Geoduck Culture in Puget Sound: Environmental Interactions

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This is a summary of environmental interactions and a response to public comment regarding the culture of geoduck clams in Puget Sound. This summary was prepared by the Pacific Shellfish Institute (PSI) and incorporates available research reports, and field experiences and observations by PSI and university researchers. PSI is a non-profit organization whose charge is to develop and disseminate scientific and technical information of value to the general public, shellfish farmers, and public officials related to environmental and health safety issues arising from shellfish aquaculture.

An Overview

The past decade has seen an expansion of intertidal geoduck aquaculture in Washington State and in the use of alternative and innovative methods for planting, cultivation, and harvest of these valuable shellfish. This has prompted new areas of research focusing on the both the environmental effects of the expanded farming operations and the influences of natural and man-made factors on geoduck.

Geoduck research has been and is being conducted by various companies and institutions in Washington State. A two-phase Small Business Innovation Research (SBIR) project was funded by the U.S. Department of Agriculture from 1999 to 2002. In Phase I, Taylor Shellfish Farms and PSI identified and tested various factors that were important in the success of planting geoduck seed in specific geographical areas of south Puget Sound. In Phase II, commercial scale production methods and equipment were employed to determine optimum production efficiencies and yields. More recently, the Western Regional Aquaculture Center (WRAC) funded a project led by Jennifer Ruesink (University of Washington Biology Dept) to assess the potential for sediment nutrient fertilization of eelgrass beds by suspension-feeding geoducks. Currently, the Hood Canal Salmon Enhancement Group is assessing the feasibility of using natural or cultivated stocks of geoducks to offset the effects of increasing eutrophication in Hood Canal. This organization is gathering data on geoduck filtration rates utilizing seed money from the Washington State Department of Ecology (DOE).

Early next year (2007) PSI will commence NOAA funded research to carry out feeding and filtration experiments in the field using a combination of underwater video, and water current and flow modeling. This will be coupled with an intensive study of habitat usage by fish and mobile crustaceans on geoduck farms. Later next year, the University of Washington, partnering with PSI, is in line for additional funding from NOAA to address a number of issues related to the environmental interactions of geoduck aquaculture. However, while the project is highly ranked, funding for the entire NOAA aquaculture program is uncertain. If the project does move ahead, the study will: 1) identify effects of predator protection methods on sedimentation, gross biomass, and salmonid prey species are different between treatments; 2) characterize differences between diploid and triploid geoduck in maturation, gonad occupation rate, growth, survivorship, and spawning; 3) describe the effects of geoduck harvest on sedimentation, gross benthic biomass, and salmonid prey; and 4) conduct other relevant genetic, growth and maturation, and biological research..

In summary, the aforementioned studies, have or will be addressing, the following environmental effects over the course of culture operations: 1) altered/enhanced recruitment and growth of eelgrass/macroalgae; 2) altered biodiversity and production of infauna and mobile macro-fauna including fish and shellfish; 3) changes in essential fish habitat as result of 1 & 2; and 4) and near-scale or localized changes in water quality and sediment composition. These and other possible effects are being explored and documented on and near cultured beds to ensure the steady expansion of geoduck aquaculture beyond existing bedlands.

Responses to Public Comment Regarding Geoduck Aquaculture

1. How much plastic enters the marine environment as a result of geoduck cultivation?

The dominant culture method temporarily installs approximately 40,000 PVC pipes, 9-12 inches long, 4-6 inches in diameter per acre. These are present for the first 1-2 years of a 5-7 year crop cycle. Each of these tubes is covered temporarily with plastic netting which is secured with a ultraviolet resistant rubber band. The shellfish growers within their environmental codes of practice has a goal of not allowing any man-made debris to escape from their farms. This has proven difficult with geoduck culture because current methods require large quantities of predator exclusion tubes, net covers and rubber bands. To mitigate the debris issue most growers do frequent patrols of their farms and beaches in proximity to them to retrieve materials which may have dislodged from the beach. In addition to individual efforts, the growers scheduled clean-ups in the spring and fall which cover broad areas beyond the farms. Beaches which are noted for accreting aquaculture materials are targeted for more frequent patrols. The beach cleaning by the growers is not limited to aquaculture debris but also includes other debris. In March of this year 10 different farms participated in a clean-up with a total of 75 people picking up debris from approximately 27 miles of beach. This effort recovered approximately 60 cu yds of debris with approximately 6 cu yds of it being from aquaculture. During two beach cleanups in 2005 geoduck farmers removed about 90 cu yds of debris with 13 of it from aquaculture. All of the aquaculture debris was separated and quantified by type (geoduck predator tube, nets, rubber bands, Manila clam harvest bags, harvest identification tags etc.) and the results were reported to geoduck farmers to facilitate eliminating the source of the problem. The areas cleaned in South Puget Sound included parts of Oakland Bay, Hammersley Inlet, Totten Inlet, Skookum Inlet, Eld Inlet, Budd Inlet, Henderson Inlet, Case Inlet, Carr Inlet, Dana Passage, and Nisqually Reach.

