Protect Our Shoreline

PO Box 6358, Olympia, WA 98507 360-357-9082
www.ProtectOurShoreline.org

In conjunction with:

Henderson Bay Shoreline Association
APHETI (Association for Protection of Hammersley, Eld and Totten Inlets)
Mayo Cove Shoreline Association
Dutcher's Cove Shoreline Association
Case Inlet Beach Association

Contact: Laura Hendricks, 253-858-9286

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Studies Related to Impacts of Intensive Commercial Shellfish Aquaculture around the World

This document list represents studies found to date by citizen groups documenting impacts of intensive shellfish aquaculture practices from around the world. Since geoduck aquaculture is new, most of the studies reflect long term cultures of other bivalves--oysters, mussels and clams. HB 1728 and SB 5645 address shellfish aquaculture in general and are not limited to geoducks, thus these studies must be taken into account when considering the expansion of shellfish aquaculture in Puget Sound. We continue to find studies related to this topic, therefore this list can only be considered a partial list.

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1. ***Scale-dependent and indirect effects of filter feeders on eelgrass: Understanding complex ecological interactions to improve environmental impacts of aquaculture***
   Ruesink (UW), Hacker (WSU to OSU), Dumbauld (USDA
   http://www.fish.washington.edu/wrac/pdfs/Filter%20Feeders%20and%20Eelgrass.pdf
   This is a progress report for a study that tests the ability of benthic filter feeders to remove particulates from marine waters, and the response of eelgrass in distribution or growth rate.
   --"We have observed direct negative effects of disturbance and of geoducks on eelgrass density."
   --"On the other hand, we have seen little evidence of indirect positive effects of geoducks: porewater nutrient concentrations appear slightly higher when geoducks are present, but this 'fertilizer' effect does not result in enhanced growth rates of eelgrass."

2. ***Report of the Working Group on Marine Shellfish Culture (WGMASC)***
   ICES Mariculture Committee
   http://www.ices.dk/reports/MCC/2003/WGMASC03.pdf
   8/15/2003, pages 1 - 54
   Pages 40-41 address the following topics: (1) Potential effects of biodeposition; (2) Potential effects of excretion; (3) Other potential effects; (4) Relative impact of different husbandry practices; (5) Discussion on sustainability of shellfish culture. Some quotes:
   --"Bivalve faeces and pseudofaeces...can cause benthic enrichment effects...leading to alternations in benthic species abundance and community compositions." P. 40
   --"Suspended culture may impact food webs and nutrient dynamics..."
   --"Shellfish excrete ammonia...which...may alter coastal nutrient dynamics."
   --"Diseases are introduced with the movement of aquaculture species, introducing and transmitting pathogens, often resulting in significant mortalities which add to the organic load within a system."
   --"It has been observed that the tables used for the intertidal culture of oyster in France are provoking an increased localized sedimentation underneath the tables."

3. ***Accelerated Sulfur Cycle in Coastal Marine Sediment beneath Areas of Intensive Shellfish Aquaculture. Applied Environmental Microbiology 2005 June; 71.***
   Hiroki Asami, Masato Aida, Kazuya Watanbe;Marine Biotechnology Institute, Japan

http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1151846
June, 2005, pages 2925 - 2933
FROM ABSTRACT: The Rias coastline (Japan) is punctuated with numerous small, semienclosed bays, many of which have been used as fishing ports. In addition, some bays have also been utilized for intensive commercial shellfish aquaculture (mainly oysters and scallops) and seaweeds for over 30 years, which has become one of the important industries in the Sanriku region. Consequently, sustainable usage of the coastline has currently become an important issue for the Sanriku community, as is the case with other coastal communities.

