ABSTRACTS

69th Annual Pacific Coast Shellfish Growers/ National Shellfisheries Association Pacific Coast Section Conference and Tradeshow

Hood River, OR, September 22 – 24, 2015

MATERIAL NEEDS FOR HABITAT PROJECTS IN PUGET SOUND

Brian L. ALLEN. Puget Sound Restoration Fund, Bainbridge Island, WA 98110

Oyster habitat restoration has for a decade involved the shell enrichment of tidelands for larval settlement and stock rebuilding. Currently, the use of relict Crassostrea gigas shell is the standard material of habitat enrichment. Shell from other sources or species is unavailable in the volumes needed for habitat projects. This is also true for Ostrea lurida, the target species.

Practical and ecological considerations have us interested in minimizing the volumes in applications of shell. We continue to investigate the relationship between oyster metrics and habitat in order to make the best use of the limited shell resource. We are nearly halfway through our goal of restoring 100 acres of native oyster bed habitat in Puget Sound…….but we will need the help of the shell-producing oyster farms in Washington State if we are to succeed. The presentation will address where we've been on shell enrichment for native oyster restoration, what we are learning, and some ideas on how we can source project materials. We look forward to an open discussion and welcome feedback from shucker-packers and oyster growers.

Aggregating farmers, restaurants and consumers of oysters and seafood into one marketplace via a new mobile app.

Sam Asher

-As a farmer, you want your oysters to grow in popularity and land in more restaurants

Pearl helps customers find out what they like at restaurants across the country

-If a customer has a preference of a certain oyster, they can demand availability

-Create transparency and educate customers about your oyster brand or farm

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PRELIMINARY RESULTS OF A 40 YEAR ANALYSIS ON NATIVE CLAM POPULATION VARIABILITY IN THE SALISH SEA

Julie S. BARBER*, James McARDLE, Tiffany HOYOPATUBBI

Swinomish Indian Tribal Community, Fisheries Department

Camille SPECK, Doug ROGERS

Washington Department of Fish and Wildlife

Long-term biological datasets can provide valuable insight to managers of commercially and recreationally-important species. Analyses of these decadal data contribute to our understanding of the ecology of various species as well as

how population fluctuations may be driven by environmental change and/or management of resources. While bivalve populations have been well-studied in select ecosystems, native veneroid clam population variability has not been extensively researched in the northeast Pacific Ocean despite the ecological, economical, and cultural value of these species. The Washington Department of Fish and Wildlife has been collecting intertidal clam data following similar methods since the 1970s in order to manage, and now co-manage with tribes, clam harvesting activities. This rich dataset, along with datasets from tribal co-managers, can be utilized to quantify decadal trends in population variability among select clam species within the southern Salish Sea. For the initial phase of a large-scale analysis we asked two questions: (1) do clam populations vary temporally by beach and species and (2) do the patterns described in the first analysis vary by bivalve management region? Results will be discussed from analyses for Saxidomus gigantea (butter clam) and Leukoma staminea (native littleneck clam) from at least four separate beaches located within different bivalve management regions.

De novo characterization of a pinto abalone (Haliotis kamtschatkana) transcriptome and gene expression analysis upon exposure to a disease stressor.

Bennett*, Sean (UW SAFS); Crosson, Lisa (UW SAFS), Langevin, Stanley (UW SoM), Friedman, Carolyn (UW SAFS)

The pinto abalone, Haliotis kamtschatkana, is a marine vetigastropod native to the Pacific Northwest that is currently listed as a Species of Concern by NOAA. Overfishing, poaching, and poor environmental conditions have led to a 90% population decline in the Salish Sea. Pinto abalones are considered non-model organisms with little genomic information currently available. Here, we propose the first comprehensive transcriptomic sequence characterization of adult pinto abalone and more specifically, look at the effects of a disease stressor (withering syndrome) on abalone gene expression over the course of a six-month challenge. Characterizing and comparing genes involved in the general stress response of pinto abalone will improve understanding of molecular mechanisms associated with the effects of disease in pinto abalone as well as other species of abalone. Results from this study can also provide meaningful insights into the physiological pathways responsible for withering syndrome disease progression and have profound implications for successful restoration of pinto abalone and other affected abalone species.

ADDITIONAL ANALYSES OF BENTHIC INVERTEBRATE DATA FROM 11 STUDIES RELATED TO APPLICATIONS OF IMIDACLOPRID TO CONTROL BURROWING SHRIMP IN WILLAPA BAY

Steve Booth

Andy Suhrbier

Kim Patten

In response to Washington State's requirements to describe the Sediment Impact Zone related to applications of imidacloprid in Willapa Bay to control burrowing shrimp, 11 separate studies were conducted among 5 growing areas and 3 growing seasons, and featured two formulations of imidacloprid. Results have previously been analyzed separately according to the WAC Sediment Rule, which defines an impact as a decline of >50% in the abundance or richness of the polychaetes, crustaceans or mollusks at a post treatment compared to a pre-treatment interval (six endpoints). The analysis for impact was often complicated by pre-treatment inequivalences and data that did not fit a normal distribution, causing additional analyses and complicating interpretation. Here, we present additional alternative analyses that are more commonly used in studies of community ecology. These include multidimensional analysis, analysis of variance, or classification analysis to further describe differences among species of benthic invertebrates in the treated and untreated plots. A meta-analysis featuring data from all years may also be presented. These analyses were funded by WDFW and in collaboration and consultation with WSU. The primary objective of the current project is to publish an article in a peer reviewed journal. The article will be a comprehensive, yet concise assessment of studies conducted in 2011, 2012, 2014, and possibly 2010. The article would include assessments of efficacy against burrowing shrimp using data collected by WSU, the fate and transport of imidacloprid in the water and sediments using data collected by UW, and the impact on benthic and epi-benthic invertebrates using data collected by PSI.

Regulatory Framework (Federal, State, and Local Permitting)

Amanda M. Carr*

Federal, state, and local governments regulate shellfish farming activities under a broad suite of laws including the Clean Water Act, Endangered Species Act, Magnuson-Stevens Act, National Environmental Policy Act, Shoreline Management Act, and State Environmental Policy Act. These laws and their accompanying regulations establish different standards and frameworks to ensure the protection of environmental resources, functions, and values. Federal, state, and local agencies have reviewed interactions between shellfish farming and native eelgrass (Zostera marina) under their respective regulatory authorities and have arrived at a range of conclusions as to how to regulate these interactions. This presentation discusses the legal frameworks governing the evaluation and regulation of

interactions between shellfish farming and native eelgrass, summarizes outcomes of those regulatory processes to date, and proposes future approaches to regulatory review and scientific research.

PLASTIC DEBRIS IN THE MARINE ENVIRONMENT: HOW MUCH IS OUT THERE, WHY IT MATTERS, AND WHAT CAN BE DONE ABOUT IT

Henry Carson*

Plastic debris in the marine environment presents risks of wildlife ingestion and entanglement, impacts from leached or adsorbed chemicals, transport of species to new environments, and physical changes to sediments. International research has found that plastic, from large drifting debris down to nanoparticles inside animal cells, is ubiquitous around the globe. Media attention to this issue has focused on unrealistic schemes to cleanup plastic already at sea, while ignoring practical solutions that can prevent plastic from entering the marine environment in the first place. I'll discuss research conducted in the middle of the "Great Pacific Garbage Patch", present a global estimate of floating plastic debris, and discuss potential solutions to this growing problem.

HEALTH RISKS AND GASTRONOMIC REWARDS OF OYSTER CONSUMPTION IN WASHINGTON STATE: THE RAW FACTS

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Raw oyster consumption patterns and trends in western Washington are assessed to inform a diverse set of stakeholders on issues such as foodborne illness risk assessment and efficient product production and distribution. With insight from local restaurateurs, oyster farmers, and public health authorities, a raw oyster consumption survey was created and distributed at Seattle-area restaurants, seafood retailers, relevant social media outlets and email threads. Average raw oyster serving size – a missing data point to update and regionalize illness risk assessment models – was calculated along with consumption frequency, oyster size and brand preference, demographic information, and other relevant statistics to describe current raw oyster consumption trends. A typical raw oyster consumer in western Washington is in his or her early forties, eats six oysters per sitting but does so only once every two months, and favors freshness and locality over price. Nearly one of every four survey participants was a tourist, and those visiting Washington ate an additional oyster per sitting (seven oysters compared to six for locals). The

Washington Department of Health can use these new data to inform risk-per-serving illness assessments that aim to regionalize and contextualize national concerns of Vibrio parahaemolyticus-associated illnesses. Experienced Washington oyster growers and restaurateurs were unsurprised by most of the survey's findings but felt the results could provide important context for new raw oyster purveyors. Lastly this study offers a fresh perspective on seafood consumption data collection specific to the fine-dining sector and creates a blueprint for future survey-based research at privately owned restaurants.

