An Assessment of the Environmental Impacts of Marine Shellfish Aquaculture In the USA

Daniel Cheney[1*]; Ralph Elston[1]; Andy Suhrbier[1]; Jonathan Davis[2], Robin Downey[3], Carter Newell[4], John Richardson[5], Tessa Getchis[6], Jamie Vaudrey[6], Dror Angel[7], Mark Luckenbach[8]

[1]Pacific Shellfish Institute, Olympia, WA USA; [2]Baywater Inc., Bainbridge Island, WA USA; [3]Pacific Coast Shellfish Growers Association, Olympia, WA 98501 USA; [4]Great Eastern Mussel Farms, Tenants Harbor, ME USA; [5]Blue Hill Hydraulics, Blue Hill, ME USA; [6]Connecticut Sea Grant, University of Connecticut, Groton, CT USA; [7]University of Haifa, Haifa, ISRAEL; [8]Virginia Institute of Marine Sciences, Wachapreague, VA USA

cheney@pacshell.org

BACKGROUND

The past two decades have seen a rapid expansion of alternative and innovative methods for the cultivation of oysters and hard-shell clams; however, there is little information on the affects of these practices on the surrounding environment. The project proposed, and currently in progress, by the Pacific Shellfish Institute (PSI) and its collaborators is an environmental and technical assessment of alternative methods to cultivate bivalve shellfish, and will include the development of specific guidance for modifications and improvements in those methods. This project addresses a suite of economically important alternative shellfish production practices which are not addressed by existing or past research projects on either coast of the U.S., but have been subject to increasingly critical environmental and regulatory oversight. These include cage and bag-on-bottom, bag-on-rack or bottom suspended oyster and clam culture, net-protected or enhanced clam culture methods, and effects of these practices on critical habitats such as submerged aquatic vegetation (SAV), and endangered or threatened species such as migratory fishes. This research is being conducted in collaboration with representatives of the East and West Coast shellfish industries and is focused to meet the goals and objectives of the National Marine Aquaculture Initiative and the North American West Coast Shellfish Industry 2010 Goals Research and Initiative Priorities, and to satisfy the research priorities of the Northeast Regional Aquaculture Center and the East Coast Shellfish Growers Association.

GOAL

The goal of this project is to provide the industry with the information and tools to move forward proactively in achieving the regulatory compliance needed to assure it can continue to operate sustainably and viably far into the future.

OBJECTIVES

1. **Characterize and quantify the effects of alternative shellfish culture methods on eelgrass.**
2. **Assess and compare benthic infauna and epifauna species, juvenile salmonids, shrimp and crab diversity, density, and biomass within and adjacent to shellfish culture and control sites.**
3. **Determine sediment and water column interactions associated with culture method and compare with control conditions.**
4. **Model carrying capacity, phytoplankton concentrations, sedimentation and planting densities for different submerged and floating aquaculture methods.**
5. **Develop recommendations for modifications to growing methods to reduce adverse, and maximize positive, environmental effects and improve production efficiency and yield in an ecologically-sound and economically-viable manner.**

This presentation represents field work conducted in year one of a four year study. Results and key points are preliminary. Detailed information for each task is available.

TASK 1.

***Characterize and quantify effects on eelgrass.* This task was conducted to determine the direct and indirect impacts of submerged shellfish depuration gear on eelgrass.**

Eelgrass (*Zostera marina* L.) beds provide critical ecological functions such as removing nutrients and stabilizing fine sediments. Coast wide, eelgrass is on the decline in most estuaries due to human impacts, primarily nutrient enhancement. Due to the increasing loss of eelgrass, much attention has been focused on investigating potential impacts to the resource, and determining methods to minimize these impacts. In many areas, bivalve aquaculture coexists with eelgrass, and the gear provides essential habitat and refuge for a wide variety of estuarine fish and invertebrates. Bivalve aquaculture also has the potential to alleviate eutrophication by incorporating phytoplankton produced by nutrient loading into biomass, which is removed and marketed. Conversely, there is the potential for local negative impacts from gear, due to uprooting, scouring, shading and increased organic deposition.

