January 15, 2007

Pierce County Planning Commissioners
Pierce County Planning and Land Use
2401 South 35th Street
Tacoma WA 98409

Re: Amendments to Pierce County Code 20.24.020 Aquaculture Practices and 20.24.030 Environmental Regulations – Uses Permitted

Dear Commissioners,

Thank you for the opportunity to comment on the proposed amendments to the Pierce County Shoreline Master Program. The Pacific Cost Shellfish Growers Association is a trade association that represents shellfish growers throughout Pierce County, Washington State and the entire west coast. One of PCSGA's roles is to ensure that proposed regulations maintain and enhance water quality and ecological functions so that our shellfish growers can continue to deliver high quality shellfish from the most pristine growing areas in the country. Shellfish farming has long standing in Washington State as ecologically sustainable. Shellfish growers depend on healthy functioning ecosystems to grow their products.

PCSGA has significant concerns with the proposed amendments to chapter 20.24. First, the regulations as proposed are overly prescriptive, and overly restrictive in nature. Regulations should be as restrictive as needed to avoid and minimize impacts to the environment. Unfortunately, it does not appear that current science and technical information have been used in development of the proposed amendment as required under WAC 173-26-201(2) (a). Also, the County does not appear to have undertaken a serious effort to gain input from shellfish growers and tideland owners in the development of these draft regulations. As discussed in detail below, potential environmental damage from shellfish farming is limited both temporally and physically, and that potential environmental benefits vastly outweigh any potential impacts.

A fundamental goal of the Shoreline Management Act is to ensure "no net loss of ecological functions." PCSGA believes that if the proposed amendments to section 20.24.030 are enacted, a net loss of ecological function is likely. The proposed amendments to the SMP jeopardize both the existence of shellfish farmers in the county and the ecological functions of Pierce County waters. These proposed rule changes will eventually lead to loss of aquatic farms that are currently allowed, and a corresponding environmental degradation due to the loss of those farms.

Finally PCSGA believes that the proposed changes constitute significant changes to the SMP and must be part of a comprehensive process to update the SMP as required under WAC 173-26-201 (1).

For these reasons, PSCGA recommends against adopting these proposed regulations in their current form. PCSGA further recommends that proposed changes to PCC 20.24 be deferred until the normal SMP update schedule. The following general and specific comments are provided to bring more clarity to PCSGA's objections to the proposed amendments.

General Comments:

Private tidelands are misrepresented as residential/recreational beaches. Washington State has a long history of private tideland ownership for the express purpose of encouraging shellfish farming, beginning in 1895 with the enactment of the Bush Act. The county must recognize that the primary purpose of privately held tideland is shellfish farming and not residential recreation. The county must work to preserve the private property rights of tideland owners to grow shellfish. To do otherwise would be to impose a take of private property (see specific comments on PCC 20.24.030 below).

Moreover, shellfish farmers have every right to post these private tidelands and prevent trespass (City of Bainbridge Island v. Brennan, 2005). While most shellfish farmers do not take such measures because they wish to be good neighbors, this is well within their rights.

Little effort has been made to contact affected shellfish growers and tideland owners. Staff has stated that they have been in contact with the two largest shellfish growers and that one of these growers has no problems with the proposed ordinance. This statement is troubling on two accounts. First discussions with the two largest shellfish growers do not necessarily convey information that is quite relevant to smaller farmers. Regulations that may work for a very large grower may be prohibitive to a small grower and would effectively limit entry into the market. Second, the one large grower that was faced with a permit that contains the requirements outlined in this proposed ordinance does not agree with several aspects of that permit and is appealing it to the Shoreline Hearings Board. Finally, county staff has not been diligent in their contact with upland shoreland owners who are indirectly affected by this ordinance, or with small growers and tideland owners who will be directly impacted by the proposed ordinance.

County Staff has not used current scientific and technical information as required by WAC 173-26-201(2)(a) and instead has deferred to innuendo and unsupported suppositions put forth by opponents of geoduck farming. Science concerning shellfish farming in general and geoduck farming specifically is well documented and recognized by state and federal agencies and non-governmental environmental groups. This science demonstrates the following points:

> **a. Molluscan shellfish farming, including geoduck farming, can greatly improve water quality by removing excess suspended nitrogen from the water column.** Contrary to what some waterfront homeowners claim, shellfish farming improves water quality. Shellfish farming is well recognized by scientists and environmentalists for its positive benefits on water quality.

