WASHINGTON STATE

Final

S.E.I.S

Supplemental
Environmental Impact
Statement

State of Washington Commercial Geoduck Fishery

May 23, 2001

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

Washington Department of FISH and WILDLIFE

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Washington Department of FISH and WILDLIFE

May 23, 2001

Dear Interested Party:

Attached is a copy of the Final Supplemental Impact Statement (FSEIS) for the State of Washington's commercial geoduck fishery. The FSEIS is an up-to-date programmatic review of the physical and biological impacts associated with geoduck harvest using the water-jet harvest method. The purpose for developing the FSEIS was to update the original EIS, completed in 1985, by incorporating all pertinent research conducted to date on the environmental impacts of the commercial geoduck fishery.

Following the requirements of the State Environmental Policy Act, the Draft SEIS was made available for public review during the following time periods:

1. Scoping Notice - April 20 - May 20, 1999
2. First public comment period - November 23, 1999 - February 4, 2000
3. Second public comment period - January 22 - February 23, 2001

Comments were integrated into the FSEIS as appropriate.

Thank you for your interest and comments. We appreciate the public's involvement in the development of the FSEIS.

Sincerely,

Doug Sutherland
Commissioner of Public Lands

Jeffrey P. Koenings, Director
Washington Department of Fish and Wildlife

FACT SHEET

Project Title: Final Supplemental Environmental Impact Statement (FSEIS) for the State of Washington Commercial Geoduck Fishery

Project Description: An Environmental Impact State for the Puget Sound Commercial Geoduck Fishery was completed in 1985 by the Washington Department of Fisheries (now know as the Washington Department of Fish and Wildlife (WDFW)). The Department of Natural Resources (DNR) as lead agency, in a joint effort with WDFW updated the original EIS in 1999 to include all research on the potential environmental impacts of the fishery since 1985 through the development of a draft Supplemental EIS (DSEIS). Public comments on the DSEIS were solicited during the following time periods:

1. Scoping Notice - April 20 - May 20, 1999
2. First public comment period November 23, 1999 - February 4, 2000
3. Second public comment period - January 22 - February 23, 2001

All comments received during the three comment periods were considered when completing the FSEIS.

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Licenses Required:
None for this update of the programmatic SEIS analysis. Implementation may require a shoreline permit.

Author and Principal Contributors:
The FSEIS and associated documents were prepared by the following people:

David Palazzi (Project manager, author & technical writer), Leigh Espy (editor). Susan Sturges and Candis Ladenburg (preparation, editors), DNR, Aquatic Resources Program. Blanch Sabottke (final technical editor), DNR, Communications.

Lynn Goodwin, (author and technical writer) Alex Bradbury (author and technical writer), WDFW, Brinnon Shellfish Lab. Bob Sizemore, WDFW, Olympia office (author and technical writer).

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FSEIS and Supporting Document Preparation:
Washington Department of Natural Resources and Washington Department of Fish and Wildlife

FSEIS and Supporting Documents Include:
- Final Supplemental Environmental Impact Statement for the State of Washington Commercial Geoduck Fishery, May 23, 2001
- FSEIS Appendices
- Responsiveness Summary to December 2000 DSEIS
- The Puget Sound Commercial Geoduck Fishery Management Plan, May 23, 2001

Final Action Date: May 23, 2001 (anticipated)
The analysis will guide the ongoing harvest of geoducks by the WDNR.

Subsequent Environmental Review:
The FSEIS is considered a "nonproject proposal" (under WAC 197-11-442). An environmental assessment is developed specifically for individual tracts that are being proposed for harvest.

Location of Reference Material:
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Availability:
Single copies of the FSEIS and supporting documentation are available from the Washington Department of Natural Resource.

Cost:
The FSEIS is provided free to the public until the initially printed copies run out. After that, charges will be assessed for the costs of copying.

Special acknowledgment for the development of the FSEIS goes to Alex Bradbury and Bob Sizemore, with the Washington Department of Fish and Wildlife, for their technical expertise and timely work. Without their quality work the production of the FSEIS would not have been possible.

FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

STATE OF WASHINGTON COMMERCIAL GEODUCK FISHERY

STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES
DEPARTMENT OF FISH AND WILDLIFE

May 23, 2001

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1.0 EXECUTIVE SUMMARY

Geoducks (*Panopea abrupta*) are large burrowing clams which are very abundant in many of Washington's subtidal waters. The Puget Sound geoduck fishery includes commercial beds (called "tracts") in southern and central Puget Sound, Hood Canal, Admiralty Inlet and, to a lesser extent, in the Strait of Juan de Fuca, northern Puget Sound, and the San Juan archipelago.

The commercial geoduck harvest began in Washington State in 1970 following the discovery of extensive subtidal populations. It is the largest and most economically important clam fishery on the west coast of North America. Geoducks are harvested by divers in depths of -18 ft. mean lower low water (MLLW) to -70ft. uncorrected depth contours. The divers use hand-held water-jets (nozzles) to dig the clams one at a time from the substrate.

The geoduck fishery is jointly managed by the Washington Department of Natural Resources (DNR), the Washington Department of Fish and Wildlife (WDFW), and the sixteen Tribes that have a right to 50 percent of the harvestable surplus of geoducks. The State and the Tribes are responsible for estimating population size, determining sustainable yield, and ensuring that adverse effects to the environment are kept to a minimum.

DNR has proprietary rights over the State's half of the fishery and sells the right to harvest geoducks to private companies and individuals. The DNR harvest agreement contract is the legal document that binds the State with the private harvest companies. Both DNR and WDFW enforce Washington State laws, regulations, and contract conditions that apply to the fishery as appropriate to the responsibilities and mandates of each agency.

A December 20, 1994 U.S. district court decision by Judge Edward Rafeedie (Unites States v. Washington, 873 F. Supp. 1422 W.D. Wash. 1994) (hereinafter Rafeedie decision) affirmed and quantified the Puget Sound Treaty Indian Tribes' right to 50 percent of the harvestable surplus of geoducks within their usual and accustomed grounds and stations.. A subsequent federal district court order and judgement confirmed the Tribes' management role (United States v. Washington, 898 F. Supp. 1453 (W.D.Wa 1995). Each Treaty Tribe that is a party to the Rafeedie decision is bound by the provisions of District Court's Implementation Order and all subsequent court orders and decrees.

Each Tribe is responsible for managing its own geoduck fishery. This includes fishing schedule, monitoring, and enforcement. These Tribes are also bound by Washington Department of Health restrictions imposed for public health reasons, as are State harvesters. The Tribes have obligated themselves through annual State-tribal geoduck harvest plans to set and follow provisions for the fishery that are environmentally-based and necessary to conserve all elements of the natural environment. For instance, the Tribes agree to restrict harvests from areas with critical eelgrass habitat. However, because of their sovereign status, Tribes are not bound by State, city or county laws such as local shoreline management regulations or ordinances in the exercise of their treaty fishing rights.

The fishery and cooperative State/Tribal management are described in annual management agreements and annual harvest plans negotiated between the State and Tribes. Separate management agreements and harvest plans are currently written for each of six management regions (Figure 1).

1.1 Statement of Purpose and Need

The original geoduck Environmental Impact Statement (EIS) was published in 1985. Since its publication, DNR has raised concerns about the applicability of the 1985 EIS on current and future harvesting decisions. Additional research has been conducted on the commercial geoduck fishery since publication of the 1985 EIS which further support impacts assessments made in the original document. DNR has identified a need to incorporate this research into the original EIS to ensure the most current research is included in the EIS, to make these findings available to the public, and to provide an opportunity for public comment.
The purpose of the proposal (see Chapter 2.1 Proposal) is as follows:

- Foster the commercial harvest of geoducks on public lands to generate revenue to benefit the citizens of the state pursuant to RCW 79.68.080 and RCW 79.96.080,
- Manage a sustainable State commercial geoduck fishery,
- Assuring compliance with local, state and federal environmental policies,
- Ensure environmental protection,
- Assess and mitigate any potential significant impacts on species listed under the Endangered Species Act.

The analysis contained in the following pages includes the best information available to DNR and WDFW and is based on 30 years of experience managing the State's geoduck resources. Because DNR and WDFW cannot responsibly claim to know and understand all facets of the natural marine environment, the agencies will continue to conduct research and monitor the impacts of the geoduck fishery. The intention of external public review of the DSEIS was to assure that any other credible information and research on geoducks that was not included in the EIS or draft SEIS is included in the final SEIS. We also hope that reviewers will provide us with input regarding other plausible research that should be conducted in the future.