STATUS AND TRENDS OF EELGRASS (Zostera marina) IN GREATER PUGET SOUND

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Pete DOWTY, Washington State Department of Natural Resources

Lisa FERRIER, Washington State Department of Natural Resources

Jeff GAECKLE, Washington State Department of Natural Resources

Helen BERRY, Washington State Department of Natural Resources

Seagrass beds are an important component of the nearshore ecosystem in Puget Sound. They provide habitat for a wide range of organisms, improve water quality, sequester carbon, and may be able to dampen effects of ocean acidification. Because seagrass beds are sensitive to a wide range of anthropogenic stressors, they are also a good indicator of habitat condition. The Washington State Department of Natural Resources (DNR) uses underwater videography to monitor status and trends of native seagrass species (Zostera marina and Phyllospadix spp.) in greater Puget Sound. Since the start of the monitoring program in 2000, the total area covered by native seagrass species has remained relatively stable (approximately 22,000 ha). However, some sites have shown long-term declines in native seagrass area. These declines are either the result of localized anthropogenic activities or broader climatic influences, and need to be further investigated to identify specific drivers. There are signs that seagrass conditions improved in recent years. Some sites in Hood Canal that were previously declining have stabilized between 2010 and 2014. At the Skokomish and Nisqually River deltas, notable increases in seagrass area were observed following removal of dikes and other restoration activities. A better understanding of the distribution of native seagrass beds and the mechanisms behind the observed changes may lead to better conservation strategies and improved designs of future restoration projects.

SURF TO TURF MUSSEL COMPOST: RECYCLING NUTRIENTS FROM BUDD INLET- AN UPDATE

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The current project expands on previous work conducted in 2011 and 2013 that demonstrated the potential of the blue mussel (Mytilus trossulus) to extract nutrients (primarily nitrogen and phosphorus) from Puget Sound waters, thus slowing the process of eutrophication. Resulting benefits may include increased light penetration, improved dissolved oxygen levels and decreased number and intensity of harmful algal bloom events.

In 2013, over 4000 pounds of mussels were harvested from pilot sites in Budd Inlet removing at least 40 pounds of nitrogen and 3 pounds of phosphorus. Harvested mussels were turned into rich, organic compost that performed well in vegetative growth trials and tested low for contaminants. This project builds on previous trials while also taking a closer look at water quality parameters, particularly dissolved oxygen, surrounding and below mussel installations. Results will be presented that measure chlorophyll, phytoplankton cell counts, nitrogen and carbon levels in water flowing through the mussel installation; and the biodeposition of feces and pseudofeces below straps using sediment traps. Stable isotope analysis of harvested mussels will be conducted to identify the contribution of marine vs. terrestrial sources of N and C.

Geographic distribution & quantification of abalone withering syndrome from wild and farmed populations along the California coast.

Lisa M. CROSSON*, Glenn R. VANBLARICOM, Samuel J. WHITE & Carolyn S. FRIEDMAN

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Wild black abalone populations and red abalone farms along the California coast and Channel Islands were surveyed in the summers of 2010, 2011 and 2013 for the presence of withering syndrome (WS-RLO). Seawater samples were collected from each wild site (n=8) and nearshore at 0, 100 and 500 m above and below abalone farm outfalls (n=5). Water samples were filtered and preserved for subsequent DNA extractions and quantitative PCR analyses. To date, wild seawater samples from Big Sur to San Diego, CA, including San Nicolas Island, tested positive for the presence of WS-RLO DNA ranging from 10 to 1,000 copies per liter. Effluent from abalone farms also tested positive for WS-RLO DNA and ranged from 1,000 to 100,000 copies per liter directly adjacent to outflows. Some farms release large volumes of seawater per day (~6 million gallons) suggesting a high potential for some facilities to act as point sources of the pathogen to nearby wild abalone populations as well as serving as sources of WS-RLO for the farms

themselves. While this presents concern, it is important to note DNA-based assays do not detect viable pathogen or infection and serve only as a proxy for exposure. There was also a strong dilution factor as WS-RLO DNA copy numbers dropped substantially at 100 and 500 m away from farm outflows. Additional experiments including deployment of sentinel abalone at wild and farm sites to assess transmission dynamics and determination of WS-RLO viability in seawater are currently underway.

HABITAT SUITABILITY MODELING OF FISHERIES TARGETED BAY CLAMS IN TILLAMOOK BAY AND NETARTS BAY, OREGON

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Estuarine habitats, which are heterogeneous and can differ greatly from bay to bay, are utilized by shellfish during many stages of their life history. These habitats are also becoming increasingly more important for the management of shellfisheries. The Shellfish and Estuarine Assessment of Coastal Oregon project conducted extensive surveys of bay clam populations and estuarine habitats in two Oregon estuaries that differ in size, geomorphology, and distribution of abiotic and biotic features. The purpose of this analysis is to evaluate clam-habitat associations and identify predictors of clam distribution for four recreationally and commercially targeted bay clams: butter clams (Saxidomus gigantea); cockles (Clinocardium nuttallii); gaper clams (Tresus capax/nuttallii); and littleneck clams (Leukoma staminea). We used non-parametric multidimensional scaling (NMS) and non-parametric multiplicative regression (NPMR) to predict the distribution of bay clams. NPMR is a flexible method for predictive habitat modeling that does not make assumptions about the topology of species responses to ecological factors, can incorporate many predictors (i.e. ecological factors), accounts for multiplicative interactions among factors, and can be cross-validated. The best fitting models identified specific variables that predicted clam density, biomass, and presence within and among estuaries. Bay clams are managed as a unit in Oregon and these results will inform management decisions and policy development pertaining to harvest, critical habitats, and land development.

PROSPECTS FOR PURPLE-HINGE ROCK SCALLOP CULTIVATION ON THE US WEST COAST: WASHNGTON STATE STUDIES ON AQUACULTURE POTENTIAL

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Renewed interest in the aquaculture potential of purple-hinge rock scallops (Crassadoma gigantea) has occurred on the US West coast. Due to their relatively rapid growth and hardiness in cultivation, rock scallops may well be highly suited for growout in a variety of locations from Alaska to southern California. A major objective of an ongoing Western Regional Aquaculture Center (WRAC) project is to evaluate the specific constraints and opportunities associated with the development of an industry sector based on suspended culture of rock scallops. Because this scallop has a cementation phase of growth that is initiated about one year post set (e.g. 30mm shell length), the means to culture scallops efficiently in commercial quantities must be developed.

Experimental tray-based studies in suspended culture are planned in multiple Puget Sound sites to evaluate a growout method based on enabling partial cementation of scallops that will assist in scallops establishing position within the tray and greatly improve product quality at harvest (110mm).

Also, little information is available on the rate of growth (size at age), survivorship or reproductive development in scallops grown out in different Washington state locations. These critical life history parameters are being simultaneously evaluated in scallops grown in suspended culture in eight (8) locations in Washington State. Sites including Hood Canal (3), Straits of Juan de Fuca (1), North Sound (1), main basin Puget Sound (2) and south Puget Sound (1). Preliminary results of these studies will be discussed along with opportunities for increased participation by interested growers in evaluating the potential for rock scallop aquaculture in the region.

USING LARGE SCALE SEAWEED CULTURE AS A MEANS TO IMPROVE CARBONATE CHEMISTRY FOR SENSITIVE MARINE ORGANISMS AND PRODUCE MATERIAL FOR FOOD, FEED AND FUELS

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Betsy PEABODY, Puget Sound Restoration Fund, Bainbridge Island, WA

Changes in carbonate seawater chemistry due to ocean acidification are impacting a large suite of marine organisms in ways that are increasingly worrisome to biologists and the general public worldwide. Yet very few means have been suggested to actually combat increased dissolved carbon dioxide in seawater, the changes this induces in carbonate chemistry overall and subsequent impacts to marine organisms. One means of potentially mitigating the effects of OA in appropriate locations involves growing large quantities of seaweeds (e.g. kelps and other macroalgae) in places that also serve as nurseries for marine organisms. Methods for cultivating brown and red

seaweeds are well established but the potential for growing seaweeds specifically to assist in improving water quality for sensitive marine invertebrates has not been evaluated. The Puget Sound Restoration Fund with funding from the Paul Allen Family Foundation and in close collaboration with scientists from the Pacific Marine Environmental Laboratory, the University of Washington and private sector is embarking on up to a four-year project to evaluate whether growing seaweed at high density can assist in improving water quality for marine pteropods and other marine invertebrates. The project based in north Hood Canal will specifically evaluate and model the upstream/downstream effects of seaweeds on the carbonate chemistry of seawater passing through a one hectare in area array of sugar and bull kelps. In addition to providing habitat, cultivating seaweeds has high potential high value as food, and substrates for a variety of commercial products. Removal of kelps can also assist in drawing down nutrients and carbon from marine systems and contribute to reducing base conditions for OA impacts. This project including the development of a downstream product stream based on the harvest of cultivated seaweeds in Washington state will be discussed within the overall context of developing better means to control and adapt to changing ocean conditions.