"EPA notes that mollusks are filter feeders and, in some cases, are recommended not only as a food source, but also as a pollution control technology in and of themselves. Mollusks remove pollutants from ambient waters via filtration."

Environmental Protection Agency, September 2002
57 Fed. Reg. 57,872, 57,885

"Filter-feeding mollusks can clarify the water by consuming plankton in aquatic systems, significantly improving water quality. Mussel farms can remove nitrogen from water at a 70% higher rate than occurs in surrounding waters.... Moreover, shellfish farmers are often among the loudest advocates for clean water."

Pew Oceans Commission, 2001
Marine Aquaculture in the United Sates

"One type of aquaculture - mollusk farming - actually reduces nutrient pollution... Because 35-40% of the total organic matter ingested by a mollusk is used for growth and permanently removed by harvest of the mollusk."

Environmental Defense, 1997
Murky Waters: Environmental Effects of Aquaculture in the US

b. Shellfish aquaculture is as good or better than eelgrass in creating forage fish habitat. (See Attachment for detailed science) Science supports the broad environmental benefits associated with shellfish aquaculture. Shellfish aquaculture is good for species diversity, eelgrass growth, and water quality.

"...we believe that there is generally a net overall increase in aquatic resource functions in estuaries or bays where shellfish are produced."

U.S. Army Corps of Engineers, September 2006
Proposed *Nation Wide Permit D for Shellfish Aquaculture*
71 Fed. Reg. 56,258, 56,275

The fact is, shellfish farming provides a supportive environment for other species. Shellfish themselves create three-dimensional structure that can be used for forage and protection from predators for many marine species – including juvenile salmonids.

In addition to the shellfish themselves, many components of the gear used in shellfish farming provide additional habitat. For example, a 2004 study led by Dr. Joseph DeAlteris found higher populations and a richer diversity of tideland species in and around shellfish beds than in the seabed habitat with seagrass or the bare seabed. Shellfish growers in Puget Sound use no herbicides or pesticides.

Any predator control consists of passive techniques such as oyster bags, clam nets and geoduck tubes that actually create habitat. Shellfish growers like other farmers are always investigating new growing techniques to cut production costs and increase productivity. However, because growers depend upon a healthy ecosystem, it is in their interests to use environmentally responsible growing techniques.

c. Shellfish farming encourages and enhances eelgrass growth. (See Attachment for detailed science.) The long-term benefits of shellfish farming on eelgrass are well documented. While some aquaculture techniques can lead to short term disruption of eelgrass, the overall and long term effects are positive. Shellfish culture can indirectly and positively affect ecosystem function by promoting submerged aquatic vegetation in four principal ways:

(1) Filter feeders enhance water clarity

(2) Benthic filter feeders fertilize estuarine sediments

(3) Filter feeders provide benthic structure as enhanced habitat for epiphytic grazers

(4) Benthic filter feeders influence eelgrass recruitment, germination, and seedling survival.

d. Geoduck harvest has only short term and localized impacts on benthic structures. Geoduck farming has garnered a good deal of attention recently. Fortunately, many geoduck farms are in the second or third crop of geoducks, providing us with 15 years of real evidence that geoduck farms are sustainable. Like all shellfish, geoducks depend on clean water and healthy beaches to thrive, and their presence is an indicator of a sustainable, healthy beach.

Geoduck harvesting is a long, gradual process. The largest operations have three harvesters working per day, meaning that the biggest daily harvest would cover an area 30 feet wide and 100 feet long. Due to tide-limited time on the beach, it takes such a crew over a month to harvest a single acre. Another indication of the health of geoduck beaches is that growers can replant geoduck beaches within days of harvest.

Rather than dig each animal with a clam gun and shovel as recreational harvesters do, which typically leaves a 4-5 foot diameter hole, approximately 3-5 feet deep, commercial geoduck harvesters use large volumes of seawater at low pressure to loosen the sand and release the geoducks (approximately 27 psi and 42 gallons per minute). This is the same method employed by commercial and tribal geoduck divers over the last 35 years on wild, subtidal geoduck tracts.