Geoduck farmers work actively to reduce the amount of man-made materials escaping from culture sites. Much of what is shown in concerned citizen photos as "debris" consists of predator exclusion tubes dislodged by geoducks as they mature. Tubes are typically pulled for re-use on other planting before they are pushed out of the sediment. They are of significant value to growers and will be recovered and re-used in subsequent plantings. It is more appropriate to classify these dislodged tubes as "clutter" rather than debris. In addition, growers are continually investigating new culture techniques to reduce man-made material requirements, production costs and aesthetic impacts. As one example, they are testing the application of large nets to cover the tube fields and retain tops and tubes that come loose. These nets mitigate the aesthetic impact of newly installed predator tubes and in some cases eliminate the need for individual tube covers and the associated rubber bands.

2. Can sediment contamination be caused by weathering of the PVC pipe for the length of time it is in place?

The recent literature has indicated a potential health risk associated with certain forms of PVC. However, the pipe supplier to Taylor Shellfish, PW Eagle, states that no PVC contaminants, such as cadmium, lead, or pthalates, are incorporated in the manufacture of the rigid pipe used for predator exclusion. There is no more, and less as a percentage of total material, tin compounds used in this pipe than is used in drinking water supply pipe. Drinking water supply pipe meets standards for human health, so we can use this as a comparison for the potential leaching of tin in the marine environment. A similar comparison to drinking water pipe can be made for the presence or leaching of vinyl monomer.

Another insight into potential harm to the marine environment from PVC pipes can be gained from the shellfish hatchery experience. Oyster larvae are very sensitive to environmental contaminants and are used for bioassays because of their extreme sensitivity to organic and inorganic pollutants. Shellfish hatcheries and bioassay laboratories have successfully used PVC pipes for decades in rearing and holding oyster and other bivalve larvae.

Based on these observations, the use PVC pipe used for geoduck predator exclusion will not result in leaching of contaminants into the surrounding sediments.

3. Over time, does the field of pipe recruit and retain sufficient material to alter the bathymetry of the site and are these changes sufficient to alter the habitat type (subtidal or intertidal)?

SBIR, PSI and UW researchers have not observed elevation changes on geoduck beds which can be attributed to the presence of a tube field. Large-scale accretion and erosion events on Puget Sound beaches appear to be mainly the result of during winter storms and boat wakes. There are presently a number of sites in Puget Sound which have gone through a complete geoduck culture cycle from planting to harvest and replanting. If there was an obvious change in bathymetry it would be visible at some of these sites. PSI and UW scientists will be conducting careful studies at selected sites to monitor less than obvious changes. These will include analyses of sediment grain size and organic content to illuminate changes in sediment and organic materials.

4. Does the pipe field change the interaction of natural light in the project area? What impacts does this change create?

The impact on light from the pipe fields can be considered along with all potential physical and biological impacts of geoduck culture gear. Potential impacts can be grouped into three broad categories: changes to the water column, changes to the sediment, and changes to the species assemblages. Geoduck gear could possibly cause some shading and in turn alter species assemblages within the culture area. Changes due to light would be combined with changes due to habitat structure and best be approached by the broader question of what changes in species assemblages in the culture area are due to the culture gear? The Pacific Shellfish Institute (PSI) has addressed this issue through time lapse underwater videotaping of geoduck culture sites. Further work on the impact of geoduck culture gear on species assemblages will be assessed through the previously mentioned NOAA Aquaculture grants. Furthermore, the Washington Department of Natural Resources (WDNR) is requesting growers to address this issue and the impacts of geoduck culture and harvest. In general, however, it is believed the low profile of the pipe field (extending 2 to 4 inches into the water column) combined with the separation of individual tubes and low bed elevation of the tube field minimize shading effects, if any occur.