SEEING THE MEADOW FOR THE BLADES – A SHELLFISH GROWERS OBSERVATIONS

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Eelgrass researchers, resource managers and policy makers often focus so intently on counting turions in a patch that they fail to see the proverbial forest for the trees or in the case of eelgrass, meadow for the blades. The proverb means that you can't see the whole situation clearly because you're looking too closely at small details (e.g. "If you plant oysters here, how many eelgrass blades will be lost?"). Nobody disputes the value of eelgrass and all of the ecological functions it provides but the picture is more complex than just blades of eelgrass. It is typical and appropriate to count turions to assess impacts from marine construction projects that eliminate eelgrass and to require mitigation. Shellfish aquaculture on the other hand typically does not eliminate eelgrass. Densities of eelgrass may be reduced or fluctuate with perturbations associated with culture activities. Often times due to the ecosystem services provided by shellfish crops and gear eelgrass is enhanced or becomes established where it hasn't been before. Typically within culture areas there are mosaics of eelgrass and shellfish at varying densities. Strictly speaking the eelgrass/shellfish mosaics or habitat created by the shellfish crops and gear may differ from eelgrass meadows in function. However, thirty plus years of anecdotal observation working in these habitats suggests they are vibrant diverse, healthy functioning ecosystems that don't get the credit they deserve from resource managers and policy makers. More research is needed to validate these anecdotal observations.

2015 OLYMPIA OYSTER, Ostrea lurida, BROODING RESULTS FROM NORTHERN PUGET SOUND

JACKIE DEXTER*, Sarah GROSSMAN+, Courtney M. GREINER, Julie S. BARBER, and James McARDLE

Swinomish Indian Tribal Community, Fisheries Department

+ Swinomish Indian Tribal Community, Department of Environmental Protection

POSTER PRESENTATION

The Swinomish Indian Tribal Community (SITC) recently began a long-term restoration project to establish, expand, and research Olympia oyster, Ostrea lurida, populations on reservation tidelands. These tidelands were identified by the Washington Department of Fish and Wildlife as a priority restoration site due to the high probability that historic native oyster reefs in the area once functioned as a source population while concurrently providing ecosystem services to the surrounding environment. For our pilot project, we evenly distributed seeded cultch in two pocket estuaries in Similk and northern Skagit Bays during the summer of 2012 and spring of 2013. Since oyster survival and growth was favorable over the following years, we initiated a long-term monitoring program that included measuring reproductive benchmarks to determine population expansion potential. While brooding data have been collected at one other site in northern Puget Sound (i.e. Fidalgo Bay), it is likely that oysters in pocket estuaries will be exposed to different environmental conditions than the Fidalgo Bay oysters. Our goal was to quantify the timing and water temperature for peak brooding of oysters in pocket estuaries. Brooding status was recorded from May to early September 2015 by site and oyster age. We also continuously logged water temperature at each of the two restoration sites. Results will compare our data with Fidalgo Bay data and can be used to inform managers of the optimal time for restoration site expansion.

WHERE DID ALL THE LITTLE THINGS GO? A CLOSER EXAMINATION OF BURROWING SHRIMP RECRUITMENT TO COASTAL ESTUARIES

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BOSLEY, Katelyn M, Dept of Fish and Wildlife, Oregon State University

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Two species of burrowing shrimp, Neotrypaea californiensis and Upogebia pugettensis are important members of intertidal mudflat communities in Pacific Northwest coastal estuaries but cause significant problems for shellfish culture. We have monitored populations of these shrimp in Willapa Bay, Washington for two decades and in several other estuaries since 2005. Densities of both shrimp species were either increasing or stable through the mid 1990's in Willapa Bay and then began to decline. U. pugettensis are now almost absent in Willapa Bay and many other estuaries along the West Coast, due in part to the introduced parasitic isopod, Orthione griffenis which compromises

reproduction. Recent surveys of N. californiensis populations however, suggest that they too declined substantially. Since both shrimp have pelagic larval stages which develop in the coastal ocean, we asked whether inter-annual fluctuations in larval survival and estuary recruitment influenced adult shrimp populations within and outside of shellfish aquaculture beds. Relatively high recruitment for both species was observed in Willapa Bay through the mid 1990's, but a period of about 10 years lapsed with very low recruitment. This loosely correlates with the decline in adult densities in that estuary. We also found relationships between recruitment and nearshore coastal transport and recruitment with the population of older shrimp present in an estuary. A substantial ghost shrimp recruitment event to Yaquina Bay, Oregon in 2010 and repeated though slightly lower recruitment to Willapa Bay from 2011- 2013 resulted in recent population increases in these estuaries, and we are tracking survival and growth of these shrimp.

SHELLFISH AQUACULTURE AND SEAGRASS SEASCAPES IN COASTAL ESTUARIES

Brett R. DUMBAULD*, Erin R. GRAHAM, and Lee M. MCCOY

Both seagrasses and bivalve shellfish provide valuable ecosystem services including estuarine nursery habitat. Seagrasses are protected by no-net-loss provisions in U.S.federal and state regulations resulting in a precautionary approach by managers that avoids any direct impacts from development activity, including shellfish aquaculture. Recent research suggests that oyster aquaculture has direct impacts to the native seagrass (eelgrass, Zostera marina) in U.S. West Coast estuaries over small spatial and short temporal scales. We quantified the impacts of oyster aquaculture on Z. marina at the larger estuarine landscape scale in Willapa Bay, Washington and examined the potential effects of sea level rise (SLR) on eelgrass and aquaculture in this estuary. We used a comparative modeling approach to first examine the distribution of eelgrass inside and outside of oyster aquaculture beds. Then, we developed a predictive model to estimate changes in eelgrass distribution for the years 2030, 2050 and 2100 under conservative and high rates of SLR. Our first model indicated that current eelgrass coverage on oyster aquaculture beds was less than the amount predicted by the model, suggesting a loss of eelgrass in aquaculture beds. When quantified on a landscape scale however, the impact of oyster aquaculture represented less than 1.5% of the total predicted amount of Z. marina in Willapa Bay. Our SLR model predicted increased Z. marina coverage across the tidal flat for all scenarios and years, resulting in as much as 36% more eelgrass in Willapa Bay by 2100 and a net increase of as much as 41% within aquaculture beds. Eelgrass as estuarine habitat is thus resilient to oyster aquaculture as a disturbance at the landscape scale in this estuary and is likely to increase significantly across the bay as SLR continues. Both of these findings have important implications for shellfish growers and habitat managers.

SHELLFISH HEALTH MANAGEMENT AND PROBIOTIC APPLICATION

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An update on shellfish health and disease status on the west coast of North America and Hawaii will be presented. Perkinsus marinus and P. olseni are reportable bivalve mollusk diseases not present on the west coast of the United States. Particular states enjoy freedom from additional shellfish diseases. Maintenance of disease freedom status increases the potential for export and decreases the losses to and cost of management of edible shellfish. Interstate movement of shellfish to receiving waters requires a permit from the receiving state, provincial or national jurisdiction. To address both the interstate movement of shellfish and export, a voluntary Shellfish High Health Program was developed in 2000 for seed producers and exporters.

Since 2007, we have field tested a mixture of beneficial or probiotic bacteria in shellfish hatcheries. These tests were based on initial small scale testing of three probiotic bacteria, which were highly beneficial for increasing survival of Pacific oyster larvae. The field testing has included an expanded collection of probiotic bacteria, customized to the site location and sourced from nearby areas. The result of using the probiotic mixtures has been uniformly reported as beneficial by commercial hatchery operators. Issues in regard to obtaining and reporting data from commercial scale hatcheries will be discussed.

EFFECTS OF OCEAN ACIDIFICATION AND HYPOXIA ON THE OLYMPIA OYSTER, Ostrea lurida

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The Olympia oyster, Ostrea lurida, is a priority species for native species restoration due to marked population declines in coastal and many inland marine waters along the eastern North Pacific Ocean. Ocean acidification is a growing concern globally and has been demonstrated to be locally exacerbated by local drivers such as terrestrial run-off and near shore biological and physical processes. Seawater pH as low as 7.3 has been recorded in Washington's inland marine waters. Low pH associated with high seawater CO2 often coincides with reduced dissolved oxygen (DO). Restoration of this species requires their ability to survive and successfully reproduce under

natural and often changing conditions. We examined the influence of varying pCO2 and DO levels on adult O. lurida reproductive physiology and larval performance.

Adult Olympia oyster fecundity was reduced and larval releases delayed by increased pCO2. Larvae were resilient to elevated pCO2 except under two scenarios: 1) Progeny of parents matured and larvae brooded at low CO2 died when larvae were exposed to high CO2 under fully oxygenated seawater, which had been hypothesized to be moderately stressful but tolerated conditions. 2) Progeny of parents matured and larvae brooded at high CO2 died when larvae were exposed to high CO2 under hypoxic seawater, which were hypothesized as worst conditions. Larvae under all scenarios had fully calcified shells and lacked any erosion. These observations suggest the potential for trade-offs for Olympia oysters to survive ocean acidification.