The Washington State Department of Natural Resources produced an environmental impact statement (EIS) and subsequent supplemental EIS on the effects of their geoduck harvest program. (*State of Washington Department of*

Natural Resources (WDNR) Department of Fish and Wildlife (WDFW). 2001. Final Supplemental Environmental Impact Statement. State of Washington Commercial Geoduck Fishery.) These documents and their supporting research found this harvest technique results in only short term and localized impacts. Opponents to geoduck farming maintain that these findings are not applicable to intertidal harvest, but give no reason for this supposition. NOAA Fisheries classifies the nearshore area as the area between the Mean High Tide line and -70 feet. It does not differentiate between intertidal and subtidal areas. These EIS documents and the studies that support them constitute the most current scientific and technical information. As there is no other science to contradict them and no logical reason to exclude them, they should be used as a foundation for creating new policies.

e. A biological assessment preformed by a nationally recognized environmental consultant found that geoduck aquaculture practices may affect but are not likely to adversely affect any listed threatened or endangered species or essential fish habitat. (*ENTRIX Inc, 2004, Programmatic biological evaluation of potential impacts of intertidal geoduck culture facilities to endangered species and essential fish habitat, prepared for Taylor Shellfish, Seattle Shellfish, and Chelsea Farms.*). While shellfish farmers directly financed this study, the scientific findings are valid. Biological assessments are typically generated by a project proponent prior to submittal to NOAA Fisheries and US Fish and Wildlife Service.

Specific Comments:
20.24.020 Section 8. There is no scientific basis for setting the 180 foot requirement. This requirement is arbitrary. This requirement may be too large or may be too small. The current language deferring to the permit review authority's judgment is a better solution.

20.24.020 A. Section 16 In general this proposed regulation is too restrictive and prescriptive for both the level of potential impact from the activity and the amount of tidelands affected by potential geoduck farming. Currently there are approximately 150 acres under cultivation for geoduck for the entire state. Pierce County only has a small portion of the tidelands that are suitable for geoduck farming and it is unlikely that this regulation will affect more than a 20 acres over the next few years. We do not believe that there are any other crops or industries in Pierce County that have warranted this level of prescriptive regulation and oversight that have such a limited foot print and such a small potential for negative environmental impact.

16 a. Color of Tubes. This regulation will only increase cost without providing a tangible aesthetic or environmental benefit. Geoduck tubes in the marine environment quickly become fouled with algae and turn a uniform brown in color (usually within two weeks of placement). Moreover, tubes that become dislodged will be harder to locate if they are the same color as the beach - especially if maintenance is being completed during the nighttime low tides in winter. Finally, because geoduck can only be planted in the extreme low end of the intertidal zone (below +2 tideline), tubes are only visible about 5% of the time when present. Tubes are also removed and reused after 1 to 3 years of the 4 to 7 year planting cycle. This requirement should be removed.

16 f. Patrol of Beach - ½ mile patrols may not be enough to capture all wayward debris, especially after a large windstorm. It would be better to require that all farm debris be removed as soon as practical after it has been dislodged.

16 h. Training: We are concerned that Pierce County staff does not have the expertise to create or approve a standardized training program in a timely manner. We suggest that this is an issue better left to shellfish farmers. Note that shellfish farmers have already created standardized training for hazardous waste containment and control, high health hazard elimination systems and development of farm plans. One aspect of a farm plan is an environmental training system. Moreover, the bulk of the proposed regulations contained in this draft were taken directly from the Environmental Codes of Practices created by PCSGA. Pierce County staff could be consulted in the creation of such a program.

16 i. Water Access: We do not understand the basis for this requirement. During wintertime night tides, maintenance activities will be considerably safer if a property can be accessed from the upland area. Does the county really want to take on the liability created by this requirement? If a tideland owner wishes to access his or her beach from his upland lot, it does not seem that the County has the legal ability to preclude that access. We concur that use of heavy equipment should be avoided, but then that is in the best interest of the shellfish farmer and no regulation is needed. The least impacting means of access may in fact be upland access with an ATV and small trailer, as there is no need for mooring buoys or anchors, and there is no prop wash. This requirement should be removed.

