

ABSTRACTS

70th Annual
Shellfish Growers Conference and Tradeshow

Pacific Coast Shellfish Growers Association
National Shellfisheries Association Pacific Coast Section

Chelan, WA, October 11-14, 2016

THE EFFECT OF TEMPERATURE ON EARLY DEVELOPMENT OF THE GIANT CALIFORNIA SEA CUCUMBER (*Parastichopus Californicus*) IN A HATCHERY SETTING.

BAIRD*, Kendra, The Evergreen State College, Puget Sound Restoration Fund

Full Abstracts to be completed by June 30, 2016

Despite the growing commercial interest of *Parastichopus californicus* there is currently no large-scale aquaculture production. The development of aquaculture techniques has been limited by the lack of comprehensive knowledge of the early life stages of the species. Seawater temperature has been observed to play an important role in the growth and physiological performance of sea cucumbers. Early development and larval stages are particularly sensitive to environmental changes and temperature is a key factor in their developmental success. My experiments will research the effects of temperature on the early development of *P. californicus*. Specifically, I will determine the effect of temperature on embryonic development and larval growth and survival. The goal of my research is to determine the optimal temperature range that *P. californicus* should be reared at in hatcheries.

ONLINE SHELLFISH GROWING AREA MAPS: IMPROVING COMMUNICATION, TRANSPARENCY AND REAL-TIME HARVEST SAFETY

BERBELLS*, Scott, Jean SNYDER, Washington State Department of Health Shellfish Programs

Washington State Department of Health (Office of Environmental Health and Safety) continually monitors and analyzes water quality and sanitary conditions at over 100 commercial shellfish growing areas and 270 public recreational shellfish beaches, across 300,000 acres of Washington marine waters. We collect fecal coliform bacteria data from over 1,700 marine water stations, and certify over 12,300 shellfish harvest sites and 350 commercial shellfish companies. Our classification and certification processes, combined with *Vibrio* and Biotoxin monitoring, ensure that shellfish in Washington State are safe to eat. This presentation will highlight our online interactive commercial shellfish map viewer launched in October 2014. It will discuss the improvements to data management, communication, transparency and real-time shellfish harvest safety through online mapping. Lastly, it will demonstrate the opportunity for commercial shellfish harvesters to evaluate the shellfish growing area conditions prior to harvest and prior to requesting new areas to harvest shellfish.

APPLICATION OF THE EXTRACTABLE LIPOFUSCIN AGING METHOD TO ESTIMATE MORTALITY AND POPULATION DYNAMICS OF THE BURROWING SHRIMP,

Neotrypaea californiensis

BOSLEY*, Katelyn M., Oregon State University

Brett R. DUMBAULD, USDA - ARS

Tom WAINWRIGHT, NOAA Fisheries

Structured population models are among the most widely applied models in population ecology and typically assume that individuals can be divided into discrete classes based on stage, size or age. The lack of robust aging methods in crustaceans has caused researchers to classify individuals based on size but differences in growth bias population parameter estimates. Recent advances in aging crustaceans with the biochemically-produced aging pigment, lipofuscin, has created the opportunity to apply age-structured models to understand the population ecology of marine crustaceans. This study sought to apply the lipofuscin aging method to estimate mortality rate in *N. californiensis*, a burrowing shrimp that inhabits estuaries along the US west coast.

While the species is an important member of the estuarine community, *N. californiensis* also has a negative impact on oyster production in the region. As a result, managers are interested in understanding more about the population dynamics of the species and developing a theoretical cohort-based model to explore these dynamics. Randomized surveys were conducted over a four year period from 2011-2014 to estimate population abundance, average density and population age structure. Mortality rate was estimated to be 0.719 yr⁻¹ (95% CI; 0.633-0.793 yr⁻¹) and did not vary significantly across cohorts. The spatial extent of the survey revealed spatial patterns in shrimp density that could be explained by variation in mortality and recruitment rates. This is the first study to apply lipofuscin aging to estimate population parameters of a burrowing shrimp and the methods presented here can be used to inform managers seeking to incorporate population ecology into management plans for *N. californiensis* and could potentially apply to other crustacean species worldwide.

SHELLFISH AQUACULTURE RELATED ECOSYSTEM SERVICES: WATER QUALITY IMPROVEMENT THROUGH BIVALVE CULTURE

BRICKER*, Suzanne, NOAA National Centers for Coastal Ocean Science

An examination of nutrient reduction and other water quality services of bivalve shellfish in local and regional waters of the US.

THE (FUTURE) RECOVERY OF CALIFORNIA SEA CUCUMBER STOCKS IN WASHINGTON STATE

CARSON*, Henry S., Washington Department of Fish and Wildlife

Harvestable populations of California sea cucumber (*Parastichopus californicus*) in Washington State have not recovered from intensive harvests that occurred during the late 1980s and early 1990s. Relative abundance on fixed index stations and catch-per-unit-effort (CPUE) continued to decline after quotas and effort were dramatically reduced. Recently, an entire fishery management area was closed due to low biomass estimate, and quotas in other areas have been further reduced. The theory that sea cucumber stocks in harvestable depths would be replenished with recruits from deeper depths does not fit with observations in Washington. Sea cucumber stocks around the world have shown vulnerability to overharvest and recovery times on the order of decades, characteristics that seem to also apply to *Parastichopus*. Despite the depressed stocks, there is widespread anecdotal and quantitative evidence of unprecedented juvenile recruitment in 2014 - 2016 across the state – possibly as a result of predation release coinciding with the sea star wasting epidemic. Meanwhile, CPUE has increased over the last two seasons from an all-time low in 2013. There was also a small increase in relative abundance detected in fall 2015, which is a first in that time series' 28-year history. A commitment by state and tribal co-managers to rigorous monitoring, responsible quotas, and a fishery closure during peak spawning months may continue to pay dividends in future years. While that progresses, a number of partners have begun pilot hatchery projects to explore the feasibility of active sea cucumber stock enhancement or aquaculture.

BLACK MARKET SHELLFISH TRAFFICKING

CENCI*, Mike, Erik OLSON, Washington Department of Fish and Wildlife

The illegal harvest and export of bivalve shellfish in Washington State is a lucrative industry. Every year WDFW conducts inspections and seizes thousands of pounds of shellfish at SeaTac airport and on the US/Canada border. The commercial fish and shellfish industry contributes 1.5 billion dollars per year into the Washington State economy. Based on the incredibly lucrative overseas market, there is a very significant financial incentive to poach shellfish and export them out of the country quickly. SeaTac and the border have proven to be a bottle neck for intercepting illicit product.

PACIFIC SHELLFISH INSTITUTE 20 YEAR RETROSPECTIVE OF SHELLFISH SHENANIGANS.

CHENEY*, Dan, Pacific Shellfish Institute

Bill DEWEY, Taylor Shellfish

Pacific Shellfish Institute over the past 20 years.

ESTIMATING RECREATIONAL EFFORT FROM AERIAL SURVEYS OF SHELLFISH HARVESTERS USING MOBILE DEVICES.

CLARK*, Roy

Conducting aerial surveys using mobile devices has increased efficiency and improved data accuracy in producing annual estimates of sport harvester effort on Puget Sound public beaches.

AN EXAMINATION OF THE USE OF SEASCAPE SCALE HABITATS INCLUDING OYSTER AQUACULTURE AND *Zostera marina* BY FISH AND CRAB IN PACIFIC NORTHWEST ESTUARIES

CLARKE*, Larissa, Marine Resource Management, Oregon State University

Brett DUBMAULD, USDA-ARS

Understanding the ecological role of shellfish aquaculture and eelgrass (*Zostera marina*) as important habitat in Pacific Northwest estuaries is important for management decisions. The aquaculture industry is currently restricted by regulations concerning estuarine habitat impacts of their activities on *Z. marina* as this grass is designated as Essential Fish Habitat (EFH) for federally managed fish species. This study is designed to quantify abundance and species diversity of fish and crab in Pacific Northwest estuaries using predation pressure, light and temperature trends, and habitat complexity to explain differences between habitat types. Our particular interest is in landscape scale features that might influence these more mobile species and we are currently evaluating longline oyster aquaculture, the edge of this habitat, and eelgrass beds. GoPro video surveys were conducted to capture fish and crab composition and use of each habitat type at three sites within a bay. Predation Tethering Units (PTUs) were deployed to evaluate predation risk and refuge value in each habitat, and temperature, relative light, and salinity were also measured. Lastly, habitat complexity in terms of seagrass abundance was examined along transects within each habitat type. Preliminary results will be presented that are expected to have important management implications.