DETECTING OCEAN ACIDIFICATION FROM STABLE ISOTOPE RECORDS OF SCALLOP SHELLS

Yongwen Gao, John Morgan, and Jennifer McKay

The use of stable carbon and oxygen isotopic compositions (d13C and d18O) of bivalve shells has received growing attention in detecting ocean acidification. Bivalve shells are composed of calcium carbonate (CaCO3), and exist in polymorphism as aragonite and calcite. Although polymorphs have identical chemical composition, they have differences such as in bioavailability, stability, and physical structure. When the anthropogenic CO2 sinks into ocean, it will produce HCO3- and CO32- and this affects the carbonate saturation state (Ω). The process can be detected from carbon sources and the isotopic fractionation of d13C between blood DIC (dissolved inorganic carbon) and the shell. In this study, we review the theory and practice of using stable isotopic tools in detecting ocean acidification, and report research examples of using sea scallop shells from the Qualicum Beach of the Vancouver Island, British Columbia, Canada. The life-time d18O values from one scallop shell showed four peaks and valleys continuously, indicating about 4-yr life history of growth. The life-time d13C values of the sea scallop, in contrast, showed a stable decrease from about +1 to -0.5‰. The d13C decrease was also consistent with the pH and dissolved oxygen variations over the scallop growth period. Overall these results suggest that shell carbonate are good proxies for reconstructing the life history and the environmental changes that the animal experienced (mainly from d18O); and the isotopic data of scallop shells have the potential to examine the effects of ocean acidification (mainly from d13C) in the past.

GENETIC VARIATION IN EARLY- AND LATE-STAGE LARVAL PERFORMANCE UNDER OCEAN ACIDIFICATION IN HYBRID LINES OF THE PACIFIC OYSTER, Crassostrea gigas

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Molly JACKSON, Taylor Shellfish, Inc.

Steven ROBERTS, School of Aquatic & Fishery Sciences, University of Washington

Brett DUMBAULD, USDA-ARS, Hatfield Marine Science Center, Oregon State University

Carolyn S. FRIEDMAN, School of Aquatic & Fishery Sciences, University of Washington

Repeated losses of Pacific oyster (Crassostrea gigas) larvae and juveniles in hatcheries over the past decade have been linked to ocean acidification (OA), namely reduced seawater saturation state of aragonite (ΩA) concomitant with high pCO2/low pH conditions. Larvae appear most sensitive to OA during bottleneck stages of initial shell formation during embryogenesis, and later during settlement and metamorphosis. Projected increases in the severity and duration of OA events point to a growing need for oyster broodstock that are better adapted to these conditions. Crossbreeding of inbred parental lines of C. gigas has been shown to dramatically improve yield in hybrid offspring through growth heterosis, with certain reciprocal hybrids exhibiting superior yield. We sought to extend this approach to identify intraspecific hybrid lines, or their reciprocals, that demonstrate high performance under OA conditions. A total of forty-two hybrid families were generated in a 7x7 diallel cross between pair-mated, inbred C. gigas broodstock. Replicate groups of embryos from each cross were then "hatched" under high (1600 µatm/ΩA = 0.95) and low (380 µatm/ΩA = 2.93) pCO2, and screened for survival and successful calcification after 36 hours. Sibling larvae from all crosses were reared under common low pCO2 conditions until competent to settle, upon which replicate groups were set and allowed to metamorphose under similar high and low pCO2/ ΩAr treatments. At one week post-settlement, all crosses were sampled for survivorship and growth, and for gene expression to identify potential physiological processes underlying observed differences between crosses and treatments. Here we will report on preliminary results from this study, which will inform the development of a selective breeding program for enhanced OA tolerance.

TRANSGENERATIONAL EFFECTS OF OCEAN ACIDIFICATION ON THE PACIFIC OYSTER, Crassostrea gigas

Daniel GILLON*, School of Aquatic & Fishery Sciences, University of Washington

Jonathan DAVIS, Baywater, Inc.

Brett DUMBAULD, USDA-ARS, Hatfield Marine Science Center, Oregon State University

Dacey MERCER, Center for Genome Research & Biocomputing, Oregon State University

Benoit EUDELINE, Taylor Shellfish, Inc.

Carolyn S. FRIEDMAN, School of Aquatic & Fishery Sciences, University of Washington

Ocean acidification (OA) is projected to negatively impact a wide range of marine species and ecosystems, with major implications for coastal economies and shellfish aquaculture in the Northeast Pacific. Recent evidence, however, suggests that shellfish may be capable of acclimating or adapting to adverse changes in seawater carbonate chemistry through transgenerational carryover effects of exposure to OA, or through selection. In a prior experiment conducted by our lab group, replicate pedigreed lines of Pacific oyster (Crassostrea gigas) broodstock (G0) and their offspring (G1) were exposed to high (H) or ambient (L) pCO2 during reproductive conditioning and larval rearing stages. Broodstock conditioned under high pCO2 produced offspring (G1) that, when reared under ambient pCO2 (treatment HL), displayed superior yield than did G1 larvae from all other parent/offspring treatment combinations, even at 9.5 months following deployment in the field. At 21 months post-fertilization, G1 oysters from 2 of 3 field sites were sampled for morphometrics and survival. Consistent with previous observations, yield remained highest in HL individuals, indicative of a sustained carryover effect of the G0 treatment. Interestingly, preliminary data suggest a difference in family representation between the highest and lowest performing G1 individuals with respect to total weight, hinting at a potential genetic contribution to variation in performance under OA conditions in tandem with epigenetic cues.

We hypothesized that (1) Variation in response to OA in the Pacific oyster (Crassostrea gigas) is heritable; and (2) Acclimation to OA may be mediated in the absence of selection. To test these hypotheses, a subset of males and females were randomly selected from genotyped G1 individuals within each of the HL and LL treatments, conditioned under ambient pCO2, then mated in a circular half-sib design. Replicate groups of larvae were then reared under elevated and ambient pCO2 through settlement, and transferred to common nursery conditions. We will report preliminary results from this study, aimed at addressing key gaps in our understanding of the ability of marine calcifiers to persist in an acidifying ocean.

Washington State's Partnership with Shellfish Growers to Protect Natural Resources during an Oil Spill

Max Gordon

The Washington Department of Ecology wants to partner with shellfish growers to protect natural resources in the event of a large oil spill. 2012 legislation prompted Ecology to create an online platform (oilspills101.wa.gov) to recruit Vessels Of Opportunity. The agency wishes to sign up boat owners who have local knowledge of sensitive marine areas so as to accelerate an oil spill response. Washington's coast has been divided into six regions for recruitment purposes: Strait of Juan de Fuca, San Juan Islands/North Puget Sound, South Puget Sound & Central Puget Sound,

Lower Columbia River, Admiralty Inlet/Hood Canal & North Central Puget Sound, and Grays Harbor. This presentation is tailored for those who have a stake in a rapid, aggressive, and well-coordinated response.

FILTRATION SERVICES OF THE NATIVE OLYMPIA OYSTER (Ostrea lurida) AND THE INTRODUCED PACIFIC OYSTER (Crassostrea gigas): IMPROVED RESOLUTION OF ECOSYSTEM SERVICES FROM PHYSIOLOGICAL AND OCEANOGRAPHIC STUDIES.

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Populations of the native Olympia oyster Ostrea lurida on the West Coast, USA, have declined since the arrival of early settlers and, in many estuaries, have been replaced by farmed populations of the non-native Pacific oyster Crassostrea gigas. It is not well understood what filtration services were lost with the extirpation of native oysters and what were recovered by the establishment of C. gigas populations. In this study, we describe results from laboratory and in situ experiments in which the feeding physiology of adult O. lurida was compared to that of C. gigas. Laboratory experiments determined species-specific responses of the clearance rates of O. lurida and C. gigas to differences in temperature, salinity, and turbidity. In situ studies determined clearance and deposition rates of these species during dry and wet seasons in Yaquina Bay, Oregon. We found in situ-based models were better predictors of oyster feeding behavior under variable natural conditions when compared with laboratory-based models that were derived from experiments with oysters held under a range of constant conditions. To improve upon previous models of oyster filtration services in Yaquina Bay, Oregon, we incorporated new estimates of residence times for this system that suggested much longer retentions than previously estimated, with considerable spatial and seasonal variation. Combining in situ feeding models and more highly resolved residence times for Yaquina Bay yields more accurate estimates of filtration services derived from the predicted filter feeding activity of O. lurida and C. gigas in this system.

Ghosts of Shrimp Past: Toxicity of Imidacloprid to Burrowing Shrimp in the Laboratory and Implications for Oyster Culture in Willapa Bay, Washinghton

Christian E. GRUE*, School of Aquatic and Fishery Sciences, University of Washington

Abstract to be submitted later

MARINE BIOTOXIN CLOSURES IN WASHINGTON STATE: HISTORICAL AND RECENT TRENDS

Adi HANEIN*. Washington Sea Grant, University of Washington, Seattle, WA, 98105 and Washington State Department of Health, Tumwater, WA, 98501.