16 j. Hours of Operation: This requirement is inappropriate for intertidal farming practices. Shellfish farmers work when the tide is out. This happens during the middle of the day from late spring to early fall and during the middle of the night from late fall to early spring. At a minimum, maintenance activities during the winter months are necessary to repair any damage due to winter storms. To place any restriction on the hours of activity is to effectively preclude shellfish farming. Shellfish farmers would be unable to stay in business if required to vacate their beds for half of the year. It is also unclear which state rules this section refers too. This requirement should be removed.

20.24.020 B. Development Standards

1.c. Marking of equipment. This standard creates additional costs with no tangible benefit. A better approach which is already adopted by most growers, is to require that all shellfish farming and marine debris be removed when found during regular beach patrols. This requirement should be removed.

1.d. Bond or Financial Guarantee. While the intent of this requirement is to ensure that no aquaculture equipment is left on the beach, the dollar amount is not within keeping of the intent and is punitive and limits entry into the market. A single acre of beach could be cleaned for as little as $1500 (labor and equipment), yet this language would require a bond of as much as $43,560 per acre. Moreover if another shellfish farming method is employed which does not utilize tubes, then no bond would be required. Finally, some farmers are leaving tubes in place for as long as three years and a single parcel of tideland may have multiple years of crops on it making it impossible for county staff to determine how long a tube has been left in place. A better approach would be to require a bond or financial guarantee based on a per acre fee of $2000 that extends the length of a tideland lease or ten years, whichever is greater.

1.g Geoduck Harvest restrictions: This requirement has no scientific basis and should be removed in light of the scientific literature that shows that aquaculture promotes eelgrass recruitment and growth. Any short-term impact to eelgrass due to harvest will be more than offset by the long-term benefits from the aquaculture activity.

1.l. Geoduck Harvest Restrictions: Pierce County mistakenly references WAC 220-52-019(2a) and RCW 77. 60.070.2. This WAC is a WDFW regulation that pertains to commercial harvest of geoduck on state owned subtidal tracts. WDFW does not and cannot promulgate regulations regarding shellfish farming including geoduck (see Attorney General Office Opinion 2007-01.) This RCW pertains to commercial harvest of geoduck on state owned subtidal tracts and has no bearing on privately held tideland and privately owned geoduck stocks. This requirement should be removed.

1.n Ten foot setback. Is a ten-foot setback consistent with standards for other agricultural or landscaping practices? If not, what is the purpose of applying that standard to shellfish farming, especially if the tideland has been surveyed and clearly marked? This regulation does not appear to provide any protection or benefits and unnecessarily and inappropriately limits use of private property. This requirement should be removed.

20.24.030 Environment Regulations - Uses Permitted. Changes in this section are the farthest reaching and will impact both existing shellfish farmers and stifle new shellfish farming efforts. To our knowledge, county staff has made no effort to contact shellfish growers or tideland owners that may be impacted by these new requirements. PCSGA has three primary objections to these changes. First the changes are significant thereby invoking WAC 173-26-201, which requires a comprehensive process for SMP revisions. County staff did not fully represent the extent of these changes during discussions with the Department of Ecology, and during those discussions, Ecology was unaware that the recent Attorney General's Opinion (AGO 2007-01) would further define the scope of regulatory authority relating to geoduck farming.

Second, the proposed changes to PCC 20.24.030 (A) and (C) would preclude any future shellfish farming in these areas and any changes to existing farms that would require permit denial. All shellfish farms use some "materials" placed in intertidal areas. Shellfish farmers, like terrestrial farmers, must innovate and change both species farmed and farming practices in order to maintain economically viability. The proposed changes to PCC 20.24.030 (C) Natural Environment are even more restrictive as no intertidal shellfish farming would be allowed. Some of these intertidal areas were sold by the state for the explicit purpose of shellfish farming. Individuals bought them and have paid taxes on them. If the county precludes this use, and this is the only productive use of these lands, then county is causing a take of this property. (See the Advisory Memorandum: Avoiding Unconstitutional Takings of Private Property. Christine

Gregoire, Washington State Attorney General, December 2003. Specifically section II B. 2. "Does the Regulation or Action Deprive the Owner of All Economically Viable Uses of the Property?")