USING SEAWEEDS TO MITIGATE OCEAN ACIDIFICATION IN THE SALISH SEA

DAVIS*, Joth, Betsy PEABODY, Puget Sound Restoration Fund

The use of seaweeds to explore whether intensive primary production can help mitigate seawater chemistry as it relates to reduced pH and high dissolved carbon dioxide is the focus of research undertaken by the Puget Sound Restoration Fund. With support from Vulcan Philanthropy and the US Navy, the PSRF has assembled a suite of research partners including the UW, NOAA Pacific Marine Environmental Laboratory, NOAA Aquaculture, WA Sea Grant, WDFW, WDNR, SSA, Tribes and others to assess changes in the carbonate chemistry of seawater passing through a dense assemblage of seaweeds (sugar and bull kelp). In addition to continuous measurements for a suite of variables associated with the carbonate chemistry of seawater, biological studies will be undertaken to assess the effects of seawater chemistry on the dissolution rates of pteropods positioned upstream and downstream of the seaweed farm. Additional studies will assess seaweed growth and production rates and the use of seaweeds as habitat for a suite of fishes and invertebrates over the seasonal cycle of seaweed cultivation. A seaweed model will be developed once data is collected in order to help predict the effects of growth and production of seaweeds on carbonate chemistry for kelp farms placed in other suitable locations. Additional study objectives include intensive analyses of potential post harvest uses of seaweeds as food, fertilizer, compost and biofuels (biogas and ethanol). The potential to use seaweeds as an adaptation tool to combat ocean acidification is critical to consider in the years ahead as changes in carbonate chemistry in the Salish Sea are predicted to increase creating significant stress on ecologically important marine resources.

DEVELOPMENTS IN THE AQUACULTURE DEVELOPMENT OF PURPLE HINGE ROCK SCALLOP GROWTH AND SURVIVORSHIP IN PUGET SOUND

DAVIS*, Joth, Taylor Shellfish Farms, Inc.

Kristin SAKSA, Brent VADOPALAS, University of Washington

Purple hinge rock scallops, *Crassadoma giganteus*, are large, relatively fast growing scallops native to the North American west coast. Recent interest has emerged in evaluating their potential for commercial production in suspended aquaculture applications. Research funded by the Western Regional Aquaculture Center (WRAC) has focused on production methods for diploid and triploid scallops, resolving bottlenecks associated with larval and nursery care and evaluating scallop growth and survivorship in a variety of grow out environments and gear types in the southern Salish Sea. Rock scallops are prone to cementing to hard substrates once

approximately 30mm in shell length. Evaluating different gear types and the propensity to cement are an important secondary objective of the research. The growth of rock scallops has been relatively rapid with mean shell length in excess of 60mm after 9 months of growth for most locations. Survivorship of scallops has also been high (>90%) in all locations evaluated to date. Cementation rates in Vexar growout cages has varied by location and is generally highest at sites exhibiting where scallops exhibit faster growth (Totten Inlet). Additional studies are evaluating the potential of using glues to attach scallops to panels, tapes and lines using approaches that are appropriate for automated deployment. The potential for developing a rock scallop industry sector in Washington State will be discussed with a focus on permitting needs, genetic considerations and site selection criteria.

GENETIC BY ENVIRONMENT INTERACTIONS FOR DESIRABLE TRAITS OF THE PACIFIC OYSTER, *CRASSOSTREA GIGAS*, ON THE WEST COAST, US.

DE MELO, Claudio Manoel Rodrigues, Federal University of Santa Catarina

Romain MORVEZEN*, Evan DURLAND, Chris LANGDON, Oregon State University

Genetic x environment (GxE) interactions were estimated for performance traits of Pacific oysters, *Crassostrea gigas*, from the Molluscan Broodstock Program (MBP), a family-based selective breeding program aimed at improving yields of Pacific oysters on the West Coast, US. We estimated the GxE interactions between common types of oyster grow-out sites in the Pacific Northwest, namely (1) subtidal and intertidal sites and (2) coastal and 'Puget Sound' sites. Covariance components were obtained using AIREMLF90 and a multiple-trait animal model, treating one type of trait in different environments as two different but correlated traits. A total of 9,970 records were analyzed from five generations of selectively bred oysters. Narrow-sense heritability estimates for yield and individual weight at harvest were similar in inter- and subtidal environments, ranging from 0.41 ± 0.02 to 0.47 ± 0.02 . However, the heritability for survival was higher (0.45 ± 0.02) in intertidal than in subtidal environments (0.29 ± 0.02). Genetic correlations among performance traits within environments ranged from small-negative (-0.08 ± 0.06) to high-positive values (0.80 ± 0.02). Genetic correlations for one trait in different environments were high between inter- and subtidal environments, ranging from 0.70 ± 0.05 to 0.80 ± 0.04 for individual weight and yield at harvest, respectively; therefore lower GxE interactions for these traits between these two environments were detected. In contrast, genetic correlations for performance traits at harvest between coastal and Puget Sound environments were low (0.23 ± 0.03 , 0.28 ± 0.03 and 0.25 ± 0.03 for yield, survival and average individual harvest weight,

respectively), indicating that strong GxE interactions were present at these two site types. The latter correlations suggest argue for establishingment of two site-specific breeding programs for at coastal and Puget Sound sites to maximize genetic gains across generations.

DEAD OR ALIVE: FACTORS GOVERNING THE TOXICITY OF IMIDACLOPRID TO BURROWING SHRIMP

DEFOREST*, Kelly, Christian GRUE, University of Washington

Imidacloprid (IMI) is being sought as an alternative to the carbamate pesticide, carbaryl to control burrowing shrimp (ghost shrimp, *Neotropea californiensis*) in Willapa Bay and Grays Harbor. The shrimp destabilize sediments resulting in poor survival and low yields of the commercially harvested Pacific oyster. Previous laboratory tests indicate ghost shrimp are overtly affected (immobilized) when exposed to IMI at concentrations up to 1,500 ppb in artificial seawater (SW), but not killed and subsequently recover. Our objective was to determine the concentrations of IMI in SW that result in mortality of the shrimp and compare these levels to those known to affect other marine invertebrates, particularly Crustacea. Additionally, we quantified time to recovery in shrimp exposed to the concentrations tested. We exposed adult non-gravid females to 0, 1, 10, 100, 1000, 10000, 100000 and 1000000 ppb (1,000 ppm) of the active ingredient (a.i. as Nuprid® 2F) in SW for 48 h (static); 5 individual shrimp per concentration) and quantified overt behavior, survival and water quality. All shrimp at concentrations > 1 ppb were overtly affected, but none died. In the recovery test, 6-8 individual shrimp were exposed to 0, 10, 100, 1000, and 10000 ppb a.i. for 24 h (static) followed by 120 h in clean SW (static renewal). One shrimp exposed to 100 ppb died and time to recovery in survivors was concentration dependent. Results suggest ghost shrimp are very sensitive to IMI in terms of immobilization, but concentrations necessary to kill the shrimp exceed those known for other marine invertebrates. The neurophysiology of Crustacea may not match the mode of action of IMI because most neural receptors in these species use glutamate as the neurotransmitter and not acetylcholine. Our results, coupled with the less than desired efficacy in the field, suggest IMI may not be an effective alternative to carbaryl.

NEOTRYPAEA POPULATION DYNAMICS 2: WHERE ARE THOSE SHRIMP COMING FROM AND HOW LONG BEFORE IT'S AN ISSUE FOR MY SHELLFISH BED?

DUMBAULD*, Brett R, USDA-ARS

Katelyn M. BOSLEY, Oregon State University

Dacey M. MERCER, USDA-ARS

Kim PATTEN, Washington State University

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 two decades and in Yaquina Bay 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 these population changes were related to estuarine recruitment which we have also monitored. Relatively high recruitment was observed in Willapa Bay through the mid 1990's but a period of about 10 years lapsed with very low recruitment. We found significant relationships between recruitment and the number of larger 1 year old shrimp present in both Yaquina Bay and Willapa Bay. 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 both of these estuaries. We used the data collected in Willapa Bay and an age structured population model to examine the influence of these events on shrimp populations over time and develop scenarios and thresholds of concern for shellfish bed management.

LARVAL CULTURE OF THE PACIFIC OYSTER *Crassostrea gigas* IN ACIDIFIED CONDITIONS: COMPARING LABORATORY AND HATCHERY ENVIRONMENTS.

DURLAND*, Evan, Chris LANGDON, George WALDBUSSER, Eli MEYER

Oregon State University

Since 2006, the West coast oyster industry has been threatened by the combined effects of upwelling and ocean acidification (OA) which has reduced the supply of eyed larvae and spat. Anecdotal accounts from commercial oyster hatcheries in Oregon and Washington suggest that larvae from selectively bred oysters from Oregon State University's Molluscan Broodstock Program (MBP) are more tolerant of upwelled acidified seawater than larvae from wild stocks, an observation corroborated by experiments in 2015 conducted at Hatfield Marine Science Center (HMSC) in Newport, Oregon.

