PCSGA 2021 Research Priorities

SUMMARY
Based on input received at the December 10, 2020 virtual Board meeting, the PCSGA's ad hoc Research Committee reformulated a list the PCSGA Board of Directors (BOD) identified as priorities for membership and the shellfish industry generally. The research topics described below represent the current PCSGA BOD's highest priorities and will likely change with time. Other research needs exist and address other critical, more regional priorities that are not described here, including IPM strategies for controlling burrowing shrimp, research to increase hatchery production and efficiency, among others.

The ongoing purpose of this document is three-fold; to encapsulate current priorities for the PCSGA and membership, assist both the research community and funders of PSCGA's research priorities and identify funding opportunities that best match up with industry needs. Together, it is hoped that this document will help the PCSGA and staff to align letters and other kinds of support to best represent PCSGA research interests.

Strategies and Tactics
Research priorities will always need to be refined to fit grant opportunities as they arise. The role of researchers is to secure grant funding for projects that benefit the shellfish industry. Over a calendar year, there is a generous number of requests for proposals (RFP's) from public grant-making agencies. An important role of the PCSGA is to identify and circulate research needs to grant makers, researchers in the region and membership through ongoing communications. The 2015 Goals document, developed by the Pacific Shellfish Institute, describes the large breadth of shellfish related research needs in the region for industry and more broadly (restoration, public health, education, etc.) and is updated every five years. Note that the GOALS 2015 document was not updated in 2020 due to Covid-19 restrictions, preventing PCSGA membership from meeting in person. The Goals document should be updated regularly to reflect PCSGA membership (industry) concerns over the long term and serves the important purpose of integrating the wide breadth of shellfish related research needs and opportunities to a wide audience.

This document, however, seeks to focus on emerging and critical PCSGA BOD research priorities. As times change and new issues emerge or are resolved, this document will focus on the most critical issues facing the industry that basic and applied research can help resolve. This document can also help serve to inform Federal and state grantors and researchers in the near term about how to best frame research RFP's and solutions that best assist the West coast shellfish industry.

PCSGA Research Priorities

1. Ecosystem Services Provided by Shellfish Farms

This research topic is timely given the current permitting climate and increasing need for shellfish industry to provide justification for farming to gain better social license. Emphasis for research should focus on:

- Carbon and nitrogen credit programs are getting closer to reality for industry participation. It will be critical for companies to accurately assess production to take advantage of emerging nutrient credit programs.
- As developing RFP's address nutrient credit opportunities, it will be critical for shellfish companies to collaborate on proposals with NGO's and state resource agencies to validate nutrient credit claims.

A number of RFP's address this topic annually with new interest in quantifying ecosystem services expressed by large NGO's including The Nature Conservancy and the World Wildlife Fund along with NOAA Federal and State grants (Saltonstall Kennedy, FFAR, Nat. Sea Grant, State Sea Grant offices).

Researchable topics important for industry to support:

1. There is a need to quantify the nutrient benefits associated with harvested shellfish in terms of carbon and nitrogen removed from growing waters (sequestered in the meat and shells of harvested shellfish). This required accurate record keeping by companies harvesting shellfish and periodic (e.g., seasonal) assessment of the carbon and nitrogen content of the shellfish harvested in both meat and shell components.
2. There is a need to quantify the amount of nitrogen and phosphorus that is produced by shellfish while growing and deposited as fecal and pseudofecal materials on the tide flats. A portion of this material can be sequestered in the sediments under some conditions and transformed by bacteria to forms of elemental nitrogen that is no longer biologically active and therefore not contributing to the nutrient pool (providing nitrogen for stimulating algal blooms, including harmful algal blooms). These are referred to as nitrification and denitrification sediment cycles associated with shellfish. There has been research on the topic on the US East coast for eastern oysters, but no work accomplished for shellfish here.
3. Gear as habitat studies should be targeted. Quantifying the ecosystem services associated with the use of shellfish gear by fish, invertebrates, birds and marine mammals should be quantified.