Third, these changes will lead to a net loss of ecological function in direct conflict with the goals of the SMA. As demonstrated in the general comments above and documented in the attachment, shellfish farming results in "...a net overall increase in aquatic resource functions in estuaries or bays where shellfish are produced ..." (USACOE, 2006). This is due to the filtering function, the benthic-pelagic coupling, and the direct habitat functions provided by shellfish aquaculture. If these changes are adopted, shellfish farmers in Pierce County will be economically marginalized and driven out of business. With the loss of shellfish farms comes the loss of ecological functions. This development pattern is well established. Witness Tillamook Bay in Oregon, San Francisco Bay in California, Chesapeake Bay on the east coast or any number of other bays throughout the world where shellfish production has been limited due to human interactions.

For these reasons PCSGA requests that Pierce County refrain from adopting these regulations. PCSGA is willing to work with staff and develop workable standards for shellfish farms, but this must be accomplished within a comprehensive update of Pierce County's SMP. Shellfish farmers are long standing champions of clean water and functioning ecosystems for without healthy, functioning bays, they cannot survive. Thank you for consideration of our concerns.

Sincerely,

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Attachment

PCSGA Comments to Proposed Amendments to Pierce County Code 20.24.020 Aquaculture Practices and 20.24.030 Environmental Regulations – Uses Permitted

Current Science regarding Shellfish Aquaculture

Shellfish as habitat. Ground-cultured oysters and shell placed in the intertidal portion of West Coast estuaries has been shown to provide equal or better habitat than eelgrass for juvenile Dungeness crab – and much better habitat than open unstructured mud or sand habitats where these small organisms have no protection from predators such as fish and crab (*Eggleston, D.P. and D.A. Armstrong. 1995. Pre-and post-settlement determinants of estuarine Dungeness crab recruitment. Ecological Monographs 65:193-216. ; Feldman, K.L, D.A. Armstrong, B.R. Dumbauld, T. H. Dewitt, and D.C. Doty. 2000 Oysters, crabs, and burrowing shrimp: Review of an environmental conflict over aquatic resources and pesticide use in Washington state's (USA) coastal estuaries. Estuaries 23:141-176.*)

In addition to the shellfish themselves, many components of the gear used in shellfish farming provide additional habitat. For example, a 2004 study led by Dr. Joseph DeAlteris found higher populations and a richer diversity of tideland species in and around shellfish beds than in the seabed habitat with seagrass or the bare seabed. (*Dealteris, J.T., B.D. Kilpatrick, R.B. Rheault. 2004. A comparative evaluation of the habitat value of shellfish aquaculture gear, submerged aquatic vegetation, and a non-vegetated seabed. Journal of Shellfish Research, Vol. 23, no. 3, 867-874.*)

Tidelands that support shellfish aquaculture also provide critical foraging habitat for a large variety of waterbirds. For example, in a 2005 study of Humboldt Bay, Drs. Connolly and Colwell found more species of shorebirds and wading birds concentrated in tidelands with shellfish farms than those without. (*Connolly, L.M., M.A. Colwell. 2005. Comparative use of longline oysterbeds and adjacent tidal flats by waterbirds. Bird Conservation International 15: 237-255.)*

Shellfish and eelgrass interactions. Filter feeders can enhance water clarity. Suspension-feeding bivalves play an important role in estuarine ecosystems as biofilters, significantly enhancing water quality and clarity, and improving growing conditions for submerged aquatic vegetation. The loss of historical oyster reefs in Chesapeake Bay dramatically illustrates these effects. (*Officer, C. B., Smayda, T. J., and Mann, R. 1982. Benthic Filter Feeding: A Natural Eutrophication Control. MAR.-ECOL.-PROG.-SER.. 9(2):203-210. ; Newell, R.I.E., 2004. Ecosystem influences of natural and cultivated populations of suspension-feeding bivalve molluscs: A review. J. Shellfish Res. 23(1) 51-61 ; and Gottleib, S. J. and Schweighofer, M. E. 1996. Oysters and the Chesapeake Bay ecosystem: A case for exotic species introduction to improve environmental quality? Estuaries 19: 639-650.)*