The SEIS is not intended to be used to introduce new issues or changes to the State/tribal geoduck management agreements. This requires collaboration between State and tribal geoduck managers.

The harvest has been conducted for over 30 years without significant adverse environmental impact other than the reduction of the local geoduck population. The fishery is controversial, with the majority of opposition from shoreline residents adjacent to harvest tracts. DNR has concluded that this SEIS provides a suitable means for inviting public and agency comment, and allowing an opportunity to review and re-assess the management of the fishery. The SEIS also provides DNR a way to responsibly meet its mandates to manage a sustainable State commercial geoduck fishery, ensure environmental protection and generate revenue for the State of Washington. The SEIS describes the environmental impacts associated with the fishery as conducted per the State-Tribal annual management agreements and harvest plans by integrating all relevant environmental studies completed since the publication of the 1985 Geoduck EIS.

The major concerns expressed about geoduck harvest have come from shoreline residents living near harvest sites. These concerns include impacts of noise during harvest; interference with other uses of the water (primarily recreational boating and visual use); impacts to Dungeness crab, eelgrass, and other plants and animals that exist with geoducks; trespass by harvesters on private tidelands; and possible reductions in the abundance of intertidal geoduck stocks. Measures to address these concerns are included in the State-Tribal management agreements, harvest plans and this SEIS.

This SEIS largely describes impacts that have actually been observed. Following 30 years of fishing, observation and research, the conclusions of the SEIS indicate that, other than the decrease in geoduck populations on harvested tracts, there is only a very slight potential for impacts based upon the low risk of adverse effects to marine organisms. Fishing affects a relatively small area of total habitat and there is a rapid recovery for the benthos at the sites disturbed by fishing. The known impacts are summarized in Table 1. DNR and WDFW have continuing programs to monitor and assess harvest impacts. An environmental assessment of each State-auctioned tract is conducted prior to auctioning geoduck quotas for harvest.

Beneficial impacts of the geoduck fishery include direct employment of approximately 50 to 60 people, (plus an additional unknown number of tribal members), marketing of about four million pounds of geoducks annually, positive international trade, and between $5 - 7 million (1990-2000) per year of revenue paid to the State from private purchasers. Revenue generated from Washington's commercial geoduck fishery provides funding for the following programs:

- cleanup and restoration of contaminated sediment in the Puget Sound,
- inventory of all nearshore aquatic habitat in the Puget Sound,
- control of the invasive aquatic weed *Spartina*,
- geoduck fishery management and harvest compliance programs
- State/tribal shellfish negotiations

- operating and capital improvement monies for Washington's Department of Fish and Wildlife including intertidal shellfish enhancement, and
- grants to local governments for the purchase, development and restoration of aquatic lands for public access and salmon habitat restoration.

The SEIS is considered a "nonproject proposal" (under WAC 197-11-442). It describes the general approach to harvesting geoducks in the Puget Sound. In addition, a subsequent environmental assessment, developed by WDFW, is conducted for specific individual tracts that are being proposed for harvest.

CONCLUSIONS:

1. Geoduck harvest provides benefits to the State and Tribes via food production, trade, employment, and direct revenue.

2. Geoduck harvest does not have significant, long-term, adverse impacts on the benthic environment and (non-geoduck) flora and fauna. Geoduck biomass on individual tracts will be reduced temporarily, and total harvestable geoduck biomass will eventually be permanently reduced. Populations on most harvested tracts may require a significant time to return to prefishing densities and biomass following harvest. In post-harvest studies done at 15 different geoduck tracts throughout Puget Sound, the projected recovery time averaged 39 years, and ranged between a low of 11 years to a high of 73 years. Population models predict that the total commercial biomass (100%) of harvestable geoducks will eventually be reduced to between 40 and 62 % of the unfished, "virgin" level. Scientific literature suggests this is adequate to maintain a sustainable fishery. Because the biomass of geoducks available to the commercial fishery represents less than a quarter of the total geoduck biomass estimate in the State, roughly three-quarters of the total geoduck biomass in the State is not available for harvest by the commercial fishery.