5. Does the pipe field create conditions that alter temperature and turbidity conditions within the project area? How do these changes impact the surrounding aquatic and nearshore environment?

PSI collected data on temperature and dissolved oxygen (DO) conditions within and adjacent to geoduck culture areas. With the exception of occasionally increased DO over the tube field as a result of increased macroalgae production, no water quality alterations were recorded. Further study of physical changes to the water column will be performed during the NOAA funded studies, and as required for WDNR monitoring. In addition to the changes in the water column, those studies will include observations to monitor changes to species assemblages in relation to control sites without geoduck culture.

The importance of bivalve populations to the health of an estuary is well documented. Studies from Chesapeake Bay, France and elsewhere demonstrate the importance of bivalve filter feeders in removing excess phytoplankton from the water column. Suspension-feeding bivalves play an important role in estuarine ecosystems as biofilters, significantly enhancing water quality and clarity, and improving growing conditions for other aquatic organisms. The loss of historical oyster reefs in Chesapeake Bay (Newell, et al 1999), and changes seen in the Marenness-Oleron in France and elsewhere (reviewed in Dame 1996) dramatically emphasize these effects. Shellfish play the central role of transforming pelagic production (e.g. phytoplankton) into benthic production. Recent laboratory studies have confirmed that suspension-feeding eastern oysters, *Crassostrea virginica*, in Chesapeake Bay stabilize phytoplankton concentrations, exert top-down control on phytoplankton and reduce turbidities, increasing light penetration to a level that can sustain benthic submerged vegetation (Newell, et al. 2002 and Newell, 2004). While this role has been lost in most portions of Chesapeake Bay, it continues to be an important element in estuaries with robust shellfish populations, such as many areas within Puget Sound.

Cultured geoducks in Puget Sound remove phytoplankton and other organic material and thus sequester nitrogen as protein in their tissues, and upon harvest, the nitrogen is removed from the bay. This may be an important attribute of bivalve culture with increasing human input of nitrogen into South Puget Sound inlets. Documentation of the total nitrogen removed from Puget Sound estuaries and bays due to the harvest of cultured shellfish including geoducks is an area of active research by area shellfish biologists and represents a significant benefit associated with shellfish harvesting activities.

6. What changes in variety and number of species occur within the project area over the time of operation?

PSI has documented a diverse community of organisms using the structure created by geoduck culture gear. Macroalgae (*Ulva*, and others) grow on the pipe, Manila clams and cockles recruit into net protected structures, and kelp crabs find refuge in the open tubes. When the tubes are removed, the benthic biota and fish use on the exposed beaches appears to be very similar to other typical low-intertidal habitats. Diving surveys performed by SBIR personnel indicated a variety of organism that move into geoduck culture areas to prey on geoducks and their co-habitants. Other studies have shown the importance of bivalve culture in providing habitat for important species. Cultured oysters in Willapa Bay provide important refuge habitat for young Dungeness crab (Dumbauld, et al. 1993 and 2000). The cultured oysters also provide structure and habitat for species that are prey for young salmonids (Simenstad and Fresh, 1995). PSI and UW researchers will be conducting further research on the changes in species over time in geoduck farm areas NOAA funded studies noted earlier.

7. At harvest, although the bathymetry of the project area is restored within 3 tide cycles, what is the recovery rate for the benthic community? Does the assemblage of species alter pre and post harvest?

This issue has been evaluated in a general sense at several Puget Sound sites, and experiments to assess pre- and post-harvest conditions will begin this summer. This will include observations of acute effects of harvest and temporary changes in sediment composition, major epifauna, major infauna and vegetation. More comprehensive assessments will be carried out as part of WDNR mandated monitoring and NOAA activities (if funded).