Eelgrass is extremely sensitive to light levels, although other physical factors (temperature, flow, organic carbon) also determine distribution (*Zimmerman, R.C., Reguzzoni, J. L., Wyllie-Echeverria, S., Josselyn, M., Alberte, R. S. 1991. Assessment of environmental suitability for growth of Zostera marina L (eelgrass) in San Francisco Bay. Aquatic Botany. (39):353-366; and Best, E. P. H., Buzzelli, C. P., Bartell, S. M., Wetzel, R. L., Boyd, W. A., Doyle, R. D., and Campbell, K. R. 2001. Modeling submersed macrophyte growth in relation to underwater light climate: modeling approaches and application potential. Hydrobiologia 444(1-3):43-70.*) Oysters played the central role of transforming pelagic into benthic production. That role has been lost in most portions of Chesapeake Bay, but in some areas has been replaced by introduced filter feeders. The arrival of Corbicula fluminea in the Potomac River estuary improved water clarity and allowed eelgrass to reappear in areas from which it had been absent for 50 years (Phelps, H. L. 1994. The Asiatic clam (Corbicula fluminea) invasion and system-level ecological change in the Potomac River estuary near Washington, D.C. Estuaries 17(3):614-621). Similarly, Potamocorbula amurensis in San Francisco Bay may be reducing phytoplankton and zooplankton densities (*Kimmerer, W. J., Gartside, E., Orsi, J. J. 1994. Predation by an introduced clam as the likely cause of substantial declines in zooplankton of San Francisco Bay. Marine Ecology Progress Series. 113(1-2):81-93.; and Jassby, A.D., Cloern, J. E, Cole, B. E. 2002. Annual primary production: Patterns and mechanisms of change in a nutrient-rich tidal ecosystem. Limnological Oceanography 47(3):698-712.*) Recent laboratory studies have also confirmed that suspension-feeding eastern oysters, Crassostrea virginica, in Chesapeake Bay exerted top-down control on phytoplankton and reduced turbidities, increasing light penetration to a level that can sustain benthic submerged vegetation (*Newell, R., Cornwell, J., and Owens, M. 2002. Influence of simulated bivalve biodeposition and microphytobenthos on sediment nitrogen dynamics: A laboratory study. Limnological Oceanography 47:1367-1379).*

At tidal elevations that can support eelgrass, some studies in west coast estuaries suggest that eelgrass is less dense in oyster aquaculture beds than in nearby eelgrass meadows (*Simenstad CA, Fresh KL (1995) Influence of intertidal aquaculture on benthic communities in Pacific Northwest estuaries: scales of disturbance. Estuaries 18:43-70 ; Rumrill, S.S. and V.K. Poulton. 2004. The ecological role and potential impact of molluscan shellfish culture in the estuarine environment of Humboldt Bay, California. Final Report to the Western Regional Aquaculture Center. 79 pp.; and Pregnall MM (1993) Regrowth and recruitment of eelgrass (Zostera marina) and recovery of benthic community structure in areas disturbed by commercial oyster culture in the South Slough National Estuarine Research Reserve, Oregon. MS thesis, Bard College, Annandale-On-Hudson, NY*). However, eelgrass is generally present on all aquaculture beds at this tidal elevation and these studies do not evaluate historical records to indicate either loss or gains in eelgrass habitat over time, nor whether eelgrass would have been there otherwise. With the exception of changes in practices like switching from on-bottom culture to off-bottom culture in some locations, the press (oyster addition) and pulse (planting and harvest operations) disturbances of oyster culture have not changed materially for decades (*Ruesink, J.L., B.E. Feist, C.J. Harvey, J.S. Hong, A.C. Trimble, L.M. Wisehart. 2006 Changes in productivity associated with four introduced species:*

Ecosystem transformation of a "pristine" estuary. Marine Ecology Progress Series 311:203-215).

Introduced oysters have increased bivalve production in Willapa Bay by 250%, but primary production by plants still is primarily due to native eelgrass. Native eelgrass production exceeds Pacific oyster production by two orders of magnitude.), so there is no reason eelgrass would necessarily be worse off now than in the past. Indeed, there is scientific evidence that native eelgrass fluctuates with environmental conditions and compelling anecdotal evidence that it has been expanding its distribution in Willapa Bay and other West coast open coast estuaries. *(Thom RM, Borde AB, Rumrill S, Woodruff DL, Williams GD, Southard JA, Sargent SL. 2003. Factors influencing spatial and annual variability in eelgrass (Zostera marina L.) meadows in Willapa Bay, Washington, and Coos Bay, Oregon. Estuaries 26:1117-1129.)*