3. The harvest of individual geoducks by divers using hand-held water-jets is the most environmentally benign method of harvest currently available.
4. The following mitigation measures have already been implemented

through the State-Tribal management agreements and harvest plans:

- Fishing is limited to the area between -18 ft. MLLW and -70 ft. uncorrected.
- A 2-foot vertical buffer or a minimum of 180 foot buffer (for tracts with a very gradual sloping contour) is maintained between the harvest area and eelgrass beds and any substrate used for herring spawning.
- An environmental assessment is completed by WDFW prior to State harvest.
- A geoduck survey of each tract is completed prior to State and tribal harvest.
- Tracts which have been fished down may not be re-fished until a new survey demonstrates that geoduck density has reached or exceeded pre-fishing density.
- Seasonal times for fishing and buffers are established on tracts located in or adjacent to areas of herring spawning.
- Annual regional harvest quotas are limited to 2.7% of commercial biomass.
- All geoduck fishing by the State must occur with on-site compliance/enforcement who will not participate in the fishery.

State harvest is closely monitored by DNR to ensure enforcement of these measures. Many of the Tribes have amended their monitoring program to work toward a higher standard of compliance.

5. The managing agencies and Tribes have the authority and flexibility to apply site-specific restrictions on harvest to control potential impacts or conflicts unique to any harvest site.

6. Additional field work needed for the geoduck fishery in order to support the sustainablity and impacts of commercial harvest strategies are:

   a. Continued studies on post-harvest recovery of geoduck populations;
   b. Continued studies on geoduck natural mortality rate and age-

frequency distribution;

c. Limited surveys in the extensive areas seaward and shoreward of the narrow zone where harvest now occurs, so that total geoduck population estimates can be refined;

d. Continued detailed studies on the possible effects of the fishery on other marine flora and fauna;

e. Possible additional work to confirm the limited extent and impact of sediment plumes generated during geoduck harvest.

Table 1. Commercial Geoduck Harvest Impact Summary

ENVIRONMENT	IMPACTS			
NATURAL	MAJOR	MINOR	NONE	COMMENTS
EARTH	P, S			Geoduck harvest creates numerous shallow depressions (harvest holes) where individual clams are removed. These depressions average about 15 inches in diameter and refill within nine days to seven months. Harvest has been shown not to change the average substrate grain size in the geoduck tracts. However, harvest may reduce the fine particle component of the substrate within individual harvest holes.
AIR		P, S		Exhaust from vessel engines will contribute emissions into the air.
WATER		P, S		Small amounts of fine sediment (silt) are released into the water, increasing turbidity.
WILDLIFE	P, L			Geoduck populations on the harvested tracts will be largely removed. Due to the slow rate of natural recruitment, recovery may take an estimated 11-73 years. The sustainable harvest rate is applied only to surveyed stocks on commercial tracts. The majority of the geoduck population lies outside these commercial tracts (inshore, offshore, and in polluted areas), providing a permanent unfished refuge.
		P, S		Other organisms living in the sediment will also be reduced, but recover rapidly. Mobile animals such as crab, fish, etc., may be temporarily attracted to the harvest site. No effects of fishing on marine birds or mammals have been recorded. Marine plants are generally limited to the inshore borders of the tracts and may be disturbed by harvest. Harvest is prohibited in eelgrass beds, which are identified through surveys prior to fishing. Harvest takes only a small proportion of subtidal geoducks, and does not occur in shallow tidal or subtidal waters.
BUILT				
ENVIRONMENTAL HEALTH		S		Except for the removal of geoducks, there are no long-term impacts to the marine environment
LAND/SHORELINE USE		P, L		Geoduck harvest does not limit shoreline uses; however, protection of commercial tracts, made valuable by harvest, may limit activities which would pollute or otherwise prohibit harvest.
		P, S		Commercial and sport fishing for species other than geoducks may occur near harvest sites and necessitate caution by these fishers to avoid geoduck divers. Noise from harvest may be noticeable on shore. Vessels harvesting the States share of geoducks are required to stay at least 200 yards from shore, to operate only during daylight hours, Monday through Friday, and to operate at noise levels less than 50 dBA (measured at 600 ft from the harvest vessel).
TRANSPORTATION		P, S		Other vessels may have to avoid anchored harvest boats. Unloading geoducks at boat ramps or marinas may occasionally inconvenience other users of these facilities.
PUBLIC SERVICE AND UTILITIES				Landing geoduck could caused delays and inconvenience for others who use the facilities, particularly when launching and retrieving boats. However, harvest vessels do have a right to use public facilities. There have also been complaints of inappropriate behavior by State and Tribal harvesters. Local public emergency services would be called upon to respond to an emergency situation created by the unlikely possibility of a dive accident, boat accident or other emergencies related to commercial geoduck harvest operations.