Preliminary studies were conducted to assess the impacts of submerged oyster depuration cages (Figure 1) on eelgrass. The experiment was conducted at field sites in eastern Long Island Sound, Connecticut. These cages are used for depuration and have relatively short (two week) soak times in comparison with grow-out cages. Indirect effects were analyzed by water and sediment quality measurements (dissolved oxygen, chlorophyll *a*, turbidity, benthic microalgae and sediment % organics). Measurements were taken at control and experiment plots in triplicate. Direct effects of cages on eelgrass (uprooting, scouring) were inspected visually and also analyzed using the following eelgrass parameters: dry weight biomass; short shoot density; canopy height; sheath length; plastochrone interval and new leaf area.

Figure 1. Typical oyster depuration cage measuring 0.9m^2 (0.45m in height). Cages have 'legs' on each corner which reduce the area of direct contact with the sediment.

Key Points

- No significant difference in water and sediment quality parameters among treatments.
- Significant differences in eelgrass growth was observed among treatments. Eelgrass exhibited increased growth rates at treatment versus control sites.
- Uprooting of fronds and/or scouring was not observed at treatment sites.
- Indirect effects of oyster cage culture are difficult to detect in a well-mixed estuary, especially when cages are set in low densities; the effects of culture may be negated by dilution.
- Direct effects of cages are minimal during short-term gear soaks, however additional studies are necessary to determine additive impacts; longer term soaks have been shown to cause damage.

TASK 2.

***Quantify biological effects.* This task consisted of an assessment and comparison of fish and invertebrates species' diversity, density, and biomass across habitat types in shellfish aquaculture and control sites.**

Infaunal, epifaunal and sediment sampling was completed at shellfish culture and control sites in Puget Sound. A total of five treatment groups were assessed, along with appropriate control sites. Treatment groups and associated abundances are noted in Figures 2 and 3 where sample locations (culture areas and areas adjacent) are displayed on the x axis. To date, a limited subset (generally 3 of 10 sampled replicates) of samples from a single site have been sorted and analyzed.

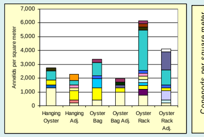

Figure 2. Average total annelid abundance (#/m^2) in shellfish culture and areas adjacent at Thorndyke Bay, fall 2004.

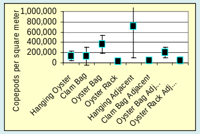

Figure 3. Average total copepod abundance (#/m^2) in shellfish culture and areas adjacent at Thorndyke Bay, summer 2005.

Key Points

- Findings from this data set indicate marked culture-specific variations in infaunal and epibenthic abundance and taxa.
- Annelid abundance was greater under the oyster culture system than in adjacent control sediments, whereas abundance of epibenthic taxa (copepods) varied among treatments.
- Although these differences are not significant, they indicate a limited effect of the culture systems on the abundance and species richness of the sampled taxa.

In Virginia extensive mats of the macroalgae *Gracillaria* sp. and *Agardhiella* sp. form seasonally on the nets of cultured hard clams *Mercenaria mercenaria* (Figure 4). To investigate the potential role of this macroalgae as habitat for decapod crustaceans we sampled this macroalgae and two adjacent habitats, seagrass beds and barren sand bottom during the fall of year 1 of this study. Ten replicate samples (572.3 cm^2) from haphazardly selected locations in each habitat type were sampled using a gasoline powered suction sampler that remove all macroalgae and sediments down to a depth of 5 cm. Samples were screened on a 2 mm mesh and all crabs removed, identified and measured.

Figure 4. Aerial view of clam nets with macroalgae.

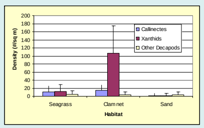

Figure 5. Mean (+ SD) of crab abundances by habitat type in Virginia.