Jerry Borchert. Washington State Department of Health, Tumwater, WA, 98501

The marine biotoxin program at the Washington State Department of Health (WDOH) has routinely collected and analyzed shellfish tissue samples for biotoxins across Washington waters since 1957. The goal of the program is to ensure that recreationally and commercially harvested molluscan shellfish is safe for human consumption. The WDOH has one of the largest sets of biotoxin data from shellfish tissue monitoring in the United States and analyzes over 3,000 shellfish samples each year. As of the end of 2014, the dataset contained over 100,000 entries with information on toxin levels for Paralytic Shellfish Poison (PSP), Amnesic Shellfish Poison (ASP or domoic acid) and Diarrhetic Shellfish Poison (DSP), various shellfish species, monitoring sites, waterbodies and collection dates. WDOH uses blue and California mussels (Mytilus edulis and californianus) as a sentinel species to monitor for biotoxins. We determined closure dates, frequency, and duration of closures for each county and waterbody using established regulatory limits. Mussel data was used to determine all closures, except on the Pacific Coast where razor clam data was used since there is no recreational harvest of molluscan shellfish on the Pacific Coast other than razor clams. By the end of 2014, biotoxins have impacted 90% of Washington waterbodies (n=105) and have closed areas from a minimum of 14 days to over 200 days. 65% of waterbodies are only impacted by PSP, roughly 20% are impacted by a combination of two biotoxins and only four waterbodies have been impacted by all three biotoxins. Closures have been seen recorded since 1958. Results also show that in several Local Health Jurisdictions (LHJ's), PSP closures are occurring earlier in the year. Longer closures have been associated with new and emerging biotoxins such as DSP and ASP. This analysis provides a better understanding of historical closures and trends allowing WDOH to manage waterbodies more effectively and guide future shellfish monitoring efforts in a changing environment.

AND WE'RE DOING THIS BECAUSE...?

Daniel HANSON*, Ekaterini HANSON, Dawn Hanson SMART

There are lots of reasons, but I think the most important, at least for me, is that my wife loves oysters…she can eat dozens…and, since I love my wife, I grow hand cultivated oysters for her half-shell consumption. Don't get me wrong, I love oysters too, but not nearly as much as my wife. Of course, we also try to sell a few of these beauties…and they are beautiful!! We don't make a lot of money from this part of it, but our non-commercial work keeps us connected to the local community in a way that is interesting and fun. We like the idea of having both personal and professional relationships with the chefs and operators of our local restaurants and markets.

Why else, I ask myself? To name just a few of the reasons ... It's good for the environment. We are growing a sustainable, healthy source of high quality protein. It's fun and we like doing it, at least most of the time. We only have to work when the tide is low enough…and it isn't THAT hard!!

And, to be honest, it gets me out of the house. Being retired comes with a lot of expectations and responsibilities…some that I can realize and some that I can't. I hope to talk about some of the reasons for taking on an enterprise like this, thoughts both serious and perhaps amusing, and share some of the resources that helped us along the way.

LESSONS LEARNED FROM THE FIRST YEAR OF IMPLEMENTING A PREVENTITIVE APPROACH TO Vibrio parahaemolyticus

Clara HARD*, Washington State Department of Health

The Washington State Department of Health (DOH) manages V. parahaemolyticus (Vp) using several strategies: regular environmental sampling during summer months, implementation of a Vp Control Plan for the commercial shellfish industry, and a health advisory for recreational harvesters. Over the past two years, DOH worked with an advisory group including industry, to revise the Vp Control Plan to make controls more preventative of illnesses rather than be reactionary. The revised rule was adopted by the Washington State Board of Health in March 2015 and implemented in May 2015. The presentation will include reflections on the initial implementation of and lessons learned from the new rule. A preliminary summary of Vp illnesses and temperature observations will be shared from multiple Washington growing areas during this past summer.

PERMITTING ASSISTANCE AND RECOMMENDATIONS FROM THE WA SIP TEAM

Laura HOBERECHT*

NOAA Fisheries

Perry LUND

WA Department of Ecology

The Shellfish Interagency Permitting (SIP) Team is a permitting coordination concept generated by NOAA's National and Washington State's Shellfish Initiatives (WSI) developed in 2011. The goal of permitting coordination is to make effective and efficient use of agency resources to facilitate timely delivery of quality decisions on shellfish aquaculture permit applications, while continuing to protect public health and the environment. In December 2011, the SIP Team was formed with participation from all governmental entities that have direct and indirect regulatory or oversight roles in the permitting and licensing of shellfish aquaculture. The SIP Team has met routinely since its inception, originally with monthly meetings in 2012, and with reduced frequency to quarterly meetings in 2013-15. The SIP Team has developed a suite of products to assist shellfish farm applicants in navigating the complex permitting process. These products may be considered as a model that, when followed as recommended, will lead to a more efficient process. The products will be described in detail to facilitate their use by the shellfish industry. Additionally, highlights from the Draft SIP Team Report on Phase I activities will be discussed. Finally, proposed SIP Team Phase II activities will be presented.

EELGRASS-SHELLFISH AQUACULTURE INTERACTIONS IN WEST COAST ESTUARIES: USING META-ANALYSIS TO QUANTIFY SOURCES OF VARIATION IN EFFECT SIZE

Letitia CONWAY-CRANOS* (NMFS Northwest Fisheries Science Center), Beth SANDERSON (NMFS Northwest Fisheries Science Center) , Laura HOBERECHT (NMFS West Coast Regional Office)

A key component of effectively managing shellfish aquaculture is understanding the direct and indirect consequences of shellfish aquaculture on nearshore ecosystems. Both seagrasses and shellfish have the potential to be highly productive ecosystem engineers in Pacific Northwest estuaries and may provide habitat for a suite of fish and invertebrate species. In many cases, shellfish aquaculture and eelgrass occur at similar tidal elevations and in similar environmental conditions, accentuating the need to understand the nature of the interaction between shellfish aquaculture and eelgrass in estuaries. Meta-analysis is a tool used to standardize results across different studies and compare them using a common metric of effect size. We have extensively searched the literature and compiled 14 studies on the west coast of the United States that experimentally investigated the effects of shellfish aquaculture on eelgrass and associated benthic invertebrate fauna. These studies take place across seven west coast estuaries

from Northern California to British Columbia. By calculating the relative effect size for each of the experiments within each study, we intend to address the following questions: 1) What is the overall impact of shellfish aquaculture practice on eelgrass? 2) What are the relative impacts of different aquaculture practices on eelgrass? And 3) Which eelgrass response metrics (e.g., growth, density, percent cover, biomass) are the most sensitive to shellfish aquaculture? This synthesis will help to clarify the range of eelgrass responses to shellfish aquaculture as well as provide insight into the potential mechanisms driving the observed variation.

Advancing ocean acidification research and actions in Washington State and on the West Coast

HOROWITZ, Julie, Washington State Governor's Office

Ocean acidification has already disrupted West Coast ocean chemistry in unprecedented ways and the impacts are expected to be profound. The occurrence of ocean acidification on the West Coast has prompted coordinated and collaborative approaches to better understand the science and identify best practices for managing the threat across state and jurisdictional boundaries.

Following major impacts to the Washington shellfish industry, in 2011, Washington Governor Gregoire created the Blue Ribbon Panel on Ocean Acidification. The Panel issued a report that included 42 key recommendations pertaining to research, monitoring and actions to mitigate and adapt to changing ocean conditions.

In 2013, the legislature implemented two Blue Ribbon Panel recommendations by creating the Marine Resource Advisory Council (MRAC) and the University of Washington's Ocean Acidification Center. In 2015, the legislature renewed funding for MRAC and the Ocean Acidification Center with continued resources for monitoring at shellfish hatcheries, forecasting to inform shellfish growers of changing conditions, and studies of ocean acidification effects on vital commercial and managed species such as salmon, rockfish, razor clams, and geoduck.

The MRAC is continuing to advance actions to further our understanding and response to ocean acidification. Washington State, as part of the Pacific Coast Collaborative, is working closely with California, Oregon, and British Columbia to share, advance, and coordinate management-relevant research and monitoring, as well as mitigate and manage the issue.

The Future of West Coast Shellfish Research-- Establishing Priorities (Workshop)

Bobbi HUDSON, Pacific Shellfish Institute

What should we respond to as a shellfish producing community? What are our priorities for research and education? Attend this workshop to have your voice heard as the shellfish producing community establishes priorities for the next decade of shellfish research and information collection. Let's set a course to strengthen the shellfish industry.

Listening to Our Stakeholders: How to Improve Shellfish Aquaculture Information

Bobbi HUDSON*, Pacific Shellfish Institute; Thom ALLEN, Washington State University Social & Economic Sciences Research Center; Danna MOORE, Washington State University Social & Economic Sciences Research Center

Pacific Shellfish Institute (PSI) and partners at Washington State University's Social and Economic Sciences Research Center surveyed residents of ten coastal counties across Washington, Oregon and California to gauge public perception of shellfish aquaculture. The survey solicited a 34% response rate (1,250 completes) and generated data covering a wide range of issues. Opinion regarding shellfish farming is generally favorable, but survey responses also indicate a need for improved education surrounding both aquaculture practices and consumer seafood preferences. A second survey was distributed to a broad array of local planners, federal and state agency staff, representatives of natural resource industries, citizen groups and conservation non-government organizations in the three states. This survey produced a 25% response rate (254 completes). Opinion of the shellfish industry, from the perspective of these shellfish stakeholders, mirrors citizen responses in many regards. When asked to rate the shellfish industry for its environmental stewardship, 54% responded "excellent", 21% responded "good", 21% "fair" and 4% "poor". Specific recommendations for improving public awareness of shellfish aquaculture issues were provided by some respondents.

When asked: "What could be done to improve public awareness of shellfish aquaculture issues in your organization's operational area?" Responses included:

• More public role by the industry in support of public education of the topic, including hands on experience. Many environmental organizations work on issues that overlap with shellfish. Make efforts to provide scientifically neutral information and exhibits for use by organizations.