This study was carried out to investigate possible influences of the aquaculture on sediment prokaryotes. This study looked at prokaryotes in sediments in two bays that were chosen in terms of their similar hydrogeological and chemical characteristics but different usage modes; the Yamada bay has been used for intensive shellfish aquaculture, while the Kamaishi bay has a commercial port and is not used for aquaculture. Results of sediment samples resulted in the hypothesis that sulfate-reducing and sulfur-oxidizing bacteria have become abundant in the Yamada sediment. In addition, potential sulfate reduction and sulfur oxidation rates in the sediment samples were determined, indicating that the sulfur cycle has become active in the Yamada sediment beneath the areas of intensive shellfish aquaculture. Prokaryotes in sediments play crucial roles in the decomposition and mineralization of organic matter in the coastal marine environment. Information obtained in these studies has been combined with results of activity measurements, suggesting that sulfate reduction is the most important electron-accepting process for organic matter decomposition in coastal and continental shelf sediments.

4. ***An Overview of Factors Affecting the Carrying Capacity of Coastal Embayments for Mussel Culture***
Graeme J. Inglis, et al. Ministry for the Environ
http://www.govdocs.aquake.org/cgi/reprint/2004/628/6280090.pdf
8/2000, P. 9
Article suggests parameters for determining phytoplankton abundance, and the effects of intensive farming locally and of the benthic community. Article reports that the Mytilus galloprovincialis is a fouling organism and that it is especially noticeable in poorly flushed waters.
--P. 9 "...organic enrichment of sediments by mussel faeces and pseudofaeces can cause increases in the rates of respiration and oxygen consumption by benthic microorganisms." "Severely affected areas are characterized by films of chenoautorophic sulphur bacteria (Beggiatoa) at the sediment-water interface..."
--P. 13 "Changes in the pattern of nutrient cycling have been linked to outbreaks of toxic red tide organisms (Cembella et al. 1997) and may indirectly affect recruitment of other important marine species. For example, it appears that blooms of the red tide dinoflagellate, Gymnodinium mikimotoi, in Japan are stimulated by increased release of ammonium and other micronutrients from the sea floor."

5. ***Pacific Oysters in the European Wadden Sea: an Irreversible Impact in a Highly Protected Ecosystem***
Stefam Nehring, Germany
http://www.stefannehring.de/downloads/142_Nehring-2003_Aliens-17_pacific-oyster.pdf
2003, P. 19-21
--P. 21. Article discusses the cultivation and escapement of the introduced Crassostrea gigas, the Pacific Oyster, as an example of what can happen to the natural ecology of a bay such as the Wadden Sea. The native oyster was originally harvested to extinction. Pacific oyster introduced from 1971. Since Pacific Oyster has a higher growth rate than some other species, there has been a decline in the original species.
--P. 20. "...the threats of intensified aquaculture and increasing international transfer of exotic species for stocking and culture posed to natural communities needs to be pushed up to political agenda."
--P. 21 "...Alien invasions in aquatic systems are irreversible and should be avoided wherever possible."

6. ***Impacts of mussel (Mytilus gallprovincialis) farming on oxygen consumption and nutrient recoiling in a eutrophic coastal lagoon.***

Daniele Nizzoli , David T. Welsh, Marco Bartoli and Pierluigi Viaroli
http://www.springerlink.com/content/j0186q2275345v11/fulltext.pdf
2005, P 183-198
From Abstract: "These results demonstrate that it is essential to take into account the activity of the cultivated organisms and their epiphytic community when assessing the impacts of shellfish farming. Overall, whilst grazing by the mussel rope community could act as a top-down control on the phytoplankton, most of the ingested organic matter is rapidly recycled to the water column as inorganic nutrients, which would be expected to stimulate phytoplankton growth. Consequently, the net effect of the mussel farming on phytoplankton dynamics, may be to increase phytoplankton turnover and overall production, rather than to limit phytoplankton biomass."