In order to compare the performance of MBP larvae under laboratory and commercial settings, two broodstock groups (95 crosses each) were spawned from MBP families and wild broodstock from Willapa Bay, Washington. The resulting pools of fertilized eggs were reared to post-

metamorphic spat at HMSC in ambient and high CO₂ conditions (pH≈8.0 and 7.6, respectively) and at Whiskey Creek Hatchery (WCH) in Netarts, Oregon in 'raw' and 'treated' seawater (pH≈7.7-8.0 and 8.3, respectively). Estimates of larval survival, growth and development were determined at 2, 6, 16 and 24 days post fertilization.

Initial results suggest that larval survival was higher overall at HMSC but MBP groups produced more spat in both HMSC ambient and WCH treated seawater. Higher pCO₂ treatments produced fewer spat at both sites and broodstock type appeared to have little effect in these conditions.

WOMEN IN AQUACULTURE-- CREATING A FORUM FOR SUCCESS

ECKDAHL*, Kari, California Sea Grant, NOAA Aquaculture

Canon PURDY, California Sea Grant, Department of Fish and Wildlife Aquaculture

Restoration and commercial aquaculture face many of the same issues regarding the permitting process, animal health, and best management practices. Aquaculture development suffers from an unclear permitting process, public misperception, and a lack of support from many communities. We seek to better the practice, perception, and effectiveness of commercial and restoration aquaculture through a unique forum. Women in Aquaculture provides a platform where women representing all aspects of aquaculture can communicate, collaborate, and actively work together to support sustainable aquaculture. This group has grown exponentially since the official launch on September 1st, and we continue to receive overwhelmingly positive responses. We are in the process of facilitating our initial projects, and look forward to increased involvement from our members. Come learn about this forum and how you and your organization can get involved.

Mission Statement:

Women in Aquaculture is a forum where women representing industry, state and federal agencies, academia, and NGOs can work together to address the unique challenges facing restoration and commercial aquaculture. This community will help facilitate public education about aquaculture, the sharing of scientific innovation, the development of industry management strategies, and improving the permitting process through open multidisciplinary dialogue. East coast aquaculture permitting. Lessons learned from 14 states that are still working this out. (BMPs for Regulators)

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE: HARMFUL ALGAE BLOOM MONITORING AND MANAGEMENT ACTIONS IN RESPONSE TO HARMFUL ALGAL BLOOMS

FORSTER*, Zach R., Dan L. AYRES, Washington Department of Fish and Wildlife

Harmful algal blooms (HABs) pose a significant threat to human health and fish and wildlife including threatened and endangered marine mammals and birds. Washington State's coastal economies also depend on revenue generated by recreational and commercial fisheries which can be disrupted by HAB events. Washington Department of Fish and Wildlife co-manages coast shellfish resources with four coastal Tribes. Together with Washington Department of Health (WDOH) we currently collect and test shellfish samples on a regular basis. If elevated levels of marine toxins are found, seasons are closed or postponed. Over the last two decades, the coast of Washington State has experienced five major harmful algal bloom events that have had significant impacts on sport and commercial shellfish fisheries and the small communities that depend on the income generated by those fisheries. To better understand and mitigate for the impact of HABs managers and researchers from local state, federal, academic and tribal nations partnered to form Olympic Region Harmful Algal Bloom Monitoring (ORHAB) collaboration in 1999. Initially funded through a NOAA-MERHAB grant ORHAB was successfully transitioned to state funding in 2004. The collaboration is focused on building early warning capabilities for HABs in Washington State and providing sound scientific data to contribute to the understating of HAB events coast wide. We will present some of our monitoring data as well as management actions in response to the 2015 coast wide domoic acid event.

THE RAZOR CLAM POPULATION AND IMPACTS OF CLIMATE CHANGE IN THE WASHINGTON COAST

GAO*, Yongwen, Joseph GILBERTSON et al.

No abstract submitted.

THE RAZOR CLAM POPULATION AND IMPACTS OF CLIMATE CHANGE IN THE WASHINGTON COAST

GILBERTSON*, Joseph, Steve ALLISON, Warren SCARLETT, Hoh Tribe

Yongwen GAO, Port Angeles Fisheries Service

Pacific razor clam, *Siliqua patula*, is an important species in the Washington coast and a popular food for the Hoh people. Although razor clam fisheries have been well managed, little is known

about the different growth and survival rates between Hoh Tribe's traditional harvesting site (Kalaloch Beach) and those to the south in Quinault (Roosevelt Beach). Here we report a pilot study by using stable carbon and oxygen isotope ratio analyses ($^{13}\text{C}/^{12}\text{C}$ or $\delta^{13}\text{C}$; and $^{18}\text{O}/^{16}\text{O}$ or $\delta^{18}\text{O}$) in razor clam shells collected in mid-July, 2015. The $\delta^{18}\text{O}$ values of razor clam shells ranged from -2.16‰ to 1.39‰, whereas the $\delta^{13}\text{C}$ values of the same shell ranged from -2.88‰ to -0.30‰. When comparing with the thick rings of early larval shell growth between Kalaloch Beach and Roosevelt Beach samples, there are distinct $\delta^{13}\text{C}$ differences between the two sites. Also there is a clear separation in $\delta^{18}\text{O}$ for the post-larval shell growth between the two sites. These suggest that the food sources of razor clams at the two sites are different in the early life stage, and the environmental conditions are also different. Overall the life-time $\delta^{18}\text{O}$ profile showed seasonal growth patterns for two or three years, while the $\delta^{13}\text{C}$ variations indicated the age of first maturity (about 1 year). Because razor clam shells are composed of calcium carbonate (CaCO_3) and related to the chemical features of the changing ocean, isotopic signatures and the chemical approach of this study would provide unique information not only for the razor clam biology and management, but for the coastal climate change and ocean acidification as well.

INVESTIGATING ADAPTATION STRATEGIES TO REMEDIATE ACIDIC CONDITIONS ON JUVENILE CLAM SURVIVAL

GREINER*, Courtney, Swinomish Indian Tribal Community and University of Washington

As the impacts of climate change and ocean acidification are beginning to be observed in local waters, there is a growing urgency to identify mitigation and adaptation strategies that can enhance the survival of calcifying marine organisms. Two emerging methods include the utilization of marine macrophytes and the indigenous practice of adding shell hash to clam beds. Limited studies show mixed results in the isolated ability of these methods to effectively remediate impacts of local water conditions on calcifying organisms. However, there are no studies that examine their combined effect on water chemistry or their potential to create a refuge for bivalves. I conducted a study in summer 2016 to assess the growth and survival of juvenile *Venerupis philippinarum* in the presence of shell hash and macrophytes at two sites in the Puget Sound. I briefly describe experimental methods and summarize the mitigation potential of these two strategies.

OYSTERS AND *Vibrio parahaemolyticus* IN WASHINGTON: 2016 SEASON AND EMERGING TRENDS

HARD*, Clara, Laura W JOHNSON

The Washington State Department of Health (DOH) manages *Vibrio 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. The revised rule was adopted by the Washington State Board of Health in March 2015 and implemented in May 2015. Vp illnesses and temperature observations from 2016 will be shared from multiple Washington growing areas during this past summer in comparison with previous years.

NON-STATIONARY, NON-EQUILIBRIUM GENETIC STRUCTURE OF THE NORTH AMERICAN PACIFIC OYSTER POPULATION

HEDGECOCK*, Dennis, X.J. SUN, University of Southern California

The Pacific oyster *Crassostrea gigas* was repeatedly and massively introduced to North America from Japan starting over 100 years ago and has established large, self-recruiting populations in the Pacific Northwest of the U.S. and Canada. A previous study of mtDNA variation revealed little population genetic structure among populations from British Columbia and Washington State. Here, we use samples from that study, more recent samples from two of the same localities, and a sample from Japan to investigate spatial and temporal genetic variation at 52 mapped, coding, single-nucleotide polymorphisms (SNPs) assayed by high-resolution melting (HRM). Little variation is detected among North American populations, which are, as a group, distinct, perhaps adaptively so, from oysters in Hiroshima, Japan. Significant excesses of heterozygotes with respect to random mating expectations and of pairwise linkage disequilibria reveal, however, that North American populations are not in genetic equilibrium. Moreover, genetic changes over 10 to 21 years in two localities are substantial, suggesting that temporal variance in allelic frequencies per generation is as large as spatial variance. These results illustrate the peril of assuming stability of population structure in connectivity or seascape genetic analyses. Because migration and locus-specific selection can be ruled out as causes of non-equilibrium population structure, random genetic drift is the most parsimonious explanation. This implies effective population sizes (N_e) on the order of hundreds to a few thousand, orders of magnitude smaller than the natural abundance (N) of this oyster. These low N_e/N ratios are compatible with the hypothesis of sweepstakes reproductive success.