Key Points

- Sampling revealed that the macroalgae on clam nets had densities of *Callinectes* that were comparable to those found in seagrass beds and significantly greater than adjacent sand bottom habitat (Figure 5).
- Mean density of Xanthid crabs in the macroalgae exceeded those in the other habitats by more than an order of magnitude.

TASK 3.

***Assess sediment and water column effects.* This task involved physical and water quality profiling of culture sites with collection of field data on water currents, pH, dissolved oxygen, chlorophyll, phytoplankton, and other variables required for simulation modeling and determination of site specific differences.**

Data collection relied on the use of different kinds of field-grade instrumentation (*e.g.,* S-4 current meters and specially configured Seabird CTDs) and the development of special dye testing techniques used to visualize the movement of water through the different culture units (Figure 6).

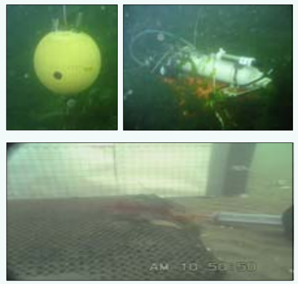

Figure 6. Data acquisition equipment and methods.

Key Points

- Significant differences in phytoplankton consumption were measured at the different study sites and these differences correlate closely with observed shellfish growth rates (*i.e.,* where phytoplankton consumption was low growth rates were less).
- Results of the dye studies indicate that the design of aquaculture gear plays an important role in determining phytoplankton availability areas used for shellfish culture.
- An additional challenge for the data collection stemmed from the fact that many of the study sites were in inter-tidal waters (Figure 7)
- Data gathered in this task was used as input for the computer models developed in Task 4.

Figure 7. Modeling environmental interactions becomes complicated at intertidal sites such as this geoduck farm location in Washington State.

TASK 4.

***Conduct simulation modeling.* This task included: (1) the construction of three-dimensional flow models of the farming locations studied in Tasks 2 and 3; (2) the formulation of special algorithms to estimate shellfish growth based on rates of food uptake; and (3) the use of particle tracking algorithms to determine the fate of suspended solids produced by the aquaculture activities.**

The completed numerical models provide a quantitative framework from which the impact of different alternative shellfish culture practices can be compared (Figures 8, 9).

Key Points

- Results of the modeling confirm many of the conclusions drawn from the results of the field surveys.
- In the case of bottom clam culture, for instance, the results indicate that clams should grow faster under nets than within bags. This is do in part to the presence of biofouling and its affect on flow patterns through the bags.
- Additional work with the numerical models is currently being completed.

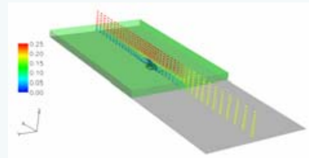

Figure 8. Calculated Flow through Depuration Cage (CT)

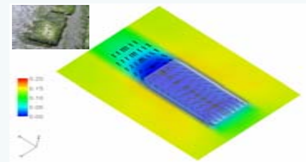

Figure 9. Calculated Flow through Clam Bag (WA)

TASK 5.

***Present recommendations and guidance for alternative shellfish culture practices.* The goal of the outreach program is to provide stakeholders with the knowledge to make informed decisions about shellfish aquaculture siting in the coastal environment.**

The research results are being compiled as they relate to specific regulatory concerns, with an emphasis on the ecological interactions of the specific culture practice. The findings will be published: 1) in a technical bulletin that will provide farmers with information on how to modify their growing methods to reduce adverse, and maximize positive, environmental effects and to improve production efficiency and yield; 2) in an booklet to provide resource managers with data to make informed decisions about aquaculture permitting; and 3) in peer-reviewed scientific reports. A comprehensive online database on shellfish aquaculture and the environment has been developed and will be maintained by the Pacific Shellfish Institute. Search the database at: http://www.pcsga.org/Research/Webliography/Biblio_Search.asp