7. ***Effects of mussel (Perna canaliculus) biodeposit decomposition on benthic respiration and nutrient fluxes***

Hilke Giles and Conrad A. Pilditch; Department of Biological Sciences, University of Waikato, Private Bag 3105, Hamilton, New Zealand

http://www.springerlink.com/content/n1534x64288t301t/
June 13, 2006, Abstract
FROM ABSTRACT: Suspension-feeding bivalves increase the quantity and quality of sedimenting organic matter through the production of faeces and pseudofaeces that are remineralised in coastal sediments and thus increase sediment oxygen demand and nutrient regeneration. Bivalves are intensively cultivated worldwide; however, no bivalve biodeposit decay rates are available to parameterise models describing the environmental effects of bivalve culture. We examined sediment biogeochemical changes as bivalve biodeposits age by incubating coastal sediments to which we added fresh mussel (Perna canaliculus) biodeposits and measured O2 and nutrient fluxes as well as sediment characteristics over an 11-day period. Biodeposits elevated organic matter, chlorophyll a, phaeophytin a, organic carbon and nitrogen concentrations in the surface sediments. Sediment oxygen consumption (SOC) increased significantly immediately after biodeposit addition and remained elevated compared to control cores without additions for the incubation period. This increase is in the range of observed in situ oxygen demand enhancements under mussel farms. Using a first-order G model, study found a decay rate that is 1–2 orders of magnitude higher than published decay rates of coastal sediments without organic enrichment but similar to rates of decaying zooplankton faecal pellets. Ammonium release increased rapidly on the day of biodeposit addition and reached a maximum after 5 days which was 3.6 times higher compared to control cores. During this period ammonium release was significantly higher in the cores with biodeposit additions than in control cores.

8. ***Contrasting the community structure and select geochemical characteristics of three intertidal regions in relation to shellfish farming***

L.I. BENDELL-YOUNG, Department of Biological Sciences, Simon Fraser University, 8888 University Avenue, Burnaby, British Columbia, Canada V5A 1S6

http://protectourshoreline.org/studies/08BendellShellfishCommunityStructure.pdf
ABSTRACT: Little is known about the impacts of intensive shellfish farming on intertidal ecosystems. To assess such impacts, several indices of ecosystem structure and select geochemical characteristics were contrasted among three intertidal regions, which represented a gradient of shellfish farming activities, namely (1) no active aquaculture, (2) actively farmed for three years and (3) actively farmed for five years. All three intertidal regions were located in Baynes Sound (British Columbia, Canada) and were geographically similar. Among the three beaches, species richness, community composition, bivalve abundance, biomass, distribution, and composition and surficial sediment per cent organic matter (carbon) and silt were compared. **The intertidal regions that had been used for farming for three and five years had lower species richness, different bivalve composition, abundance and distributions, and a foreshore community dominated by bivalves, as compared to the intertidal region where no active farming occurred. Beaches that were actively farmed also had greater accumulations of organic matter and silt. Simplification of the intertidal benthic community, coupled with accumulations of organic matter and increased siltation, may have altered the ecology of the foreshore region used for intense shellfish harvesting.** To access the foreshore for shellfish farming in a sustainable manner, studies are needed to determine the scale to which

intensive use of the foreshore for shellfish purposes alone is feasible without undue harm to the environment.

9. ***Potential Impacts of mechanical cockle harvesting on shorebirds in Golden and Tasman Bays, New Zealand. Doc Science Internal Series 19.***
Frances Schmechel
http://www.doc.govt.nz/upload/documents/science-and-technical/DSIS19.pdf
"The cockle (Austrovenus stutchburyi) is abundant in Golden and Tasman Bays, but since mechanical harvesting began there, concern has been expressed about potential adverse impacts of harvesting on shorebirds. Information for Golden and Tasman Bays is sparse, but studies in Europe show a link between the state of shellfish stocks and oystercatcher survival. Bird numbers/densities did not need to be at 'carrying capacity' to be negatively impacted by changes in their food supplies, but only within a range where density-dependent factors were operating. In addition to the direct impacts of food loss, there could also be indirect impacts of harvesting on non-target invertebrates such as tubedwelling polychaete worms on which shorebirds feed. In a study on the Burry Inlet, UK, using methods similar to those in Golden and Tasman Bays on muddy sand with high cockle densities, impacts on non-target species were significant, recovery rates slow, and foraging by shorebirds declined after a short-term increase immediately following the harvesting. Other adverse impacts from harvesting included damage of small cockles; reduced cockle spat numbers over the short term; mixing of anoxic layers of mud with upper layers; and chemical changes in the sediments which inhibit recolonisation. Work in Europe also showed almost complete losses of eel grass (Zostera) beds as a result of harvesting, suggesting that eel grass beds in Golden and Tasman Bays, which are particularly rich communities and may also be important sources of cockle spat,could be sensitive to mechanical harvesting of cockles. Research needs and recommendations for Golden and Tasman Bays are listed. A precautionary approach to management is recommended, in which potentially sensitive areas (those with high cockle densities and tube-dwelling polychaetes) are set asidefrom harvest until the impacts on sediment structure and