• Public statements by qualified governmental leaders and academics who can separate the fallacy from the reality by summarizing the weight of evidence from scientific research regarding environmental interactions associated with the industry and the relative environmental benefits and cost--with a willingness to state a position.

• Track number of jobs and revenue brought in from shellfish aquaculture. These revenues supplement our property and sales taxes, and may reduce their rate of increase.

• Make it a local issue and work with elected officials and business groups; grocers, restaurants, chambers, EDCs, environmental. These groups can help share your story, economic and environmental benefits with local stakeholders.

• A high level of honesty and a low level of advocacy would be helpful.

• Lower the rhetoric.

This work was funded through Washington Sea Grant, pursuant to NOAA award #NA14OAR4170078.

What Effect Does Shellfish Cultivation Really Have on the South Puget Sound Ecosystem?

Bobbi HUDSON*(Pacific Shellfish Institute), David PREIKSHOT (Madrone Environmental Services), Daniel CHENEY (Pacific Shellfish Institute) and Teri KING (Washington Sea Grant).

We used local and regional data, predictive modeling tools and stakeholder working groups to provide recommendations for multi-use spatial planning. Physical, production and ecological carrying capacity were assessed using Farm Aquaculture Resource Management (FARM) and EcoWin modeling tools. Ecological and social carrying capacity were assessed using the EcoPath with EcoSim (EwE) modeling framework, in conjunction with stakeholder working groups, citizen and stakeholder surveys, and the Assessment of Estuarine Trophic Status (ASSETS) tool. This presentation will focus on the EcoPath with EcoSim (EwE) modeling results, and the outcome of several scenarios used to examine the probable outcomes of changes to the south Puget Sound marine ecosystem. Production scenarios tested various increases in bivalve aquaculture and the effects of certain 'control' fisheries. Specifically, using the EcoSim model we explored how a doubling or an order of magnitude increase in each of four bivalve aquaculture sectors could influence the availability of phytoplankton and zooplankton to other species groups. Results indicate that bivalve populations do not exert control over other species of interest in south Puget Sound. In other words, under most scenarios we ran in EcoSim, increases in bivalve aquaculture does not cause population declines for other species we examined. Additional scenarios tested outcomes for other ecosystem changes, such as increases in bivalve predators and jellyfish populations, and changes to plankton and eelgrass abundance. The goal of this research was to provide shellfish growers, regional resource managers, and the general public with tools and information for assessing the ecological and social capacities of shellfish aquaculture in south Puget Sound.

This research was funded through Washington Sea Grant, pursuant to NOAA award #NA14OAR4170078.

INVESTIGATING LOCAL ADAPTATION IN WASHINGTON STATE PURPLE HINGED ROCK SCALLOP

Molly JACKSON*, Taylor Shellfish Farms and University of Washington

Brady BLAKE, Washington Department of Fish and WildlifeJoth

DAVIS, Taylor Shellfish Farms and Puget Sound Restoration Fund

Brent VADOPALAS and Lorenz HAUSER, University of Washington

Management of potential aquaculture of Purple-hinged rock scallop (Crassadoma gigantea) requires greater understanding of wild population structure. If present, local adaptation, in Washington C. gigantea populations could be greatly affected by intentional and unintentional hatchery releases of the species. To quantify the extent of determine if local adaptation, we will carry out a reciprocal transplant experiment using broodstock collected from three locations, Dabob Bay (Hood Canal), Sekiu (Strait of Juan de Fuca) and Cypress Island (San Juan Islands). Broodstock were brought into common conditions at the Taylor Shellfish hatchery in Quilcene WA and spawned. Their progeny will also be reared in a common hatchery environment until moved for growout in suspended culture. Once transplanted into the field, seed will be monitored for growth, survival and fecundity. A suite of mixed effects models will be used to test for significant interaction between source population and site, which would indicate local adaptation. Findings will advance sustainable domestic marine aquaculture development and inform regulatory decisions on broodstock and seed transfer in Washington State.

UPDATE ON DEVELOPMENT OF COMMERCIAL HATCHERY PRODUCTION TECHNIQUES FOR PURPLE HINGED ROCK SCALLOP

Molly JACKSON*, Taylor Shellfish Farms and University of Washington

Sara WYCKOFF, Taylor Shellfish Farms

Brent VADOPALAS, University of Washington

Joth DAVIS, Taylor Shellfish Farms and Puget Sound Restoration Fund

There is growing interest in aquaculture development of the Purple-hinged rock scallop (Crassadoma gigantea), a species with enormous market potential in all four U.S. states bordering the Pacific Ocean. Before commercialization can occur better hatchery methods for production must be developed. As a part of a Western Regional Aquaculture Center (WRAC) project we are midway through a four-year study focused on the development of commercial hatchery methods for rock scallop production. Due to the lack of larval rearing and setting protocols for rock scallops we are developing methods for the species. Specifically, we are evaluating a number of setting systems for rock scallops based on different means of water movement in the setting tanks as well as using different setting

substrates. Methods will be described and results presented on setting trials with recommendations for commercial scale hatchery production.

MONITORING AND MANAGEMENT OF TREATY-SHARE BIVALVE RESOURCES ON PRIVATE TIDELANDS - SURVEY, HARVEST & ENHANCEMENT

Luke KELLY*, Suquamish Tribe Fisheries Department, Suquamish, WA 98392

The Suquamish Tribe's Shellfish Program works to maintain reliable harvest of shellfish for Tribe Members on private and public tidelands within the Tribe's Usual and Accustomed fishing grounds. Clam harvesting is a traditional activity that Suquamish Tribal Members have engaged in for thousands of years. Continuing the tradition today utilizing proper resource assessment and management ensures there will be sustainable harvests for future generations. This presentation will summarize how the Tribe's shellfish program conducts intertidal clam surveys, commercial clam harvests, and enhancement work (where possible) on private tidelands.

SNEAKY SEAWEEDS: A POSSIBLE VECTOR FOR VIBRIO.

Teri KING, Washington Sea Grant, University of Washington

UNDERSTANDING THE RELATIONSHIP BETWEEN DENSITY OF Ulva spp. AND Crassostrea gigas GROWTH AND SURVIVAL ON TWO COMMERCIAL OYSTER FARMS IN PUGET SOUND

Audrey Lamb, The Evergreen State College

Dr. Joth Davis, Taylor Shellfish Farms

Dr. Erin Martin, The Evergreen State College

Ocean acidification is an emerging threat to water quality in the shellfish industry. One proposed mitigation strategy for reducing ocean acidification suggested by the Washington Marine Resources Committee is seaweed-based phytoremediation to sequester carbon dioxide. However, this practice is at odds with current management strategies in the shellfish industry, which can include removing seaweed from shellfish beds, as it is believed to reduce the growth of farmed shellfish and increase mortality. In areas with dense seaweed growth during spring and summer months, shellfish farmers can frequently spend considerable time managing seaweed through manual removal from

shellfish beds, particularly during sensitive life stages such as cultivating seed. However, there is little research examining the effects of seaweed density on oyster growth and survival, and as such, it is unclear if these manual removal techniques are actually needed. This study is currently investigating the relationship between sea lettuce (Ulva spp.) density and Pacific oyster (Crassostrea gigas) growth and survival on two commercial oyster farms in Puget Sound in hopes of improving the understanding of the necessity for seaweed removal. It is hypothesized that high densities of Ulva spp. will result in reduced growth rates of Crassostrea gigas and increased mortality. The study was conducted growing juvenile oysters in grow bags with different wet weights of sea lettuce (3 kg, 1.5 kg, 0 kg) at two sites in Puget Sound. Results of oyster growth over a period of four months will be presented.

UPDATE ON THE MOLLUSCAN BROODSTOCK PROGRAM

Chris LANGDON*, Blaine SCHOOLFIELD, Evan DURLAND. Hatfield Marine Science Center, Oregon State University, Newport, Oregon 97365.

Claudio DE MELO, Carlos GOMES. Laboratorio de Moluscos Marinhos/UFSC, Servidão dos Coroas s/n, Barra da Lagoa, Florianópolis/SC-Brasil Cep.88061-600

The Molluscan Broodstock Program (MBP) produced cohort 25 in 2014 and planted this cohort at Taylor's test sites in Oyster Bay, south Puget Sound, and in Willapa Bay. In 2015, MBP produced cohort 26 and 2015 pods and used the REML animal model to identify genetically superior broodstock families instead of basing selection on only phenotypic characteristics. The performance of cohort 26 larvae in MBP and commercial hatcheries was excellent. Comparative laboratory experiments indicate that MBP larvae perform better than larvae derived from wild Willapa broodstock under both normal and acidified seawater conditions. Quantitative genetic analyses indicate that heritabilities for growth of early life stages (pre-plant out) are high, indicating scope for further improvement. Results from field tests of the new Kumamoto stocks and cohort 25 families will also be presented, followed by an open discussion of future directions for MBP.

THEORETICAL AND REALIZED HERITABILITIES OF PERFORMANCE TRAITS OF PACIFIC OYSTER FAMILIES PRODUCED BY THE MOLLUSCAN BROODSTOCK PROGRAM (MBP)

Chris LANGDON*, Hatfield Marine Science Center, Oregon State University, Newport, Oregon 97365.