2. Investigate Durability of Shellfish Gear

Alternatives to plastics use in aquaculture is important to address industry wide. Initial work should target the plastic cages and other gear used to grow shellfish. This includes grow out bags, geoduck mesh tubes and the variety of floating cages in use today. Limited research to date suggests that the *UV treated manufactured* gear in use today, however, contributes very little plastic degradation into microplastics (particles < than 5mm) polluting the world's oceans and beaches. The vast majority of plastics associated with microplastic pollution are associated with *fibers and plastics that are not UV treated*. The shellfish industry is vulnerable, however to pollution based on plastics associated with ropes and twines and represent a critical problem for the industry to resolve. Alternatives to the use of yellow polypropylene rope in longline oyster culture is a critical need, for example. A second need is to eliminate plastic (nylon) cable or zip ties from one-use applications in shellfish aquaculture.

- Sampling for plastics associated with the aquaculture industry is not difficult and probably not fundable as a research topic. Better to focus on continued beach cleanup efforts and small-scale gear experiments to resolve the waste stream problems.
- Researchable topics do include studying alternatives to plastics based ropes and twines and the PCSGA should support these efforts. Specifically, there is the need to trial alternatives to plastics including natural (e.g., bamboos and coir based twines) and carbon fiber based gear that have outstanding longevity and strength to weight characteristics.
- Support of research that better identifies the source and fate of microplastic generation in the marine environment, including gear associated with the shellfish industry.

3. Quantify Effects of Macroalgae Removal from Shellfish Ground

Macroalgal mats (*Ulva, Enteromorpha* and others) create a significant nuisance for shellfish growers as the materials proliferate on and in gear associated with oyster and geoduck culture and nets used for Manila clam aquaculture. Excess macroalgae cover can result in significant reductions of dissolved oxygen in seawater, especially at night when the plants are respiring, increased hydrogen sulfide concentrations as the material decomposes and reduced flows of fresh seawater around the shellfish. Recent information from the WDFW suggests that removing the algae that accumulates on a grower's gear is a 'grey area' and in need of resolution by WDFW. In the meantime, research on the effects of removing macroalgae should proceed and be supported by the PCSGA.

Researchable topics include the following:

1. Quantify the effect of macroalgae removal on water column dissolved oxygen, water flow and transport, substrate dissolved oxygen, substrate H_2S concentration substrate biology including infaunal and epifaunal invertebrate abundance and diversity in plots maintained free of excess macroalgae compared to control plots with macroalgal cover.
2. Quantify macroalgal production on per square meter basis on a seasonal and geographic basis.
3. Quantify the carbon, nitrogen and phosphorus in seaweeds that are removed as excess nutrients.
4. Investigate means of automating macroalgae removal – including the relative costs and benefits to the health of shellfish. Macroalgal removal methods should be investigated, specifically the means for individual farms to design raft-based Venturi dredge based methods to remove macroalgae from farm beds.
5. Research on product development from harvested macroalgae should be a priority for the PCSGA to support. Uses include soil amendments, compost and fertilizers, among other materials should be investigated.

4. Shellfish Breeding for Increased Production and Sustainability

The PCSGA and shellfish industry continues to express strong interest to retain and enhance the capacity to sustainably and profitably farm oysters and other shellfish into the future. Disease threats have emerged on the West coast at a time that growers are already grappling with ocean acidification and other environmental changes associated with rapid climate change.

The use of genetics and breeding that helps to increase the sustainable production of oysters has been long recognized as an important tool to assist the industry in adapting to emerging threats. University led oyster-breeding programs at Oregon State University and the University of Washington predated the establishment of The Molluscan Broodstock Program in 1996. The MBP (now iMBP) has focused mainly on increased yield in Pacific oysters and maintaining stocks of Kumamoto oysters among other priorities. Other emerging shellfish breeding efforts are focused on crossbreeding in combination with selection, coupled with polyploid development.

The recent reemergence of an ARS funded position and laboratory in Oregon is encouraging and the Industry should support the position and develop collaborations when possible, with new research being developed at the ARS laboratory currently.

PCSGA BOD Priorities:

- With the recent detection of ***Ostreid herpesvirus 1*** (OsHV-1 μvar), or Pacific Oyster Mortality Syndrome (POMS) in the United States, there is critical interest to conduct primary research on 1) genetic mechanisms in oysters associated with resistance; 2) the application of breeding approaches to provide genetically based resistance to POMS in broodstock for subsequent seed production; 3) the means to build the industry's capacity for disease surveillance and breeding for resistance to herpes microvars; 4) the potential for ***Ostreid herpesvirus 1*** (OsHV-1 μvar) to impact other species including commercially important clams and Kumamoto oysters, and; 5) the means to utilize a suite of coast-wide growers to assist in POMS research, including, for example Alaskan growers to maintain genetic lines potentially resistant to POMS in the cold waters there.