P = Probable L = Long-term S = Short-term

2.0 DESCRIPTION OF PROPOSAL AND ALTERNATIVES

2.1 Proposal

The proposed activity is the continued harvest of subtidal geoduck clams from State lands in Washington based on the State of Washington Commercial Geoduck Fishery Management Plan (Plan). The proposal is described in detail in the State-Tribal annual management agreements and harvest plans for each of the six geoduck management regions (Figure 1) and is summarized below.

Harvest is managed jointly by DNR, WDFW and the Tribes. Subtidal lands are owned by the State of Washington and are managed for the State by DNR. The federal court has affirmed the reserved right of treaty Tribes to half the harvestable shellfish (including geoducks) in Washington.

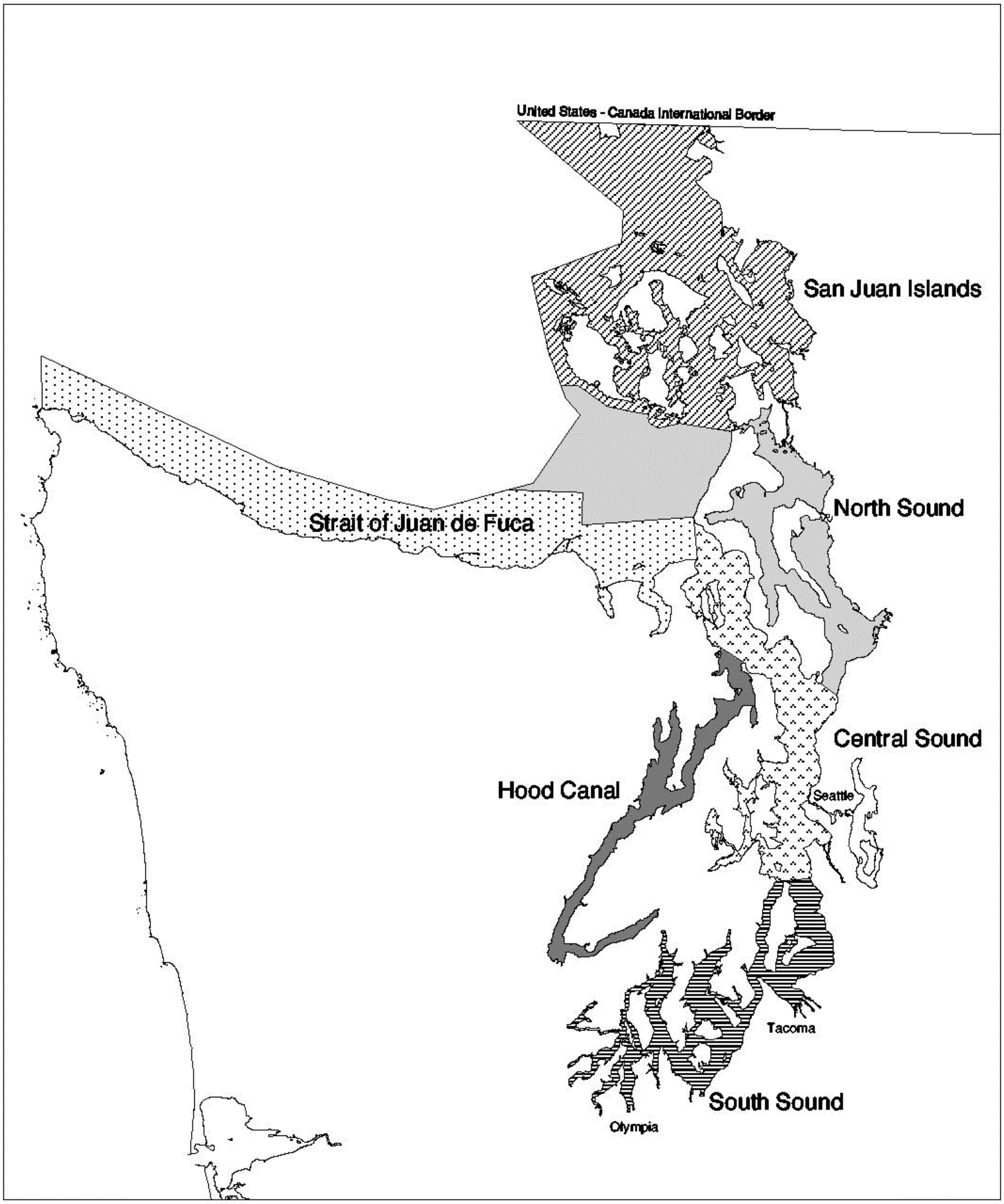
The goals of geoduck management are to manage a sustainable geoduck fishery, protect the marine environment, encourage a stable and orderly fishery while maximizing the economic benefits of the fishery for the citizens of the State.