10. ***Need for restricting bivalve culture in the southern basin of the Lagoon of Venice***
Lu. L Sorokin, O. Giovanardi, F. Pranovi and
http://www.springerlink.com/content/u53156t15796ql71/fulltext.pdf
1999, P. 141-148
Abstract: At present, one of the environmental emergencies in the Lagoon of Venice is the impact of short-necked clam (Tapes philippinarum) fishery, which is practically an unregulated fishery. Although one of the proposed solutions would be the restriction of Tapes fishery to licensed areas, high seeding density can cause undesired effects on the environment. In this study several hydrobiological variables are compared between small areas of the Lagoon of Venice traditionally used for bivalve culture (clam, T. philippinarum and mussel, Mytilus galloprovincialis), and areas in the southern basin with seagrass meadows. Labile and suspended organic matter in the water was higher in areas with bivalve farming than in Zostera areas (undisturbed control). The same pattern was recorded for contents of total organic matter and acid volatile sulphides. The biomass of microplankton in farming areas was quite high. Mesozooplanktonwas extremely abundant, particularly at night, when its biomass was 1-2 orders of magnitude higher than during the day. Its composition was different in the culture areas and in Zostera areas. The biomass of Tapes in culture beds and their filtering capacity were also estimated.

11. ***Impacts of Intensive Mariculture on Coastal Ecosystems and Environment in China and Suggested Sustainable Management Measures***
Qishing Tang and Jianguang Fang for the Yellow Sea
http://www.protectourshoreline.org/articles/ImpactsIntensiveMaricultureCoastalEcosystemChina.htm
Discusses impacts of mariculture on ecosystems and the environment.
--"Comparing the present data of benthos biomass of organisms with the historical data, we found that the biomass of seaweed and bivalves in the seabed of intensive mariculture areas has declined dramatically since the 1970s. For example, although the resources of eelgrass Zostera marina were so rich that it could be found almost everywhere along the coastal zone from north to south of China before the 1970s, it is now very difficult to find. Although there are many factors causing the decline of eelgrass resources, the accumulation of bio-sediment from the intensive suspending culture may be the one of the most important factors involved."

-- "This biosediment matter can change not only the texture of the seabed, but can also be disturbed into the water column, especially during the storm season. This resuspended particulate not only can cause heavy mortality by blocking the gills of bivalves, but may sometimes induce the occurrence of harmful microalgae blooms because it can increase nutrient concentrations such as N, P, etc., in the intensive mariculture areas very rapidly during a very short period after storms. According to the statistical data, heavy mortality of bivalves cultivated in coastal zone has increased year by year since early 1990s in China. Though it is not known whether such heavy mortalities are caused by the turbidity of seawater, or by disease, it is recognized that the accumulation of bio-sediment on the intensive mariculture seabed is harmful to the ecosystem, the environment, and to mariculture.

Recommendations:
1) To establish models to predict the potentiality of new sites for mariculture based on their mariculture carrying capacity and ecological carrying capacity.
2) To pay great attention to study the impact of mariculture on ecosystem and environment, the interaction between mariculture and environment, the relationship between intensive mariculture in the coastal zone and the variability of marine fisheries resources, etc.
3) To re-evaluate intensive mariculture sites in coastal zones not only based on their carrying capacity, but also according to standards of human health.
4) To establish a sustainable management system that can determine and control the mariculture species, areas and scale, density, culture models in different sites based on the specific ecological and environmental conditions of different regions.