Eelgrass growth can be influenced by numerous factors including light and nutrients. The importance of these factors differs by location. Thus in some areas outside the Pacific Northwest, nutrients may be limiting and shellfish can provide these via pseudofeces and feces *(Peterson BJ, Heck Jr. KL (1999) The potential for suspension feeding bivalves to increase seagrass productivity. J Exp Mar Biol Ecol 240:37-52 ; and Peterson BJ and Heck Jr. KL (2001) Positive interactions between suspension-feeding bivalves and seagrass --a facultative mutualism. Ma Ecol Pro Ser 213:143-155).* Light does seem to limit growth in PNW estuaries and thus eelgrass may even shade itself when dense. Thus eelgrass grew faster in ground cultured oyster beds in Willapa Bay. While growth was faster, overall production was still lower due to reduced eelgrass density.

Benthic filter feeders fertilize estuarine sediments and this process may be in part responsible for the recruitment of eelgrass in areas of shellfish culture where previously it was not supported. Suspension-feeding bivalves act to couple the pelagic and benthic processes through their filtration of suspended particles from the water column and their deposition of material, in the form of mucus-bound feces and psuedofeces, onto the substrate. The rate of this biodeposition is a largely a function of bivalve species, density and the local environment. A study examining the biodeposition and sediment resuspension rates on a commercial clam farm found a significant correlation between biodeposition rates and the density and biomass of cultured Manila clams, with deposition rates being up to four times that of control sites. (*Han Jie, Zhang Zhinan, Yu Zishan, and John Widdows, 2001. Differences in the benthic-pelagic particle flux (biodeposition and sediment erosion) at intertidal sites with and without clam (Ruditapes philippinarum) cultivation in eastern China. Journal of Experimental Marine Biology and Ecology 261 (2001) 245-261).*

Positive impacts of filter feeders on eelgrass have been documented elsewhere in US coastal waters (*Peterson and Heck 1999 and 2001*). The nutrient cycling aspects of shellfish populations may be a significant element in maintenance and growth of eelgrass communities. Eelgrass can derive nutrients from both the sediments and the water column. Peterson and Heck (1999) found lower ratios of C:N and C:P in eelgrass cocultured with mussels than in control plots, because of the pore water enrichment with nitrogen and phosphorous from the mussel biodeposits. In brief, the interstitial water contained relatively higher concentrations of dissolved inorganic and organic nutrients than the water column, and it is from these interstitial (pore) waters that eelgrass obtains most macronutrients for growth. Sediment reservoirs of nutrients can become depleted when biogeochemical regeneration rates cannot meet plant demands (*Short, F. T. 1983. The response of interstitial ammonium in eelgrass (Zostera marina L.) beds to environmental perturbations. J.-Exp.-Mar.-Biol.-Ecol. 68(2), 195-208; and Short, F. T. 1987. Effects of sediment nutrients on seagrasses: Literature review and mesocosm experiment. Aquat.-Bot. 27(1), 41-57*). However, in the course of removing water column particulates, filter feeders also alter sediment characteristics. Positive impacts occur because they move carbon and nutrients from the water column to the benthos.

Filter feeders consume water-column phytoplankton and particulate organic matter that can interfere with light penetration, required for eelgrass photosynthesis (Best, Buzzelli, Bartell, Wetzel, Boyd, Doyle, and Campbell 2001, and Koch and Beer 1996). Pseudofeces and feces produced by bivalves can increase both sediment organic content and nutrient levels in sediment porewater (*Reusch TBH Chapman ARO, Gröger JP. 1994. Blue mussels (Mytilus edulis) do not interfere with eelgrass (Zostera marina) but fertilize shoot growth through biodeposition. Mar Ecol Pro Ser 108: 265–282; and Reusch, T.B.H. and Williams, S.L. 1998. Variable responses of native eelgrass Zostera marina to a non-indigenous bivalve Musculista senhousia. Oecologia 113(3):428-441.)*

In Florida seagrass beds (Thallasia testudinum), the presence of mussels (Modiolus americanus) within the beds has been shown to enhance eelgrass productivity and blade growth rate (Peterson and Heck 2001). The mechanistic explanation has been clearly demonstrated: mussels enhance porewater nutrients, which enhance nitrogen and phosphorus content of seagrass blades and lead to faster growth.