- There is strong Interest in developing oyster lines resilient to OA as growers recognize that OA impacts will increase in the years ahead making it increasingly difficult to maintain larval and seed supplies in the face of increasingly corrosive seawater.

- There is strong interest to utilize breeding approaches to decrease mortalities in both diploid and triploid oysters grown on intertidal beds exposed to high summer temperatures and warmer mean seawater temperatures.

PCSGA BOD priorities related to breeding for increased production traits in shellfish other than Pacific oysters on the US west coast include:

- Breeding in Manila clams is a priority with the development of clams with unique shell patterns (e.g., designer clams). The production of triploid clams is desired by a number of companies on the US West coast where Manila clams are farmed.

- Breeding in Kumamoto oysters combined with more widely available seed is an important need expressed by a number of companies.

- Support safe and sustainable alternatives to producing sterile shellfish outside of traditional triploid and tetraploid production technologies. This specifically includes research on identifying and silencing early sex-determining genes during embryogenesis.

5. Quantifying Ecological Equivalency Between Shellfish Farms and Eelgrass Beds including Ecosystem Services Provided by Shellfish Farms

Shellfish growers on the west coast have farmed in and around eelgrass beds for over a century. In recent years, resource management agencies with statutory requirements to protect critical habitat for threatened and endangered species and essential fish habitat for federally managed species have become much more critical of shellfish culture activities in and around eelgrass. Army Corps Programmatic Nationwide Permit 48 requires new farming activities to buffer out of eelgrass and restricts oyster culture to certain off-bottom techniques with prescribed spacing in fallow areas with eelgrass. *To avoid further restrictions there is an urgent need for research to understand the habitat value of various shellfish crops and gear in comparison to eelgrass, optimal eelgrass densities for habitat functionality and the potential merits of farming in a way that preserves eelgrass patches and increases edges for optimal foraging and refuge.* This is generally referred to as assessing equivalency among and between habitat types (e.g., on-bottom oyster culture compared to native eelgrass beds). The Pacific Shellfish Institute has done initial work developing a Habitat Suitability Index as a tool to assess the habitat value of various culture methods and mixed eelgrass systems for managed species of interest. There is a need to refine this and/or other tools that allow for a comparative analysis of the relative habitat value of shellfish crops and gear and varying densities of eelgrass for various species.

PCSGA BOD Priorities:

- Equivalency of eelgrass to mature oyster habitat in terms of the ecosystem benefits provided should be better understood. Emphasis on fish use of oyster beds (esp. salmonids), mobile invertebrates (e.g., Dungeness crab) and the capacity for oyster beds to support prey organisms associated with salmonids (e.g., harpacticoid copepods). How equivalent are oyster beds to eelgrass beds based on a suite of measurable metrics?
- While difficult to research because it requires the means to track the behavior of fish for meaningful periods of time over seasonal cycles to assess habitat use in different geographical habitats along the West coast, this work is urgently needed. Video analysis, pop and Fyke net studies, electronic tagging, eDNA approaches have all been used in past studies, mainly led by Brett Dumbauld, ARS Ecologist and his co-researchers. Food web analyses have also been an excellent approach to assess what habitats migratory fish or their prey utilize. Continued work in this area is urgently required to inform regulators of equivalencies between oyster and eelgrass habitat in order to ease regulatory restraints related to farming shellfish in eelgrass.

- Following up on Jeff Cordell's (UW SAFS) work (recently retired) with the Pacific Shellfish Institute and others on benthic zooplankton populations, including harpacticoids and amphipods important to juvenile out-migrating salmonids, is an important priority.

    - Specific research quantifying the abundance and diversity of salmonid prey items within and adjacent to oyster beds and eelgrass meadows is needed to assess the level of habitat equivalency.

- Research that evaluates this question across the range of West coast habitats and considers different oyster culture techniques and practices (on bottom, bag on bottom, off-bottom longline, flip bag, etc.) is urgently needed.

- Quantify equivalencies of oyster habitat to eelgrass habitat for migratory birds, fish and other commercially important species that utilize eelgrass for food.