12. ***Effects of physical, chemical and rheological characteristics of mud on bioenergetics and habitat selection of the sommon sole Solea solea.***
Christine Couturier, PHD Thesis, Funding by EU 5th Framwork Program (ETHOFISH)
http://www.ifremer.fr/crema/thesards/CCouturier/couturier_anglais.htm
"The ecological impacts of the accumulation of biodeposits in bivalve culture zones are poorly known. But preliminary experiments showed the accumulation of organic matter on sea bed can influence the value of mudflats as nursery grounds for benthic fishes. **The results highlighted that the water viscosity increase can impair the ventilatory activity of fish, reducing their physiological and adaptive performances (behavior and population structure).**"

"The most visible consequence of this filtration process [of bivalves] is the accumulation of faeces and pseudofaeces on sea bed at the vicinity of bivalves farming facilities During periods of intense filtration, shellfish culture in Marenness-Oleror Bay was calculated to generate up to 6 tons (dry weight) of biodeposit per hectare and per day."

13. ***A Review of the ecological implications of mariculture and intertidal harvesting in Ireland***
M.L. Heffernan; Irish Wildlife Manuals No. 7; Series Editor: F. Marnell
http://82.112.120.223/PublicationsLiterature/AllPublications/file,2389,en.pdf or
http://www.protectourshoreline.org/studies/Review_Mariculture_Ireland.pdf
This literature review study speaks to effects of mussel and clam aquaculture and documents effects (some site specific) of anti-predator netting, hydrology, harvesting, sediment enrichment, etc.
P. 80 "We must resist introduction of such a method (as is used in Washington State for culture of Pacific oysters) to Ireland.
P. 96. "...most eipbenthic crustaceans were depressed under the predator exclusion nets compared to the unnetted control."
P. 96. "...the presence of the netting was shown to increase sedimentation which elevated the ground profile by about 10 cm and caused a small but significant increase in the percentage of fines and organic content of the sediment."

14. ***The Potential Impacts of the Commercial Geoduck (Panope generosa) Hydraulic Harvest Method on Organisms in the Sediment and at the Water-Sediment Interface in Puget***
Georgina Willner
http://www.protectourshoreline.org/ThesisGeoduckHarvestImpacts.pdf

The Potential Impacts of the Commercial Geoduck Hydraulic Harvest method on Organisms in the Sediment and at the Water-Sediment Interface in Puget Sound. Georgina B. Willner, Masters Thesis, Evergreen State College, June 2006
This document reviews literature related to hydraulic harvest methods of geoducks in subtidal areas of Puget Sound. Conclusions are:
-- All organisms in the sediment are impacted.
-- Sediment changes contribute to community changes, which may cause irreversible changes in the ecosystem functions and nutrient cycling processes could be lost.
-- Organisms removed or killed likely cause changes in cohesiveness and stability of the community structure and their loss may cause modification to microbial distribution, activity and processes that impact nutrient cycles.
-- Changes in function diversity and functional composition of infaunal comminutes will impact ecosystem processes.
-- Pulses of nutrients, pollutants and release of dormant cysts and eggs could cause increase in phytoplankton blooms, paralytic shellfish poisoning and other heath risks to Washington State citizens.
-- The relationship of the geoduck biomass with other organisms has not been studied.
-- Geoduck and other infaunal populations will become fragmented, affecting recovery rates.

15. ***Sustainable Shellfish: Recommendations for Responsible Aquaculture***
Heather Deal
http://www.davidsuzuki.org/files/Oceans/Shellfish.pdf
Recommends a "precautionary" ecosystem-based management approach. Addresses concerns regarding intensive aquaculture: cumulative effects, biodiversity, carrying capacity, non-native species, siting and disruptions or destruction of fish habitat.