UPDATE FROM THE KENNETH K. CHEW CENTER FOR SHELLFISH RESEARCH AND RESTORATION

HELKER*, Alice, Ryan **CRIM**, Ryan **STUART**, **Puget Sound Restoration Fund**

This presentation is an update on the Kenneth K. Chew Center for Shellfish Research and Restoration (Chew Center). The Chew Center, opened in 2014, is located at the National Oceanic and Atmospheric Administration Manchester Research Station and operated by the Puget Sound Restoration Fund. The Chew Center is dedicated to the research and restoration of native marine species. At its opening, the main activity was the production of restoration-grade Olympia oysters (*Ostrea lurida*), but the Chew Center has since become home to research and restoration projects on species such as the pinto abalone (*Haliotis kamtschatkana*), California sea cucumber (*Parastichopus californicus*), purple-hinge rock scallop (*Crassadoma gigantea*), and kelp (various species). Not only has the Chew Center diversified in marine species since its doors first opened, but it has also expanded in aquaculture capabilities such as improved water filtration and microalgae production. This presentation will review the Chew Center's restoration and research goals, the production and research that has taken place there, and its ever-improving aquaculture capabilities.

TEMPORAL AND SPATIAL DISTRIBUTION OF OLYMPIA OYSTER (*Ostrea lurida*) EARLY LIFE HISTORY IN PUGET SOUND, WA

HINTZ*, Megan; **University of Washington**

Bonnie BECKER, **University of Washington Tacoma**

Brian ALLEN, **Puget Sound Restoration Fund**

Marco HATCH, **Northwest Indian College**

Oysters play an important role in the health of the ecosystem; they are ecosystem engineers providing biogenic habitat, increasing biodiversity, and filtering local waters. Olympia oysters (*Ostrea lurida*), a species of concern in Washington State, have failed to fully recover after both over exploitation and environmental degradation. Although state agencies and environmental groups have made it a priority to restore *O. lurida* because they are the only native to the west coast of North America and provide key habitat and ecosystem services to the Puget Sound, our understanding of *O. lurida* temporal and spatial distribution remains limited. Understanding the early life history of the Olympia oyster is key because their migratory larvae are this is the only stage where they can disperse to other populations. Although large commercial fisheries do not

exist for Olympia oysters, a small market remains where they are produced, raised and harvested. This information can help inform restoration efforts and small commercial operations that rely on the natural reproduction cycle for their hatchery practices. The Olympia oyster broods their larvae for 10-12 days before releasing free swimming planktonic larvae into the water, which then settle out of the water after 3-8 weeks. Reproduction was monitored at two locations in Puget Sound, Dyes Inlet in central sound and Fidalgo Bay in north sound, during summer of 2015. Three stages of reproduction were monitored; reproductive adults, planktonic larvae, and recruitment. There was low level of reproduction throughout the season, although peaks were still observed in all reproductive stages and could be tracked through time. The better we understand the spatial and temporal trends and variability in reproduction, the better we can respond to new and changing climate conditions.

TOP TEN RECOMMENDATIONS FROM THE SIP TEAM TO IMPROVE THE PERMIT PROCESS IN WA

HOBERECHT*, Laura K, NOAA Fisheries

Perry J LUND, Washington Department of Ecology

The Shellfish Interagency Permitting (SIP) Team has been meeting regularly since December 2011 to address issues around the permitting process in Washington. The primary goal of the SIP Team is to develop a coordinated and consistent process for improved timeliness of permit decisions while ensuring regulatory compliance. The SIP Team worked through the permit process for several pilot projects, which helped inform the development of products and recommendations. The products serve as guidance for shellfish aquaculture applicants to follow for a more efficient process. The recommendations reflect the issues that have come up since the SIP Team began and how these issues might be addressed. All ten recommendations will be presented with an emphasis on the top three which were consistently identified by SIP Team members and other stakeholders as the highest priorities. The top three recommendations are:

- Establish a State Shellfish Aquaculture Coordinator
- Create a Centralized Mapping and Data Tracking Portal
- Develop Consistent, Practicable, and Effective Best Management Practices

The SIP Team has accomplished a lot but there is more work to be done. With adequate support and clear goals the SIP Team will continue to work to improve the permitting process and provide tangible results.

WASHINGTON SHELLFISH INITIATIVE - PHASE II: PROGRESS AND OPPORTUNITIES

HOROWITZ*, Julie, Governor's Policy Office, Washington

Phase II of the Washington Shellfish Initiative was launched in January of 2016. The Initiative advanced important goals including improving water quality, restoring native shellfish, improving shellfish aquaculture permitting, addressing ocean acidification, and advancing shellfish research and education. This presentation will provide updates on new actions and accomplishments of the initiative and discussion on efforts underway.

CARING FOR OUR WILD WATERS: EMPOWERING THE NEXT GENERATION WITH SCIENCE AND SOLUTIONS

HOULE*, Katie, Aimee CHRISTY, Pacific Shellfish Institute

Pacific Shellfish Institute has conducted education and outreach in South Sound schools for more than 10 years. Our K-12 science programs have been evaluated by the Pacific Education Institute and support Next Generation Science Standards. By participating in hands-on classroom activities and experiential field trips, students make connections between upland land use and downstream water quality. PSI uses shellfish as a way to teach students about pollution prevention, inspiring students and their families to practice watershed healthy habits. In this talk I will share how PSI engages South Sound students in the science behind local water quality issues including eutrophication, bacterial contamination, microplastics/marine debris and ocean acidification.

EELGRASS RESULTS FROM NOAA GRANT

HUDSON*, Bobbi, Pacific Shellfish Institute

No abstract submitted.

SUGAR KELP CULTURE STATUS IN ALASKA

HUDSON*, Bobbi, Pacific Shellfish Institute

No abstract submitted.

THE EFFECT OF DIET ON SURVIVAL, GROWTH, AND RADULA MORPHOLOGY OF *Haliotis kamtschatkana* POSTLARVAE

KUEHL*, Lillian Western Washington University

Josh BOUMA, Puget Sound Restoration Fund

Deborah DONOVAN, Western Washington University

Haliotis kamtschatkana (Pinto or Northern abalone) restoration efforts currently rely on hatchery production of juveniles. Hatchery managers report a bottleneck in production at the benthic postlarval stage, in the first six months after metamorphosis from a lecithotrophic and planktonic larval stage. Postlarvae suffer high mortality, and slow growth inhibits efficient production of restoration-grade juveniles. Other abalone species have shown correlations between radula morphology, diet type, and feeding efficiency. We measured growth and survival of postlarval *H. kamtschatkana* on six monospecific diatom diets, and correlated these performance indicators to physical characteristics of the diatoms. We used the diatom species *Achnanthes brevipes*, *Amphora salina*, *Amphiprora paludosa*, *Cylindrotheca closterium*, *Navicula incerta*, and *Nitzschia laevis*. These species were used as fresh cultures; *Navicula incerta* was used in addition as a paste (commercially available from Reed Mariculture, Inc.). A starvation treatment was included. We also monitored changes in radula morphology in response to the different diets. Postlarval growth and survival were measured weekly for nine weeks post-settlement, and radula samples were taken weekly and analyzed using scanning electron microscopy (SEM). Results of the experiment will be discussed.

2016 WASHINGTON BIOTOXIN SEASON: EMERGING TRENDS AND SCIENCE

KUKLOK*, Audrey, Jerry BORCHERT, Washington Department of Health.

The Washington State Department of Health (DOH) monitors for three marine biotoxins: Paralytic Shellfish Poison (PSP), Amnesic Shellfish Poison (ASP), and Diarrhetic Shellfish Poison (DSP). The goal of the program is to ensure that recreationally and commercially harvested molluscan shellfish is safe for human consumption, even as environmental conditions change and new toxins emerge. The presentation will include a summary of biotoxin trends in Washington waters from 2016 in comparison with previous years, and introductions to research projects DOH is partnering with to better understand changing trends.

DOH, in partnership with the National Oceanic and Atmospheric Administration (NOAA), Jamestown S'Klallam Tribe, US Food and Drug Administration (FDA), Alfred Wegener Institute, Wayne State University School of Medicine, Olympic Region Harmful Algal Bloom partnership and the Sound Toxins partnership, is undergoing a three year study of Lipophilic shellfish toxins in Washington waters. The objectives of this study include identifying the spatiotemporally characteristics and distribution of phytoplankton species that produce DSP toxins and azaspiracids accumulating in Washington Shellfish.

DOH, in partnership with Pacific Northwest National Laboratory (PNNL), NOAA, and University of Washington, is undergoing a two year study to develop a Harmful Algal Bloom (HAB) Risk Index to provide a resource to agencies on the likelihood of occurrences of HAB events during the shellfish season in Washington.