8. Is there a point at which the "crop" rotation exhausts the project area? After three or four geoduck harvest cycles, have things been so altered or impacted that it is no longer a good site for farming or the aquatic community in general?

The SBIR study assessed carrying capacity in terms of biomass of geoducks per area. This provided useful data on density to help avoid unsustainable farming density. The proposed harvest effects studies will compare further physical endpoints to controls as beaches go through more cycles of harvest. Sediment carbon enrichment, sediment grain size, and redox potential will be measured as physical features of possible cumulative change in substrate conditions. We have received no reports of reduced growth or yields on beaches that are now in their 3rd crop cycle. Oyster and Manila clam beds in the same inlets where geoduck culture is occurring have been yielding sustainable farmed crops since the early 1900's. PSI research on suspended mussel raft systems in Totten Inlet (south Puget Sound) and Penn Cove (Whidbey Island) demonstrated no significant short-term or long-term phytoplankton depletion in the immediate farm area. These systems have much high biomass densities than exist on any geoduck bed.

9. Does the farming activity recruit any species into the area? Does it replace any species? Does it prevent normal species interaction in an area?

Refer to the response for question 6. Further studies on change in species assemblages in farmed geoduck culture area compared to control sites will be conducted during the studies mentioned earlier.

10. What are the cumulative impacts of multiple geoduck farms in an area?

The cumulative impacts of geoduck farming to a given area within Puget Sound will be similar to the cumulative impacts of other shellfish culture operations. South Puget Sound has a long history of intensive shellfish culture in several areas including Totten Inlet, Eld Inlet, and Oakland Bay. These bays continue to produce shellfish through intensive culture after decades of shellfish culture. Other shellfish bays including Samish Bay and Willapa Bay also demonstrate that intensive shellfish culture can be sustainable in Washington estuaries. Several other intensively farmed productive bays around the world offer examples for comparison including the Rias of Galicia, bays of oyster culture in France, and mussel culture in the Netherlands (Dame 1996).

Totten Inlet was the focus of a recent study on the cumulative impacts of shellfish farming. Totten Inlet sustains culture of oysters, manila clams, mussels, and geoducks. Brooks (Brooks, 2000) and Dame (Edaw, et al. 1998) modeled the carrying capacity of Totten Inlet for shellfish culture. Brooks determined that shellfish density in Totten Inlet was less than the median value for other productive estuaries. PSI observations on mussel culture on rafts in Totten Inlet during 2002-03 indicated phytoplankton concentrations returned to reference levels within a relatively short distance (10 m or less) down-current of the rafts.

Presently we can estimate filtration rates for geoducks to assess the impact they will have on the water column. Estimates made in the laboratory utilizing natural assemblages of plankton for test purposes suggested that geoducks in the size range typically harvested (2 lb) are capable of filtering between 3-10 liters per hour. We see a need to measure these filtration rates and feces/psuedofeces production directly under natural conditions for use in assessing the impact of geoduck farming as it is likely that the effect of filtration from cultured geoducks are significant given their biomass and filtration capacity.

11 What are the impacts of geoduck farming on birds?

A variety of birds use the intertidal area where geoduck farms are located. SBIR observers frequently sighted seagulls, crows, and other shorebirds in the intertidal areas near or on the geoduck culture areas. At high tide sea-ducks including scoters, buffleheads, goldeneyes, and scaups were seen over culture beds in the fall through spring. Bald eagles, a species listed as threatened under ESA, use the beaches at low tide to forage for food (ENTRIX 2004). Geoduck farms may impact the birds in a couple of ways. Birds may use the increase in diverse species associated with the farms as a food source. This may have a positive impact on the birds as an increase in food supply (Connolly and Colwell, 2005). For example, bald eagles have been observed on geoduck beaches at the same time geoduck siphon nipping was noted. The bald eagles may use the occasional extended siphon as a food source. Alternatively, birds could potentially become entrapped in netting used for predator protection or debris containment. The likelihood of bird entrapment in geoduck nets can be estimated by comparing the amount of bird entrapment occurring on manila clam nets. We are unaware of injury to bald eagles or other birds due to manila clam nets installed on the beaches. Mesh size is an important factor in the interaction of a given bird with a net. Mitigation if entrapment is a risk may include the use of appropriate mesh size and type.

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