Claudio DE MELO, Carlos GOMES. Laboratorio de Moluscos Marinhos/UFSC, Servidão dos Coroas s/n, Barra da Lagoa, Florianópolis/SC-Brasil Cep.88061-600.

Blaine SCHOOLFIELD, Evan DURLAND. Hatfield Marine Science Center, Oregon State University, Newport, Oregon 97365.

Using a REML animal model, covariance components for performance traits (Initial Weight at planting, as well as Yield (kg), Survival (%), and Individual Weight (g) at harvest) were estimated using 15,249 records from five generations of selectively bred Pacific oysters in the West Coast, USA, Molluscan Broodstock Program (MBP). Heritability estimates for traits in 1st, 2nd and 3rd generations were high to medium (0.94 to 0.35); however, in the 4th and 5th generations they were medium to low (0.41 to 0.11), except for Initial Weight (0.79) in the 5th generation. These results indicate an increase in error variance after the 3rd generation, perhaps associated with changing ocean conditions on the West Coast, USA. Genetic correlations among traits ranged from positive and high (0.95, between Yield and Survival) to negative and medium (-0.31, between Individual Weight and Survival). Realized heritabilities were estimated for the 4th and 5th generations and ranged to -0.27 (Individual Weight) to 0.79 (Yield); however the number of control families used for these estimates were small, likely resulting in inaccuracies. Overall, the positive heritabilities and covariances among traits for Yield indicate the selective breeding can be effective in improving yields of Pacific oysters.

MOLLUSCAN AQUACULTURE IN BRAZIL

Carlos GOMES*, Claudio DE MELO. Laboratorio de Moluscos Marinhos/UFSC, Servidão dos Coroas s/n, Barra da Lagoa, Florianópolis/SC-Brasil Cep.88061-600

Bivalve production occurs along 8,000 kilometers of Brazil's coastline. Most shellfish produced in the Southeast and Northeast Brazil are from harvests of wild adults that are brought directly to market. Spat of Native oysters, mainly Crassostrea gasar, are collected from the wild and transferred to farms, representing an important income source for local communities; however, collection of naturally occurring oyster spat do meet farm demands. In contrast to other regions, Santa Catarina, located in the southern region of Brazil, has copious amounts of oyster seed due to hatchery and nursery production at the Marine Mollusc Laboratory (LMM), Federal University of Santa Catarina. The Santa Catarina region produces 95% of the nation's molluscs, including the brown mussel Perna perna, the Pacific oyster Crassostrea gigas, and the scallop Nodipecten nodosus. Production from Santa Catarina totaled 21,553 tons from a total of 610 farmers. Shellfish production has been steadily increasing over the past several decades due to incentives provided to farmers by LMM, the Agricultural Research and Rural Extension Company (EPAGRI) and local municipalities in the form of training, sharing of technological developments, and investing in shellfish market development. Furthermore, Federal and State regulations have played an important role by creating policies that contribute to environmental and product quality surrounding bivalve aquaculture, creating consumer confidence. With

domestic markets saturated, Brazilian shellfish aquaculture now faces new challenges including enhancing domestic demand and entering international markets.

ASSESSING POPULATION STRUCTURE AND LOCAL ADAPTATION OF ROCK SCALLOPS TO INFORM AQUACULTURE PRACTICE

Natalie LOWELL*, Brent VADOPALAS, Lorenz HAUSER. School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA 98105.

Molly JACKSON. School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA 98105. Taylor Shellfish Company, Shelton, WA 98584.

Ryan CRIM, Joth DAVIS. Puget Sound Restoration Fund, Bainbridge Island, WA 98110.

Brady BLAKE. Washington Department of Fish and Wildlife, Port Townsend, WA 98368.

High market potential for purple-hinge rock scallop, Crassadoma gigantea, has motivated substantial interest for aquaculture development along the U.S. west coast. Large-scale development could, in some cases, overlap with the native wild populations of C. gigantea, leading to unknown genetic interactions between wild and cultured individuals. These interactions could prove detrimental for the resilience of populations if C. gigantea exhibits significant population structure and local adaptation across its range. We will use a next-generation sequencing approach and a quantitative genetic model to measure the degree of local adaptation to ocean acidification at two spatial scales: across wild populations in California, Washington, and Alaska, and across wild populations in Puget Sound and the coast within Washington. We will quantify neutral genetic divergence, test for molecular evidence for adaptive genetic differentiation, and identify highly discriminatory markers for routine screening of wild populations and captive broodstock. Our findings will contribute to wild stock resilience and C. gigantea aquaculture sustainability, and inform pending regulatory decisions on broodstock and seed transfer.

BIOFOULING BENEFITS SHELLFISH PRODUCTION

Andrew JEFFS*, Jenni STANLEY

Institute of Marine Science, University of Auckland, New Zealand

Serena WILKENS

National Institute of Marine & Atmospheric Research, Wellington, New Zealand

Hamish MCDONALD

Hydrocadent Ltd, Warkworth, New Zealand

Hatchery and nursery production of shellfish seed is a major cost of aquaculture production due to the significant labor and capital costs involved in these operations. Increasing larval settlement, survival and growth of juvenile shellfish can deliver major financial and production gains, however, conventional approaches of fine tuning existing methods tend to produce smaller incremental gains.

Whilst researching biofouling on vessels we discovered a key reason for the rapid establishment and growth of biofouling, including some shellfish, on vessel hulls. Since this discovery we have been working on how to apply this knowledge to benefit the shellfish aquaculture industry by developing methods by which the same conditions that promote biofouling can be introduced into shellfish hatcheries and nurseries.

In this presentation we will outline some of the research results showing increases in larval settlement, survival and growth of juvenile shellfish of commercial interest and the opportunity for the wider application of the technology in shellfish aquaculture.

BEYOND ACRES AND TURIONS: IMPROVING METRICS FOR EELGRASS MITIGATION

Marlene D. MEADERS*, Confluence Environmental Company

Chris CZIESLA, Confluence Environmental Company

Phil BLOCH, Confluence Environmental Company

Grant NOVAK, Confluence Environmental Company

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Native eelgrass (Zostera marina) provides a wide variety of ecological functions that support nearshore ecosystems, and is one of the only rooted vascular marine plants on the West Coast. Recognition of the functions provided by eelgrass has led to increasing regulatory attention and scrutiny of projects with the potential to affect eelgrass systems. In 2014, the National Oceanic and Atmospheric Administration published guidance for projects that impact eelgrass habitat: the California Eelgrass Mitigation Policy (CEMP). This guidance provides a framework for mitigation associated with projects that impact eelgrass habitat. However, it fails to account for projects that may co-exist with eelgrass habitat, or where effects to eelgrass beds are limited or transitory. While the CEMP recognizes that there are ecological functions provided by shellfish aquaculture, there is no guidance on how to calculate changes to functions by adding shellfish to eelgrass habitat.

A framework for a credit-debit accounting system for marine habitats was developed using an accounting tool from wetland ecology. The credit-debit framework is designed to provide guidance on how to value three ecological functions: (1) water quality, (2) habitat structure, and (3) prey resources. These functions support over 90% of the

importance for which eelgrass is recognized. A set of questions was established for each function that values a habitat based on site potential, landscape context, and watershed or regional priorities. This framework is intended to initiate a detailed conversation about how to value ecological functions associated with a variety of marine habitats, including eelgrass, shellfish aquaculture, mudflat, and salt marsh.

Shellfish Aquaculture and SAV: A State of Science Assessment to Inform Management

Kenneth P. Riley and James A. Morris, Jr.

Shellfish aquaculture is the largest and fastest growing aquaculture industry in the U.S. Located primarily along the Pacific and Eastern coasts, shellfish growers utilize a diverse array of culture methods to produce clams, oysters, geoduck, and scallops. Cultivation methods include both onbottom and offbottom practices of varying intensities from large corporate farms comprising hundreds of acres to small family-based operations of less than an acre. Given that shellfish are filter feeders, intense cultivation can improve local water quality. Today, coastal managers must weigh environmental benefits and costs in tandem with a growing number of other coastal uses. One such conflict includes the interactions between shellfish aquaculture and submerged aquatic vegetation (SAV). Due to the importance of SAV as essential fish habitat, managers are concerned with how shellfish cultivation techniques impact SAV biomass. Reports from both coasts suggest that shellfish aquaculture can have both positive and negative impacts on SAV depending on the cultivation technique and health of surrounding SAV communities. Additional ecosystem services such as enhancement of surrounding SAV biomass and increased diversity and habitat make it difficult to evaluate net impact. To better understand these interactions, the NOAA National Ocean Service's Coastal Aquaculture Planning and Environmental Sustainability (CAPES) program is conducting a State of Science Assessment. This assessment will provide a review of regulatory mandates, shellfish cultivation practices, SAV interactions including both negative and positive, and approaches for habitat equivalency comparisons. Management recommendations will also be provided including SAV monitoring, evaluation, mitigation, and restoration approaches.