16. ***Effects of shellfish aquaculture on fish habitat***
Canadian Science Advisory 2006, P. 25-26.
McKindsey, C.W., M.R. Anderson, P. Barnes, S. Courtenay, T. Landry, and M. Skinner
http://www.dfo-mpo.gc.ca/csas/Csas/Publications/ResDocs-DocRech/2006/2006_011_e.htm
"Field studies reported in the same study found that mussels consumed (based on stomach content analysis) copepods (<1.5 mm), crab zoeas (2mm), fish eggs (1-2mm), and even amphipods (5-6mm). Subsequent to this, Lehane and Davenport (Lehane and Davenport 2002) showed that mussels consumed organisms up to 3mm in length and that cockles (Cerastoderma edule) and scallops (Aequipecten opercularis) are also capable of consuming considerable quantities of zooplankton, both when suspended in the water column and when on the bottom. The size classes of organisms consumed in these studies suggest that the larvae of most commercial species may be at risk from this type of predation."

17. ***A framework for developing "ecological carrying capacity"***
Dr. Roger Newell
http://www.fra.affrc.go.jp/bulletin/bull/bull19/07.pdf
P. 1—"This emphasis means that other important aspects of ecosystem carrying capacity, such as the ability of the culture site to process the excrement produced by the animals, may not be adequately modeled."

18. ***Ecosystem influences of natural and cultivated populations of suspension-feeding bivalve molluscs***
Dr Roger Newell
http://www.hpl.umces.edu/faculty/newell/ecobivalve2.pdf
P.1—"Environmental conditions at bivalve aquaculture sites should be carefully monitored, however, because biodeposition at very high densities may be so intense that the resulting microbial respiration reduces the oxygen content of the surrounding sediments. Reduction in sediment oxygen…….can be toxic to the benthos."

19. ***Influence of Eastern Oysters on nitrogen and phosphorus regeneration in Chesapeake Bay, USA***
Dr. Roger Newell
http://www.hpl.umces.edu/faculty/newell/Newell%20et%20al.%202005%20NATO%20paper.pdf

P. 6—"…once the oyster's nutritional needs are satisfied, even phytoplankton cells are rejected in pseudofeces, in addition to less nutritious detrital and silt particles. This response of eastern oysters ….is quite different from other suspension-feeding bivalves such as infaunal cockles and clams, which mainly regulate their ingestion rates by constraining their clearance rates rather than rejecting excess particles as pseudofeces…"

20. ***Influence of simulated bivalve biodeposition and microphytobenthos on sediment nitrogen dynamics***.
Dr. Roger Newell
http://aslo.org/lo/toc/vol_47/issue_5/1367.pdf
P. 1—"Suspenion-feeding eastern oysters …may then have exerted top-down control on phytoplankton and also reduced turbidities,…..Alternatively, oysters may have simply recycled inorganic nutrients rapidly back to the water column, with no lasting reduction in phytoplankton biomass resulting from oyster feeding activity."

21. ***Influence of intertidal aquaculture on benthic communities in Pacific Northwest estuaries:scales of disturbance***
Charles Simenstad
http://estuariesandcoasts.org/cdrom/ESTU1995_18_1A_43_70.pdf
P. 65—" Management strategies that fail to consider the tolerance of estuaries to anthropogenic disturbance, such as that posed by intensive aquaculture, may well threaten the sustainability of estuarine resources and ecosystems processes upon which coastal economies depend. Estuaries have a critical role in the life histories of many economically and ecologically important animals. Salmon, herring, smelt, crab and flatfish feed in Pacific Northwest estuaries…. and several species of migratory waterfowl and shorebirds feed on the large invertebrate production that occurs on the mudflats….."

Growth and survival of animals in estuaries not only depends on specific habitats but on linkages between habitats and areas with the estuary."

Shellfish Industry Documents of Intensive Commercial Shellfish Aquaculture

The following documents are the only documents we have seen put forward by the shellfish industry related to intensive geoduck aquaculture. All other documents they cite, to our knowledge, are related to naturally occurring geoduck.