UPDATE ON THE MOLLUSCAN BROODSTOCK PROGRAM – STATUS OF MIDORI, KUMAMOTO AND SUMINOE STOCKS

LANGDON*, Chris, B. SCHOOLFIELD, K. PRESTON, J. JENNINGS, E. DURLAND, R. MORVEZEN, Oregon State University

B. DUMBAULD, USDA/ARS

C. DE MELO, Federal University of Santa Catarina

The Molluscan Broodstock Program (MBP) has developed a program to maintain and improve less common oyster varieties, in addition to selection of the established West Coast (Miyagi) Pacific oyster for improved performance. These varieties will provide farmers with market opportunities and alternatives, in case the Miyagi-derived stock becomes vulnerable to future environmental threats or diseases. In this regard, new Kumamoto oyster broodstock, collected from Japan in 2006, has been integrated with existing West Coast Kumamoto stocks and evaluated in a third generation (G3) cohort. In 2016, MBP produced a G3 generation of Midori oysters - a deep-cupped, warm-water variety of the Pacific oyster - that is a good alternative to Kumamoto oysters for the half-shell market. Furthermore, Midori larvae are not dependent on low salinities required by Kumamoto larvae, resulting in a less complicated and expensive hatchery phase. In 2016, MBP also received a batch of Suminoe oyster larvae from Dr. Ximing Guo at Rutgers University. This commercially valuable oyster species was farmed in Yaquina Bay, Oregon, until the late 1990's and has been shown to grow well in Puget Sound and Tomales Bay, California. Strict quarantine protocols, coupled with disease exams, were implemented while rearing the imported larvae. Seed that is free of detectable diseases and released from quarantine will be used to restore this valuable aquaculture species on the West Coast.

HOW SHELLFISH GROWERS CAN CONTRIBUTE TO OIL SPILL RESPONSE

LIEBERMAN*, Eli

A large oil spill in Puget Sound has the potential to have significant impact on the Washington state shellfish industry both environmentally and financially. This presentation will cover how shellfish growers can help mitigate the impacts of an oil spill by joining the Washington State

Department of Ecology's Vessel of Opportunity (VOO) program. Shellfish growers who volunteer in the VOO program will supplement the system of organized professional spill responders already in place throughout the state. VOO can support spill response efforts in several ways, including: assisting in oil skimming operations, transport/deploy oil spill containment boom, deliver logistical support, and provide communication assistance. The presentation will also cover information on how insurance and claims process are handled during oil spill incidents.

MODERN SHELLFISH FARMING IN ANCIENT HAWAIIAN FISHPONDS

LOWREY*, Amanda R.K.

Fishponds were built and utilized by native Hawaiians as an important component of the ahupua`a (traditional land stewardship framework) that contributed to a healthy and robust food system. They are unique aquaculture systems that exist throughout the state, which continue to feed and connect communities around the islands. Their role in the shellfish farming community is fairly new and the numerous and unique challenges they have faced will be discussed.

A SPATIO-TEMPORAL HOT SPOT ANALYSIS OF SALISH SEA CLAM SPECIES

McARDLE*, James, Julie BARBER, Lindy HUNTER, SITC

Camille SPECK, Doug ROGERS, WDFW

Mapping of bivalve biomass through the use of GIS can be a valuable tool for managers of commercially and recreationally-important clam species. An improved knowledge of spatial patterns of clam species, can help managers predict possible settlement and future populations. Following similar methods, the Washington Department of Fish and Wildlife (WDFW) and the Swinomish Indian Tribal Community (SITC) have been conducting intertidal clam surveys with GPS coordinates since the 1990s and early 2000s, respectively. Using data collected on these surveys, the biomass of *Leukoma staminea* (native littleneck), *Saxidomus gigantea* (butter), *Clinocardium nuttallii* (cockle), and *Tresus* sp. (horse) was mapped on multiple beaches. In order to visualize data spanning from the 1990s to present day, each quadrat dug was assigned a unique geographic area through the application of Thiessen polygons. Statistically significant clusters of these polygons were then identified using a Getis-Ord G_i^* Hotspot Analysis. Results give a pronounced and distinct picture of distribution and clustering of specific clam species on beaches for a given period of time. Additionally, this analysis provides evidence, with varying degrees of probability, of underlying spatial processes at work to produce bivalve clusters.

Spatial knowledge of clam populations can provide managers with crucial insight into how to best make important decisions regarding clams as a resource.

SHELLFISH AQUACULTURE AND THE ENVIRONMENT: THE WILD WORLD OF SCIENTIFIC LITERATURE

MEADERS*, Marlene, Chris CZIESLA, Phil BLOCH, Grant NOVAK, Hans HURN

Understanding the interactions of shellfish aquaculture and the environment is not a trivial task. The current stressors on the natural environment are hard to disentangle from each other, and understanding direct relationships is a challenge for the regulatory, research, and operations sides of the equation. Using the existing literature, there are three challenges that we are undertaking right now:

1. Identify ecological functions provided by shellfish aquaculture and how they relate to other structured habitats.
2. Identify data gaps in our understanding.
3. Find a path forward for how operations can support both economic progress and sustainable culture methods.

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. Shellfish aquaculture provides a similar suite of ecological functions, but is a human-induced modification that comes with obvious trade-offs. For example, culturing oysters using longline methods can result in a reduction of eelgrass density directly associated with the longlines. The literature provides an understanding of the mechanisms that drive this reduction and ways to reduce potential impacts (e.g., line spacing). However, comparing just eelgrass presence or absence may not be the most important metric for determining the ecological functions provided by areas with and without oyster longlines.

Progressing this idea further, we understand from existing research that oyster aquaculture can have a number of potential interactions with the ecosystems where operations occur, including consumption of phytoplankton, altering the composition of benthic and pelagic prey communities, and influencing the abundance and distribution of higher trophic level consumers. However, research associated with potential interactions between aquaculture and estuarine habitats are often limited by the conflict between sampling methods (e.g., fyke nets, otter trawls,

beach seines) and the presence of culture gear and aquatic vegetation. Furthermore, community structure can be variable based on timing and tidal elevation, which complicates efforts to compare habitat types. Compiling this information, along with important data gaps, opens up ideas for future growth in our understanding of these interactions.

Confluence has done a number of literature reviews, for the purposes of permitting and regulatory compliance of shellfish aquaculture operations. In addition, we have identified data gaps that can progress our understanding, which led us to identify a team of research scientists, tribal, state, and federal resource agency professionals, and commercial fishing and aquaculture company participants to address the interrelationship between shellfish aquaculture and estuarine habitat productivity as it relates to sustainable U.S. fisheries. This effort was recently approved by the Saltonstall-Kennedy Competitive Research Program, which builds and works with other research being conducted in West Coast estuaries. We believe that the wealth of research available and into the near future can start to help us compare different habitats with and without shellfish aquaculture.

OCEAN ACIDIFICATION EFFECTS ON THE ECOPHYSIOLOGY OF EARLY LIFE HISTORY STAGES OF MARINE INVERTEBRATES AND ALGAE.

PADILLA-GAMINO*, Jacqueline

Global change is a multi-dimensional problem that can affect organisms at many levels of biological organization and at multiple life history stages. I will show how larvae of marine invertebrates and algal spores respond to ocean acidification in California and examine the natural variation and adaptation potential of species located across gradients in upwelling intensity. I will also present current work with Catalina Sea Ranch (shellfish aquaculture ranch) exploring the role of parental effects and identifying temperature resistant genotypes of the farmed mussel *Mytilus galloprovincialis*. This study will allow us to determine the relative contribution of acclimatization, maternal and genetic effects in growth and survival of mussel offspring during a thermal stress, which will provide critical information to mussel farmers for designing genetic improvements in broodstock in the context of climate change. The research presented here will help to understand the physiological flexibility and potential for local adaptation of marine organisms in ecologically and economically important ecosystems already affected by global change.

MOVING FORWARD WITH THE NEXT GENERATION OF SHELLFISH IPM FOR BURROWING SHRIMP

PATTEN*, Kim, Washington State University

A multi-tiered IPM approach for burrowing shrimp management was developed. This included a photo-guide to identifying shrimp burrows and fecal pellets, new monitoring protocol for adult and juvenile shrimp, and options for prevention, modified action thresholds and control recommendations that are dependent on conditions. A new method for recruitment monitoring was developed and used to monitor new populations of juvenile shrimp in 18 locations across Willapa Bay in 2016. The bay-wide average of new recruits, carapace less than 4.5 mm, was 68/m². This is a three-fold increase in recruit density from our previous sampling in 2012. Of the 18 sites surveyed, 5 sites had recruits densities greater than 73m². At one location, the mean size of the recruit population was monitored monthly during summer 2016. There was a mean increase in carapace length of 1 mm/month. A new subsurface application method were developed to treat burrowing shrimp in areas of thick vegetation, with excellent efficacy (data from spring 2015).