MONITORING RISK: OCEAN CONDITIONS INFLUENCE MUSSEL ATTACHEMENT

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A mussel's attachment is critical for its survival on rocky shores and aquaculture lines. Mussel form stretchy tethers called byssal threads that keep them anchored against hydrodynamic forces. Byssal thread integrity is subject to environmental conditions, such as temperature, that may weaken threads increasing the chances of mussel fall-off. Two closely related farmed mussel species Mytilus trossulus and M. galloprovincialis show opposite responses in their attachment strength to elevated temperature. When temperatures reach over 19˚C in the lab, M. trossulus shows a decrease in attachment strength producing weaker and fewer threads while M. galloprovincialis shows an increase in attachment strength as it increases thread production. We expand on these results in situ at three Washington State mussel farms by examining how these two species attachment strength changes seasonally with changes in water temperature. We measured attachment strength monthly on mussels growing in suspension culture in Penn Cove, WA (M. trossulus), and Quilcene Bay, WA and Totten Inlet, WA (M. galloprovincialis) in conjunction with Penn Cove Shellfish and Taylor Shellfish. We hypothesized M. trossulus will experience peak attachment strength in the cooler winter months while M. galloprovincialis will experience peak strength in the warmer summer months. We found M. trossulus attachment strength decline correlates with rising temperature ($r^2=0.6$, $p < 0.01$) while to date (October 2014 – May 2015) M. galloprovincialis strength does not correlate with seasonal changes in temperature. These results suggest M. trossulus aquaculture should be favored in areas where maximum temperatures do not approach 19˚C while M. galloprovincialis should be favored in warmer bays where temperature approach and warm beyond 19˚C.

LARVAE WITHOUT BORDERS: UNDERSTANDING HOW SALINITY AFFECTS THE REMOTE SETTLEMENT OF EASTERN OYSTER (Crassostrea virginica) LARVAE IN THE MID-ATLANTIC

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As the demand for oyster larvae used for aquaculture and restoration activities increases, so does the practice of setting larvae in salinities different from their rearing salinity. Our knowledge of the effects of low salinities and of salinity changes on settlement of the Eastern Oyster (Crassostrea virginica) is primarily based on field observations and some laboratory experiments on larval survival. Few experiments have tested the effect of salinity on settlement, and little literature exists concerning the settlement preferences of larvae reared in low-salinity environments. Our

study was conducted to 1) determine how salinity (S) affects settlement success of larvae reared in a low salinity hatchery (S=10), and 2) compare those settlement preferences to those of larvae from hatcheries of higher salinities (S=15 to 27.5). Multiple cohorts of competent larvae from 4 hatcheries were placed in triplicate settlement chambers of 12 salinities ranging from 5 to 35 and allowed to settle for 4 days. Larvae from all hatcheries settled in all salinity treatments. I will discuss preliminary results and implications for emerging aquaculture industry in waters of highly variable salinity regimes such as the Chesapeake Bay and Gulf of Mexico.

Seagrass responses across disturbance regimes

RUESINK, JL University of Washington

Disturbance regimes are typically defined by the size, return time, and intensity of events that remove biomass. Here, I compile results from experimental studies of seagrasses in which biomass was removed by clearing, thinning, or defoliating shoots. This review confirmed that recovery of gaps in seagrass is faster when shoots are larger, gaps are smaller, or remnant shoots remain. The role of seeds in recovery has been variable, except critical to the recovery of large gaps, e.g. >100 m2. Single defoliation events have had little effect in many seagrass species, but in Zostera marina the loss of leaves immediately slows growth and longer term reduces shoot size and branching. In one case, defoliation resulted in shoot mortality. Zostera marina appears more sensitive to loss of leaves but better able to recover after loss of shoots relative to other seagrass species. Within Zostera marina across populations with dense, small or sparse, large shoots, patterns mirror those among species, especially slower recovery for smaller shoots.

THE BASICS OF ALGAE CULTURE: HOW TO GROW ALGAE FOR SHELLFISH AQUACULTURE

Stuart Ryan. PSRF: Kenneth K. Chew Center for Shellfish Research and Restoration

The production of microalgae as a live feed for bivalves and other shellfish is an essential component of successful hatchery operations. The ability to grow a sufficient quantity of multiple algal strains is necessary for rearing most shellfish species. In this session I will discuss basic principles of algal culture, such as maintaining stock and starter cultures, scaling up, and harvesting methods. I will also cover essential techniques and equipment as well as the pros and cons of a number of culture methods. I will draw heavily from my experience managing microalgae production for the Kenneth K. Chew Center for Shellfish Research and Restoration.

NOAA Seafood Inspection Program

Eric Staiger

Eric Staiger, Chief of the Northwest Inspection Branch, will discuss the inspection services provided by the National Oceanic and Atmospheric Administration (NOAA) Seafood Inspection Program that are used by many processors and exporters of shellfish. The Program offers inspection services to recognize Approved Establishments and issue official health certificates.

Small Farm Vibrio parahaemolyticus Avoidance Techniques

Andrew Suhrbier, Steven Booth, Daniel Cheney

Summary of results of 2015 deep water holding trials of pacific oysters (Crassostrea gigas) from a Hood Canal shellfish farm. Oysters were moved from an intertidal growout site to a subtidal holding system in June and July of 2015. These oysters were tested for Vibrio parahaemolyticus and PSP (paralytic shellfish poisoning) during summertime daylight low tide series and compared with those remaining at the intertidal site. A brief introduction to the permitting process will be included.

Red sea cucumber (Parastichopus californicus) poly-aquaculture for nutrient uptake and seafood export.

Andrew Suhrbier

Discussion of the first phase of multifaceted project dealing with red sea cucumber (Parastichopus californicus) poly-aquaculture. Tasks of this project include determining the genetic population structure of these animals in CA, OR, WA and AK; growout trials with sablefish and mussels in Washington; growout trials in AK; and development of Washington State and Alaska hatchery technology. Initial findings, obstacles and activities will be discussed.

NOROVIRUS: WHAT WE CAN LEARN FROM THE PAST YEAR AND WHAT TO DO TO PREVENT FUTURE OUTBREAKS

Lawrence SULLIVAN*

Norovirus is the leading cause of acute gastroenteritis in the United States with 19 to 21 million cases occurring each year. Shellfish can become contaminated with norovirus if human sewage is present in the water shellfish are feeding

in, leading to norovirus infection among those who consume the raw or undercooked shellfish. In late November and early December 2014, 21 people from Washington and Oregon reported norovirus-like illness after consuming raw oysters. Oysters were initially traced back to two harvest sites that were located in close proximity to one another. A sanitary survey identified a failing septic tank near one of the harvest sites, resulting in an emergency closure and a recall of all molluscan shellfish harvested from this site and surrounding harvest sites. Stool specimens from six ill persons, oysters collected from the harvest site and material removed from the septic tank all tested positive for norovirus GI.2. Genetic sequencing showed that the viruses were 100% similar.

EELGRASS VERSUS THE 'BLOB' AND OTHER SCARY THINGS: SORTING OUT MECHANISMS OF EFFECT AND RESILIENCE

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Eelgrass (Zostera marina L.) is the most widespread species among ~60 species of seagrass, suggesting that eelgrass has adapted to a wide range of conditions. Yet, losses of seagrasses are occurring globally owing to a wide array of threats. Losses at the local scale are attributed to physical disturbances (e.g., propeller scars, overwater structures), whereas regional-scale losses have been attributed to stressors including wasting disease and eutrophication. On the west coast, recent collapses of eelgrass in bays in Washington state and California have occurred. Although causes for the collapses remain largely unresolved, studies suggest that climate-related mechanism can drive considerable variation in eelgrass abundance, and may exacerbate already stressful conditions for eelgrass. The rate of return of eelgrass depends on the size and severity of the impact plus the sources of renewal (i.e., seeds or rhizome spread). Recovery by planting appears to be viable option in situations where conditions at a site are suitable, the stressors have been abated, and appropriate planting methods are employed. We are finding that eelgrass is resilient, but multiple stressors (e.g., climate variation + local disturbances) can exceed the tipping point and convert former eelgrass meadows to an alternate state. As a practical issue, recovery from this alternate state requires a substantial investment in energy, cost and time. We have been using a numerical modeling in Puget Sound to grade the entire ~3000km of the shoreline for its suitability to support eelgrass. Our modeling effort was preceded by a comprehensive analysis of stressors to eelgrass. The results are now being evaluated through field observations, test plantings and large-scale plantings. Based on our restoration work, and modeling, we developed a set of recommendations to enhance the resilience of planted eelgrass in order to maximize the chances of successfully hastening the recovery of eelgrass meadows.

Shellfish Nutrition: What to grow and what to feed

Nate Wight*

Bremerton Environmental Labs and BWH Shellfish

The success of a shellfish hatchery is dependent upon the quality (diet composition) and quantity (ration) of microalgae that is grown and fed to larvae and post-larvae (PL). The nutrition requirements for optimizing survival and growth in larval and PL shellfish require a mix of algae species to provide essential nutrients particularly carbohydrates, proteins, lipids and fatty acids. I will initially present a research review on high food-value algae species and then talk about the corresponding algae regimens used in shellfish hatcheries. Lastly, I will present from personal observations and experiences relating to shellfish nutrition from my 10 years of experience conducting research, managing a commercial hatchery's algae production, and currently running my small, private shellfish hatchery.