1. ***Comprehensive Literature Review and Synopsis of Issues Relating to Geoduck (Panopea Abrupta) Ecology and Aquaculture Production***
UW, Pacific Shellfish Institute, Baywater Inc. February 6, 2004
http://www.protectourshoreline.org/DNR/ComprehensiveLitReview.pdf
This document, put forward by industry to support geoduck aquaculture, basically documents aspects of naturally occurring geoduck such as life history, predator prey interactions, community effects of geoducks, spatial structure of geoduck populations, etc. It describes geoduck hatchery processes and has general but limited information about the development of geoduck aquaculture production systems in different countries.

Chapter 9 lists three pages of data gaps identifying research needs that include intensive shellfish aquaculture: These gaps include: 1) reproduction, recruitment, and genetic interactions 2) predator-prey interactions 3) community and ecosystem interactions including 4) suspension feeding activities and water column effects 5) sediment interactions 6) farming practices

This document confirms that there are mostly unknowns in the area of intensive geoduck farming and that extensive research is needed before expanding geoduck farming activities.

2. ***Programmatic Biolological Evaluation of Potential Impacts of Intertidal Geoduck Culture***

Facilities to Endangered Species and Essential Fish Habitats
Entrix Inc for Taylor Shellfish, Seattle Shellfish, October 27, 2004
http://www.protectourshoreline.org/taylor/7BiologicalEvaluation.pdf

This document was commissioned by Taylor Shellfish, Seattle Shellfish and Chelsea Farms. We have asked for clarification on topics contained in this document from August, 2006 such as: 1) how long was the study 2) what was the methodology 3) was the study peer reviewed or published 4) what were the qualifications of the persons conducting the study, etc. No response has been given to date.

This study only refers to endangered species. It does not appear to include peer reviewed studies on intensive geoduck aquaculture farming and harvesting practices but claims to have measured short and long term effects of planting/harvesting disturbances, water quality, sediment, habitat conditions and biota . It does not include data related to carry capacity or affects on any of the other 1000 marine creatures cited in the July 10, 2006 interim report of the Puget Sound Partnership as being imperiled.

3. ***Hood Canal Salmon Enhancement Group Molluscan Study Final Report***
October 10, 2006
http://www.protectourshoreline.org/articles/HoodCanalMolluscan103006.pdf

This document is "an investigation into the ecological value of filter feeders in Hood Canal." It cites studies related to mechanisms of bivalve functions in eutrophic waters, sediment effects, phytoplankton population control, seagrass productivity, carbon and nutrient storage in tissue, distribution and abundance of Hood Canal Bivalves and suggests a series of experiments to address data gaps related to these topics.

It describes how filter feeders provide a service by transferring nutrients from the water column to the sediment as feces and pseudofeces (biodeposits) and the various end results of this process depending on sediment characteristics, including 1) nitrogen trapping by photosynthetic plants and bacteria (shallow depths), 2) denitrification, a process of conversion to nitrogen gas which escapes into the atmosphere (mid depths), 3) nitrogen burial in the sediment (deep water). Many of the studies cited are from areas very different from Hood Canal, such as San Francisco Bay and the Thau lagoon in France and cite both positive and negative effects of shellfish aquaculture.

States that "in Hood Canal the production of oxygen by aquatic plants is not likely to help the low dissolved oxygen because of the strong stratification and low vertical mixing."

States that "bivalves and specifically geoducks can affect the water-column...by the resuspension or regneration of nutrients and organic matter from biodeposit-enriched sediements...to fertilize phytoplankton growth or be metabolized by water-column microbes, consuming oxygen."

Suggests the uncited theory that geoducks in their growth phase assimilate more nutrients that older geoducks and that therefore "harvesting amplifies the benefits of nutrient storage by removing the organism" and implies that cultured geoducks, which are harvested every 5-6 years, are thus better than natural ones which have slow recruitment. This particular idea does not contain any citations and does not include feces/pseudofeces waste from growing geoducks as part of the equation. It also does not address the effects of intensive planting/harvesting methods on sediment properties and potential resuspension of enriched sediments during harvest.