6. Automation/Robotics Applications to Shellfish Farming in Sub-optimal Environments

Shellfish farmers continue to face a number of production challenges spread across the four primary phases of recurring farm activities: Planting, Crop Tending and Maintenance, Harvest, and Packing/Shipment. All these activities are labor intensive, and labor is increasingly difficult to find and maintain for many companies.

At the same time, research is critically needed on developing methods to farm shellfish in sub-optimal environments, including farming in burrowing shrimp ground and supporting research on the impacts of mechanical/non-mechanical control of shellfish pests and predators.

Robotics technologies in several other industries are advancing rapidly in terms of both function and affordability. Next generation optical oyster graders, for example have revolutionized handling time and sorting chores for larger growers. At the same time, sea-based robotics are likewise advancing and bringing along with them the designs and materials appropriate to the marine environment. Particularly important is research on ways to farm sub-optimal environments, including ground inhabited by burrowing shrimp. Fortunately, robotics technologies and costs are becoming more appropriate as practical labor substitutes in shellfish farming. Across many critical enabling factors, technology and affordability trends support near-term advances in this domain.

Research topics include:

1. Document the value chain of the major shellfish farming species/method combinations with special emphasis on labor requirements and quality.
2. Develop low cost systems for farming/monitoring sub-optimal intertidal ground with work potentially occurring during mid to high tides using robotic approaches, underwater drone technologies, specialized watercraft, etc. to avoid necessity for working at low tides.

3. Develop a high-level cost model for the major shellfish farming species/method combinations with special emphasis on labor requirements and critical quality factors. Extend this model include industry level estimates of the impact of labor shortages, escalating labor rates, and the potential value of labor substitution
4. Conduct a survey of the marine science and robotics industries to identify new and converging technologies, and related industrial entities, which would be candidates for participation in applied research projects focused on new, cost-effective robotic technology labor substitutes in shellfish farming.

7. Research on Public Health and the Shellfish Industry

Maintaining and improving the quality of growing waters remains the highest priority for the shellfish industry. However, primarily a task for State and Federal regulatory agencies, the maintenance of certifications of growing waters for shellfish production remains an urgent need. Research on the public perception of the shellfish industry and its reliance on excellent water quality is needed relative to threats associated with *Vibrio parahaemolyticus* and *V. vulnificus*, HAB's and Norovirus relative to public health.

Research priorities include:

- Increase capacity to forecast emergence of virulent *Vibrios* in shellfish growing waters that impact shellfish.
- Increase capacity to forecast emergence of Harmful Algal Blooms (HABs) impacting growing waters including the capacity to model emergence of HABs at a finer (bay-scale) resolution than currently available.
- Increase capacity to forecast emergence of Norovirus threats.
- Public perceptions of shellfish relative to urgent necessity to maintain certified growing waters on the US west coast

8. Achieving Increased Resiliency in the Shellfish Industry

The shellfish industry operates in a social environment without significant governmental support, unlike other forms of agriculture. Examples abound associated with the difficulty and expense associated with permitting shellfish farms for continued operations. This is ultimately due to a lack of public support to operate and it is incumbent for the industry to work to increase their *collective social license* to operate in a social environment that often does not understand nor appreciate the values shellfish farming bring to communities. Research is needed in the following areas.

1. Quantify economic value of industry and contributions to communities in terms of direct and indirect employment. This metric needs development and should be developed and marketed as a published, annual contribution of shellfish farming to the economic and social health of communities.

2. Story-telling to local media (print, podcast, and doc. filmmaking) about the value of family shellfish farms to their communities is needed and a powerful means of increasing trust (and social license to operate) within local communities.
3. Workforce and market sector development is urgently needed to increase attractiveness of employment opportunities on shellfish farms. At the same time, there is a necessity for research on automation (see #6 above) to reduce reliance on farm labor for basic operations.
4. Increase social license for shellfish farming by providing unbiased research on ecosystem benefits and services shellfish farms provide (see # 1 above). Public trust in shellfish farming can increase if benefits and services shellfish farms provide can be effectively demonstrated and communicated to the public.
5. Environmental education with emphasis on how shellfish can enhance the health of the marine environment is needed to increase public acceptance of shellfish farming and combat inaccurate information provided to the public by NGO's averse to shellfish farming.