A similar study has been carried out in southern California examining interactions between eelgrass (Zostera marina) and an introduced mussel (Musculista senhousia) over a range of densities of each (Reusch and Williams 1998). Mussels were placed in eelgrass beds and near eelgrass transplants at several densities. The study demonstrated that, at high densities, mussels inhibited rhizome extension of eelgrass, but across a range of densities, blade growth rates were enhanced.

Researchers at a western Baltic study site reported sediment porewater concentrations of ammonium and phosphate doubling in the presence of M. edulis. There was a strong correlation between porewater ammonium concentration and plant size. M. edulis was believed to facilitate Z. marina by the biodeposition of organic material via mussel feces and pseudofeces. Plants in an M. edulis addition treatment had a 36 % higher leaf area than the controls, whereas mussel removal led to an area decrease of 16 % compared to the controls (*Reusch, Chapman, and Groeger 1994*). Eelgrass growth is likely accelerated in areas where the plants co-mingled with shellfish.

Benthic structure provided by filter-feeders enhances habitat for epiphytic grazers. Another response to the presence of mussels includes a significantly reduced epiphytic load on the seagrass leaves (Peterson and Heck 2001). Spaces between shells of adjacent mussels are thought to provide a predation refuge, reducing predation pressures on epiphytic grazer species such as small gastropods and amphipods. Increased densities of epiphytic grazers could then lead to an increased amount of epiphytic grazing from seagrass leaves, which consequently might lead to an increase in leaf light absorption.

Preliminary evidence suggesting that the presence of a periphyton grazer can have substantial (indirect) impact on the proliferation, biomass and reproductive potential of seagrasses was collected during experiments conducted between 1995 and 1996 in Florida. This study also noted that the mussels themselves may potentially reduce epiphytic loads by consuming the epiphyte propagules before recruitment to the leaves, or elevated productivity of the plant may cause the reduced epiphytic loads (Peterson and Heck 2001).

Benthic filter feeders may influence eelgrass recruitment, germination, and seedling survival. Interactions between filter feeders and eelgrass may be both positive and negative depending on the life history stage of *Zostera marina,* the physical conditions present, and the density and species diversity of filter feeders. Negative effects are primarily attributed to very high shellfish densities which can out-compete seagrass for space *(Reusch and Williams 1998*).

Positive effects of filter feeders at seagrass recruitment, germination, and seedling stages are likely to be driven by the following mechanisms. First, by providing a larger boundary layer and slowing water current speed, filter feeders may increase recruitment of floating seeds either as they travel singly or within detached reproductive shoots. Entrapment could also be facilitated by the structure bivalves provide. Seed dispersal is limited outside *Zostera marina* beds (~80% seeds travel within 10 m of parent plants so this effect is presumably only important when eelgrass beds are nearby *(Orth, R. J., Luckenbach, M., and Moore, K. A. 1994. Seed dispersal in a marine macrophyte: Implications for colonization and restoration. ECOLOGY 75(7):1927-1939; and Ruckelshaus, M. H. 1996. Estimation of genetic neighborhood parameters from pollen and seed dispersal in the marine angiosperm Zostera marina L. Evolution 50(2), 856-864).*

In addition, seeds are also a common food item for crustaceans and it seems plausible that filter feeders provide refuge for newly dispersed seeds (*Wigand C and Churchill A C. 1988. Laboratory studies on eelgrass seed and seedling predation. Estuaries. 11(3), 180-183)*. Second, by filtering seawater and increasing sediment organic content, bivalves provide superior conditions for seed germination. *Zostera marina* seed germination is dependent on burial depth with the highest germination occurring at the anaerobic/aerobic interface *(Bigley, R. E. 1981. The population biology of two intertidal seagrasses, Zostera marina and Ruppia maritima, at Roberts Bank, British Columbia. Thesis. University of British Columbia, Vancouver, British Columbia, Canada).* Seeds buried below this depth have very low germination and are essentially lost from the population. Filter feeders may act to bury and fertilize seeds at a depth that is appropriate for germination. Third, filter feeders may increase the survival of seedlings, which have very high mortality rates by increasing light levels, nutrients, and protecting against erosion and herbivory (*Orth, Luckenbach, and Moore 1994, and Ruckelshaus 1996).*