JAPANESE EELGRASS - WHAT EFFECT DOES ITS CONTROL IN WILLAPA BAY HAVE ON BIRDS, FISH, INVERTEBRATES, AND *Zoster marina*

PATTEN*, Kim, Washington State University

Scott NORELIUS, Washington State University

Research was conducted to study the ecological impacts of *Z. japonica* in Willapa Bay. Studies were conducted utilizing large replicated paired plots, with and without *Z. japonica*. Imazamox was used to remove *Z. japonica*. *Z. japonica* was a major deterrent for foraging of the ESA-listed green sturgeon. It had no effect or a very minor beneficial influence on small foraging fish, sand shrimp and Dungeness crab. Higher numbers of ducks utilized *Z. japonica* compared to bare sediment, but the opposite was true for shorebirds. *Z. japonica* was not a significant forage food for Brant compared to *Z. marina*. Removal of *Z. japonica* had no significant impact across different invertebrate phyla. *Z. japonica*, however, was detrimental to density of young Manila clams, but enhanced the populations of the invasive Polychaeta, *Pseudopolydora paucibranchiata*. The post-treatment assessment of commercially treated beds in 2014 and 2015 found that the occurrence of affected eelgrass outside the treated area very limited. *Z. marina* seedling density one-year after treatment was higher treated beds than untreated beds.

EAST COAST AQUACULTURE PERMITTING: LESSONS LEARNED FROM 14 STATES THAT ARE STILL WORKING THIS OUT (BMPS FOR REGULATORS)

RHEAULT*, Bob, East Coast Shellfish Growers Association

On the east coast we have fourteen states and five Army Corps Districts that are each developing their own regulatory approaches to shellfish farming. The approaches are about as varied as one can imagine. In states where the regulatory hurdles have been cleared we see oyster sales climbing at 20 percent annually with permits being granted in as little as three months.

Meanwhile at least one state is struggling to clear the way for its first lease.

Time won't permit a comprehensive review of the regulatory matrix for all 14 states, and in many states regulations are in a dynamic state of flux. I will therefore attempt to describe the approaches that work well (and those that don't) to guide the development of workable regulations by regulators who would like to foster the responsible growth of sustainable shellfish culture and green jobs in their states.

ACIDIFICATION QUESTIONS: A PLEA FOR BETTER SCIENCE

RHEAULT*, Bob, East Coast Shellfish Growers Association

Ocean Acidification is the simple result of adding CO₂ from fossil fuel combustion to seawater. Dissolved CO₂ can also come from decomposing organic matter or coastal upwelling. As we pump gigatons of CO₂ into the atmosphere from fossil fuels, much of it dissolves in the oceans where it depresses pH making it harder for shell-forming organisms to grow. There are also other climate changes that are impacting aragonite saturation levels. The last time CO₂ levels were as high as we are projecting for the end of this century there were mass extinctions in the marine environment.

Unfortunately, based on the scientific work I have been reviewing, it is still unclear how these projected changes will impact the shellfish aquaculture industry in the decades to come. I will share some of the scientific uncertainty and present some of the conflicting evidence that suggests we will need much better scientific studies before we can confidently predict the future impacts of OA on shellfish.

TIME TEMPERATURE INDICATORS (TTIs) – CURRENT APPLICATION AND USAGE FOR Vibrio MONITORING IN SHELLFISH

RONNOW*, Peter

Dr. Ronnow will examine the collaboration between regulators, industry and Swedish based Vitsab International AB in the development of a full function time/temperature monitoring device calibrated for vibrio doubling times.

THE INCREASING PREVALENCE OF TANNER CRAB (*Chionoecetes bairdi*) AS BY-CATCH IN THE PUGET SOUND COMMERCIAL DUNGENESS CRAB FISHERIES.

ROTHAUS*, Don, Don VELASQUEZ, Washington Department of Fish and Wildlife

Starting in January of 2011, the Washington Department of Fish and Wildlife (WDFW) received reports from commercial crabbers regarding significant numbers of Tanner crab (*Chionoecetes bairdi*) occurring within Dungeness crab pots in the Eastern Strait of Juan de Fuca and San Juan Archipelago. Similar reports in mid-December 2011 prompted a joint WDFW Tribal effort to conduct focused surveys of the Smith Island area in the Eastern Strait of Juan de Fuca and assess the relative abundance and catch rates of Tanner crab. Surveys were conducted in January 2011, March 2013, February 2014, August 2014 and January 2015. Later surveys included some additional areas in the San Juan Archipelago. Three pot styles were used with varied effectiveness. Temperatures were taken at pot depth during February and August 2014 and January 2015. In January 2015 State and Treaty fishery managers formalized agreements to allow a limited take of *C. bairdi* as by-catch during the active Dungeness crab commercial fisheries. A summary of the survey data, landings data and theories regarding the sudden increase in Tanner crab by-catch are presented.

THE SOCIO-ECOLOGICAL SYSTEM OF RAZOR CLAMS AND THE QUINAULT INDIAN NATION: MODELING THE POTENTIAL IMPACTS OF OCEAN CHANGE ON A STEADFAST FISHERY

RUDD*, Merrill, Katherine CROSMAN, Eleni PETROU, Michael TILLOTSON, University of Washington

On the outer coast of Washington state, cultural values and traditional lifestyles are closely entwined with the marine resources affected by ocean change (e.g. climate change, ocean acidification, fishing, coastal development, etc.). Our research explores how ongoing ocean change may challenge the social-ecological system surrounding the Quinault Indian Nation's razor clam harvest. We conducted semi-structured interviews with Quinault tribal members, scientists, and resource managers to generate a conceptual model of the social-ecological system, which we use to 1) understand the emergent effects of changes in availability of razor clams and

2) explore how the tribal community might prepare for or adapt to these impacts. We find that razor clams are a staple food and key income source for the Quinault people due to their high abundance, low cost to harvest, and long season of availability relative to other natural resources. Low-income families experience disproportionate economic impacts during razor clam harvest closures, but less tangible social and cultural impacts are felt broadly throughout the community. Although razor clams have been abundant and safe for harvest in many recent years, the Quinault perceive many threats to the resource, including climate change, harmful algal blooms, pollution, and habitat damage. We use the perceived risks identified from the interview results, along with expert interviews and peer-reviewed literature, to develop several scenarios relating to ocean change. Using a stage-based population model of the Pacific razor clam, we explored the relative impacts of these scenarios on annual razor clam harvest over a twenty year period. The simulation of scenarios was developed in a user-friendly web-based application as a planning tool for the Quinault Indian Nation, to explore qualitative connections between ocean change, razor clam availability, and community-level variables such as indigenous health and well-being and income. This work is an ongoing effort from graduate students in natural resource policy and fisheries science as part of the IGERT Program on Ocean Change at the University of Washington.

DETERMINING EFFECTIVENESS OF DUNGENESS CRAB ESCAPEMENT IN DERELICT TRAPS COMMONLY USED IN THE WASHINGTON WATERS OF THE SALISH SEA

RUDELL*, Paul, Natural Resources Consultants, Inc.

Joan DRINKWIN, Jason MORGAN, Northwest Straits Foundation

Kyle ANTONELIS, Natural Resources Consultants, Inc.

The prevalence and impacts of derelict crab traps in the Washington waters of the Salish Sea have been well documented by partnering organizations and agencies within the region. Several efforts have been made to reduce trap loss, extract accumulated traps and reduce the impacts (i.e., Dungeness crab mortality, habitat degradation) of traps that become derelict. When properly equipped with legally compliant biodegradable escape cord, a derelict trap becomes "disabled" upon escape cord degradation, allowing an egress route for entrapped crab to escape. However, among the multiple trap designs commonly used in the region, the effectiveness of escapement varies. A laboratory experiment simulating derelict traps was conducted to analyze the escapement effectiveness of 13 trap designs, some equipped with simple modifications. The least successful trap designs in allowing crab escapement were those with escape routes that

require crab to push open a door situated on the topside of the trap, offset from the edge. Escapement effectiveness in these traps improved when equipped with a bungee, designed to spring the door open upon escape cord degradation, but escape rates still did not reach the desired 1.00 escapee per crab tested. The traps most successful at allowing crab escapement were those that provided an unobstructed escape panel either on the wall of the trap or along the edge of the topside of the trap. Traps that are not initially designed with this feature can be easily modified by detaching one escape ring, and re-attaching it with escape cord. The opening in the trap following escape cord degradation from the ring falling to the seafloor provides crab the ability to freely escape. This was the first reporting of escapement effectiveness from derelict crab traps of the region, and results can assist in resource management and gear manufacturing decisions.

THE EFFECT OF MICRO ALGAL DIET ON GROWTH AND SURVIVAL OF THE CALIFORNIA SEA CUCUMBER (PARASTICHOPUS CALIFORNICUS)

RYAN*, Stuart, Ryan CRIM, Alice HELKER, Puget Sound Restoration Fund

The California sea cucumber (*Parastichopus californicus*) is currently being investigated for its aquaculture and restoration potential. Micro-algal diets used in hatchery rearing of sea cucumber larvae have the potential to impact survival and growth during the critical larval stage. In this study the effects of 8 different micro-algae species on growth and survival of California sea cucumber larvae were assessed. Larvae were fed single and two species diets from 3 days post hatching until settlement. The results of these feeding trials will be presented in this session.

