparison evaluates size and temperature-dependent feeding patterns that have implications for future spatial distributions and energy requirements of Dungeness and graceful crabs across Puget Sound. Future management of the fishery and ecological impacts under changing conditions are discussed.

CAN NATURAL SCENTS CONTROL PREDATOR BEHAVIOR BY THE EUROPEAN GREEN CRAB? (SEX PHEROMONES, FEEDING CUES AND DETERRENTS)

**YAMADA*[2], Sylvia B., Jörg D. HARDEGE[1], Nichola FLETCHER[1], John TERSCHAK[1], Bree YEDNOCK[3], Angela DOROFF[3]**

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European green crabs (Carcinus maenas) are aggressive invaders that have resulted in significant impacts to native species, shellfish culture and valuable eelgrass habitat. Their continual persistence on the west coast of North America, and their recent upsurge in numbers, stresses the need to develop effective control tools before this invader builds up its population and measurably impacts native communities and shellfish growing areas. Sex pheromones, and related behavior-altering natural chemical signals, hold great promise as such tools. These

powerful, species-specific attractants are used routinely for monitoring and controlling out breaks of insect pests, such as gypsy moths and Mediterranean fruit flies, and also may prove effective in lamprey control.
We "baited" Fukui traps with female and male sex pheromones and molting pheromone, using no-scent gels and tuna red meat as controls. Despite the low pH in our study site, early results look promising. We will report on our preliminary trials using pheromones as well as those using synthetic feeding cues and a deterrent.

## THE ROLE OF OPEN OCEAN CONDITIONS ON THE RANGE EXPANSION AND ABUNDANCE OF THE INVASIVE EUROPEAN GREEN CRAB

**YAMADA*[1], Sylvia B., Richard E. THOMSON[2], Graham E. GILLESPIE[3], Tammy C. NORGARD[3]**
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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 (1993), Oregon (1996), Washington coastal estuaries (1998), and to the west coast of British Columbia (1998) in winter. Range expansions through larval transport to the Central B.C. coast occurred in 2009 and into the Washington Salish Sea in 2015 and 2016.
Both the range expansion of green crabs and their abundance in Oregon estuaries are strongly linked to ocean indices during their larval development. Green crab year class strength in Oregon can be predicted from (1) strong northward flow of coastal waters during winter, (2) relatively warm winters (sea surface temperature >10°C), which enable larvae to complete their development in the near-shore, 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. Green crabs are especially successful following major El.Niños. The strongest year classes and 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 Washington Salish Sea.