FUNCTIONAL ROLE OF SHELLFISH AQUACULTURE HABITATS: COMPARING INVERTEBRATE AND FISH USE OF EELGRASS AND SHELLFISH HABITATS

SANDERSON*, Beth, NOAA Fisheries

Tish CONWAY-CRANOS, Washington Department of Fish and Wildlife

Laura HOBERECHT, NOAA Fisheries

Bill DEWEY, Taylor Shellfish

Kurt FRES , NOAA Fisheries

Shellfish aquaculture provides habitat for invertebrates and fish, yet our understanding of how this habitat compares to native habitats such as eelgrass remains limited. This limitation poses management challenges in the spatial planning of nearshore habitats. Understanding the ecological role played by shellfish aquaculture relative to eelgrass and other habitats will help

resource managers assess potential tradeoffs when planning the sustainable expansion of shellfish aquaculture. We are beginning a new project to better understand the ecological functions provided by shellfish aquaculture. Specifically, we will compare invertebrate and fish communities in shellfish aquaculture and eelgrass habitats. This will involve developing new methodologies to collect data on macro invertebrates and fish use of shellfish aquaculture and eelgrass habitats using underwater video cameras. Results from this work will help inform coastal management decisions made by NOAA Fisheries and the state and local agencies responsible for permitting and shoreline planning. Furthermore, the results will help us to understand the ecological implications of converting among nearshore habitat types.

U.S. V. WASHINGTON: WORKING WITH THE TRIBES AND DETERMINING TRIBAL SHELLFISH HARVEST RIGHTS

SMITH*, Robert

No abstract submitted.

HOW NANOOS REAL-TIME AND CLIMATOLOGICAL DATA PRODUCTS CAN AID UNDERSTANDING OF WATER CONDITIONS AND VARIATION

SPRENGER*, Amy, Jan NEWTON, Emilio MAYORGA, Troy TANNER, Burke HALES

The Northwest Association of Networked Ocean Observing Systems (NANOOS) has worked with the shellfish grower community for years to provide data and data products relevant to growing shellfish in a dynamic and changing coastal ocean. Currently, several web-based apps are available for easy access to useful information. The NANOOS Visualization System (<http://nvs.nanoos.org/>) offers access to many real-time water quality data streams from the Pacific Northwest (PNW) via our Shellfish Growers app. This app also has the capability to make plots for comparing several variables to co-variation. Through our NOAA-funded work to develop a new pCO₂ sensor, we developed the IOOS Pacific Region Ocean Acidification (IPACOA) portal, which extends the spatial coverage of the datastreams to the entire Pacific coast, with data from Alaska, British Columbia, and California as well as the PNW. Access to offshore NOAA Ocean Acidification Program buoy data allows visualization of gradients or variation between nearshore hatcheries and the offshore coastal ocean. Lastly, we introduce a NANOOS Climatology app that provides users with a rich interface to long-term average conditions (climatology) and present-day departures from average (anomaly). Data visualizations are from buoys, satellites, and weather stations in the Pacific Northwest, enabling users to

compare current conditions against conditions measured in the past. In this way, users can monitor how exceptional or not current conditions are. Recent visualizations during the recent "blob," El Niño, and drought demonstrate how profound some of these excursions have been.

FARM BASED *Vibrio parahaemolyticus* AVOIDANCE TECHNIQUES.

SUHRBIER*, Andrew, Pacific Shellfish Institute

A brief recap on summer 2015 and 2016 deep water holding strategies to reduce and avoid *Vibrio parahaemolyticus* accumulation in oysters. This study looked at oysters collected from intertidal areas with historically high background Vp levels and held at a depths of 50' and below. Vp levels were tested at time of deployment and at 1, 3, 5, and 7 days post deployment. Study results on resulting Vp levels will be discussed.

SEA CUCUMBER AQUACULTURE IN WASHINGTON STATE, AN UPDATE ON A PILOT SCALE STUDY.

SUHRBIER*, Andrew, Pacific Shellfish Institute

A brief update on goals for a project focusing on the development of red sea cucumber (*Parastichopus californicus*) poly-aquaculture for nutrient uptake and seafood export.

1. Examine the genetic population structure of spatially distinct aggregations of the sea cucumber *Parastichopus californicus*.
2. Develop hatchery and nursery technology in Manchester, Washington and Seward, Alaska.
3. Estimate mortality, initial growth, and target densities of sea cucumbers in co-culture with farmed mussels, salmonids or sablefish in Alaska (Ketchikan) and Washington (Totten Inlet and Rich Passage).
4. Quantify sedimentation and water chemistry characteristics prior and during sea cucumber introduction (Dissolved oxygen, pH, carbon chemistry, nutrients, sedimentation rates and size) in Washington (Totten Inlet and Rich Passage).
5. Advance federal, state and local permitting processes for sea cucumber aquaculture in Washington and Alaska.
6. Document and describe required steps for further development of commercial/farm-scale applications.

EVALUATING THE EFFECT OF *Z. JAPONICA* REMOVAL ON THE COMMUNITY COMPOSITION AND UTILIZATION OF INTERTIDAL HABITATS BY FISH AND CRAB IN WILLAPA BAY, WASHINGTON.

SUND*, Daniel M., Oregon State University

Brett R. DUMBAULD, USDA-ARS

Introduction of non-native species often results in fundamental changes in the structure and function of the invaded environment. Interaction between shellfish aquaculture and expanding populations of the non-native seagrass *Zostera japonica* in US Pacific Northwest estuaries has prompted Washington State to allow for selective removal of this plant on aquaculture tracts. We contrasted community composition and habitat utilization between intertidal areas where *Z. japonica* was removed with adjacent control areas and *Z. marina* habitat at three sites in Willapa Bay, Washington. Paired deployment of video cameras and small fish traps revealed the presence of 13 species of fish and invertebrates with the five most common species being three-spine stickleback, shiner perch, staghorn sculpin, Dungeness crab and starry flounder. Although there were differences in abundance by site, results suggest that only starry flounder and shiner perch were influenced by the presence of eelgrass and that most of these animals were either foraging or just transiting the area. Starry flounder were observed more often in treated areas while shiner perch were more often caught in *Z. marina*. Community analyses and comparisons with previous work in Yaquina Bay suggest that the distribution of *Z. japonica* relative to the native *Z. marina* also influences utilization by these species.

EXPLORING DRIVERS OF FECAL COLIFORM POLLUTION TRENDS IN PUGET SOUND

SWANSON*, Trevor, Lindsey HAMILTON, Scott BERBELLS, Lawrence SULLIVAN, Jean SNYDER, Washington Department of Health

Washington State is the leading producer of farmed shellfish in the United States, contributing 270 million dollars to the region's economy and creating over 3,200 jobs. These filter feeders can absorb bacteria, viruses and other contaminants that are in the water. In poor conditions, contaminants can accumulate to the point where the shellfish are unsafe to eat. The Shellfish Growing Area Section (Office of Environmental Health and Safety) at Washington State Department of Health continually monitors and analyzes the potential health impact of over 100 commercial shellfish growing areas, across 300,000 acres of Washington marine waters. For over 25 years they have been collecting fecal coliform bacteria counts from about 1,700 stations

between 6 and 12 times a year. Through collaboration with local government and non-government entities, continuous monitoring allows the department to ensure shellfish are safe to eat, and provide early warnings of water quality impairment. The Water Quality Restoration Program engages with external stakeholders and partners to develop and evaluate ongoing marine pollution identification and correction programs in areas where fluctuating fecal coliform bacteria counts put shellfish harvest beds at risk. Trend analysis is important for ongoing evaluation of program success and evaluating the impacts of changing environmental conditions. This presentation will highlight current efforts to analyze water quality data and develop long-term trends in the interest of identifying historic actions resulting in improving or declining marine water quality. It will discuss challenges in discerning accurate trends through variable water quality data and confounding environmental conditions. Lastly, it will report results and identified actions and activities that have had significant impacts on water quality in shellfish beds.

URCHINOMICS: TURNING AND ECOLOGICAL CRISIS INTO AN ECONOMIC OPPORTUNITY

TAKEDA*, Brian Tsuyoshi, Urchinomics AS, Kaston AS

The Global Challenge

Due in part to the over fishing of predatory species like lobsters, crab, cod and sheephead, sea urchin populations have exploded globally, resulting in the overgrazing of precious kelp forests and sea grass meadows. Urchins that have decimated kelp forests inevitably starve over time, resulting in an ocean floor full of urchins without any of their valuable roe, the yellow lobes of flesh that can fetch up to \$400.00 USD/kg when processed for Asian markets. Predatory species and fishermen avoid catching these urchins, as they have no nutritional or economic value. Left alone, these urchins will either continue to occupy an ocean floor for decades, preventing kelp forests from recovering, or will wander to new areas to decimate other pristine kelp forests. Overgrazing urchins are now a crisis in nearly all countries with active coastal fisheries.

The Solution

Our business model proposes to specifically fish out urchins from the barrens, feed them a specially designed, 100% natural urchin feed once a week for 12 weeks, hold them in custom designed pens hung off of oyster/mussel long lines, and sell them at premium prices to high end restaurants throughout Asia. Through "roe enhancement" of the barren urchins, we are able to increase the roe yield from less than 3% to over 25%. This places high value on the typically

empty and valueless urchins, giving fishermen an economic incentive to fish them and, in partnership with shellfish growers, turn them into potentially the world's most luxurious, sustainable seafood export. And as a result of removing urchins from the barrens, we help turn the lifeless barrens back to a dynamic kelp forest, generating untold value in terms of improved marine biodiversity, improved coastal erosion protection, and carbon capture and sequester.

Results So Far

In partnership with the University of Miyagi, Japanese oyster and abalone farmers have been conducting trials with the feed and pens since 2014. Their results have led to fishermen and farmers earning 10x more for their urchins after having "enhanced" them for just 3 months. On top of this, there is growing evidence that their kelp forests are returning to their original, pristine state. When factoring time, value and effort, urchin "roe enhancement" looks to be the most profitable, sustainable and environmentally IMPROVING aquaculture venture known today. Mitsubishi corporation, Japan's largest conglomerate, has now committed to help deploy our technology throughout Japanese waters to turn the tide against overgrazing urchins, which now adversely affect nearly all coastal prefectures in the country.

Aquaculture to the Rescue

As a result of the Japanese success, Australian, Canadian, American, Greek, Norwegian, and Icelandic shellfish growers, fish farmers and marine conservationist groups are looking to trial the technology by the fall of 2016. In North America, trials are planned in Southern California, Northern British Columbia, Southern Newfoundland and Eastern Quebec in 2016 to evaluate whether the technology can turn their barren urchins into a profitable export product, while improving their coastal ecosystems. Major universities and research institutes will participate in these trials to help ensure that they are conducted appropriately and can yield meaningful results for industry, regulatory and conservationists.

Urchin Barrens in the West Coast: The New Opportunity?

With the exception of some areas repopulated by sea otters, the West Coast of the United States also suffers from significant urchin barrens. Some areas in California for example have already lost over 70% of their kelp coverage due to urchin overgrazing. We would like to explore the possibilities of collaborating with pacific shellfish growers to see if our technology could not only spawn a new, lucrative industry, but also begin to turn unproductive and undesirable urchin barrens back to productive kelp forests.

**PREDICTING GEODUCK REPRODUCTIVE MATURATION WITH PROTEOMIC TOOLS
TIMMINS-SCHIFFMAN*, Emma, Grace CRANDALL, Brent VADOPALAS, Brook
NUNN, Steven ROBERTS, University of Washington**

Geoduck represent an increasingly important aquaculture species in the Pacific Northwest and the expansion of this industry depends on more efficient means of production. Currently, the process of spawning involves guesswork and results in mismatched spawn timing and unknown sex ratios of broodstock. Molecular markers would allow us to non-lethally sample geoduck and make informed decisions as to which clams to spawn. Proteomics, the measurement of the functionally expressed proteins, can provide a snapshot of the cellular physiology at the time of collection. We have leveraged mass spectrometry based proteomic technology to better understand the physiology of geoduck gonadal cells during maturation. In this study, we have 1) characterized the gonad expressed proteome of male and female geoduck at three different reproductive stages and 2) identified peptide-based biomarkers that could be used to assess geoduck sex and reproductive readiness. We developed and applied targeted peptide assays for 22 different proteins, representing cellular processes that are predominantly expressed in early- or late-reproductive stage males or females. These tools represent the first steps towards developing efficient assays that can be used to increase the productivity of geoduck aquaculture.

**HARVESTING 6 1/4 INCH MALE DUNGENESS CRABS - A "BEST MANAGEMENT
PRACTICE"? PERHAPS NOT.**

VELASQUEZ*, Donald, Richard CHILDERS, Washington Dept. of Fish and Wildlife

As much as twelve million pounds of Dungeness crab (*Cancer magister*) are harvested annually from Puget Sound Washington by the combined efforts of tribal and non-tribal commercial fisheries and a large recreational fishery. The fishery is managed primarily by a minimum size (6 1/4 inches), sex (males only), and season, commonly referred to as the "3S" strategy. The guiding assumption of the 3S strategy being that male crab $\geq 6 \frac{1}{4}$ inches are surplus and can be harvested at a high rate and not threaten reproductive success or the sustainability of the resource. Annual exploitation rates as high as 90% of all legal-sized male crabs likely occur in Puget Sound but studies suggest this will not adversely affect the mating success for females. However, fishery managers are questioning whether the size limit is limiting the maximum commercial poundage and value that could be achieved in the fishery. This study presents the potential benefits to the resource and the fishery from hypothetical scenarios whereby the legal size limit is increased for the Puget Sound fishery.

LOW COST OPTICAL TECHNIQUES FOR SCREENING OYSTER SPAT AND LARVAE FOR FITNESS IN A CHANGING OCEAN

WALDBUSSER*, George G., Jessamyn JOHNSON, Lauryn J MOORE, Hannah B. GARCIA, Amy N. LE, Isaiah N. KELA-PACHECO, Nikolai DANILCHIK, Annaliese HETTINGER, Oregon State University

While chemical monitoring of ocean acidification and other ocean chemical conditions has advanced significantly in the past several years along the U.S. Pacific coast, biological monitoring has lagged significantly behind. In order to provide tools to shellfish growers we have modified commonly used staining techniques and developed hands-on tools for rapid assessment of condition and calcification in the field. Utilizing commonly available handheld magnifiers and clip-on cell phone lenses, we will illustrate the techniques and findings from measurements of oyster spat on shell following the first month post-settlement. We will further highlight the automated image analysis techniques for analyzing pictures from smart-phones and describe the potential for a national monitoring program using oyster spat and larvae as sentinel species. We call such a program the Global Oyster Lipid Index (or GOLDI for short).

AN OVERVIEW OF CURRENT RESEARCH IN THE BIRTHPLACE OF MODERN SHELLFISH AQUACULTURE -- THE MILFORD LABORATORY

WIKFORS*, Gary H. NOAA Fisheries

The Milford Laboratory is well known for pioneering work leading to the development of hatchery production of bivalve shellfish seed. In the 21st Century, Milford staff, working with a wide array of scientific collaborators and industry partners, continues to provide innovative research and services focused on the removal of barriers to sustainable growth in US shellfish farming. While opportunities to improve technical procedures for hatchery function remain part of our portfolio (e.g., development of probiotic bacteria for larvaculture and shellfish genetic selection), environmental challenges have gained prominence as seed-production methods have become more reliable, shifting our focus to the field. The importance of disease mortality in oyster production led us to develop expertise in shellfish immunology that we apply to studies of environmental stresses and climate change effects upon health of cultivated shellfish. Beyond supporting shellfish production itself, we have recognized that social carrying capacity – the "social license to farm" – must be addressed with a scientific basis for regulators to have the confidence to permit new shellfish farms. Research on environmental interactions of culture

practices, including infrastructure and harvest methods, and plankton and nutrient dynamics, have been undertaken. Our research is communicated to industry and regulatory communities through traditional scientific products, but also through specialized fora, such as the Milford Aquaculture Seminar and the Milford Microalgal Culture Workshop. We think of ourselves as the Nation's shellfish aquaculture support laboratory and remain eager to provide science and services to our constituents on all coasts.

THAT FLUPSY IN MY BAY, SHOULD I BE WORRIED ABOUT IT?

**WIKFORS*, Gary H., Shannon L. MESECK, Judy Li MAY, NOAA Fisheries
Karen RIVARA, Aeros Cultured Oyster Company**

The Precautionary Principle has placed the burden on the shellfish farming community to demonstrate that the benefits of this industry outweigh collateral consequences; accordingly, evidence leading to a scientific consensus is needed to allow sustainable expansion. In this context, we conducted an intensive study of environmental interactions of a FLUPSY oyster nursery in a very small, enclosed embayment in Riverhead, New York called East Creek. East Creek was an ideal site for such a study because of its small size (630 X 150 m) and linear configuration with clear salt marsh and estuarine end members to accommodate established oceanographic methods. Using an estuarine-transect model, we measured variables at established stations in East Creek over a shellfish-growing season describing the physical and chemical ecology of the embayment, including state variables, dissolved and particulate nutrients in the water column and sediments, and plankton indicators, such as chlorophyll a. We also collected high-resolution (15 min) physical and chemical data at FLUPSY inflow and outflow points and sampled inflow and outflow water for additional variables periodically. Finally, we conducted a mesocosm study to determine if development of the plankton community was different in water that had passed through the FLUPSY compared to unprocessed bay water. Summary findings were that no "signal" of the FLUPSY in underlying sediments was detected relative to variation throughout the embayment. A slight enrichment in water-column dissolved inorganic nitrogen was detected in the vicinity of the FLUPSY which brought N:P closer to the Redfield ratio of balanced nutrients. Seed oysters in the FLUPSY, which doubled in biovolume every 3-7 days during high-growth periods, removed only a small percentage of the chlorophyll-containing particles.