Geoducks are found throughout many marine areas of Puget Sound, the Strait of Juan de Fuca, and the San Juan archipelago. They are very abundant in subtidal waters and range in depth from extreme low tide to depths as great as 360 ft. They also occur intertidally but in lesser numbers. Commercial geoduck harvest is limited to selected tracts within a narrow bathymetric band along the shores of Puget Sound. The shoreward boundary is the -18 ft line (corrected to the mean-lower-low water (MLLW) level) or a line 200 yards seaward from the line of ordinary high tide (RCW 77.60.070), whichever is the greatest distance from shore. The 200 yard restriction applies only to State harvesters; the shoreward boundary for Tribes is currently the -18 ft line (MLLW). No harvest occurs deeper than 70 ft below the water surface unadjusted for tides (WAC 220-52-019(11)); State/Tribal agreements and annual harvest plans and DNR harvest agreement contract). The shoreward boundary protects shallow water geoducks, minimizes impacts on nearby shoreline residents, and helps protect eelgrass beds and other sensitive nearshore habitats. The deep-water boundary is the limit at which divers can efficiently and safely operate without extensive decompression.

Harvest is limited to specific tracts which have geoducks in commercial quantities (normally greater than 0.04 geoducks per ft^2), contain market-quality geoducks (dependent on size and meat color), present no practical difficulties for harvest, and which do not conflict with existing uses such as ferry routes, etc. These tracts must also be certified by the Washington Department of Health (DOH) as meeting State and national sanitary requirements.

Harvest is not allowed in areas where it will result in significant long-term adverse impacts to the surrounding environment, other than reduced geoduck populations in harvested tracts. Figure 2 shows subtidal areas in Washington which have been identified by WDFW, DNR and the Tribes as major tracts. Many of the major tracts have been designated as "commercial" based on the criteria mentioned above. For greater detail of all surveyed tracts, see Appendix 1 (2000 Geoduck Atlas). It is intended that all of the identified commercial tracts will eventually be harvested. These tracts are currently found in Island, Snohomish, King, Pierce, Thurston, Mason, Kitsap, Jefferson, and Clallam counties. Future surveys may result in new tracts being added to the list of commercial tracts. Future surveys or changes in tract status may result in some current commercial tracts being removed from the list.

Figure 1: Six Current Geoduck Management Regions in Washington



Geoducks are large burrowing clams which usually live buried 2-3 ft deep in soft bottom sediments (mixtures of sand, silt, and gravel). They average 1.9 pounds in weight, and the largest geoduck dug during routine dive surveys was 7.2 pounds (Goodwin and Pease 1991) . In general, geoducks in southern Puget Sound grow larger and faster than those further north (Goodwin and Pease 1991). To harvest geoduck clams, divers are required (RCW 75.24.100) to use water-jets to loosen the substrate immediately around the clam which allows removal by hand. The water-jet is a nozzle about 18 inches long. The water-jet is inserted next to the exposed geoduck siphon ("neck"), or in the hole which is left when the siphon is retracted (Figure 3). A short burst of water liquifies the sediment water liquifies the sediment allowing the geoduck to be easily removed. A diver using this method can often harvest 1,500 pounds per day (approximately 800 clams) on a good tract.

Divers operate from anchored boats, normally 25 to 70 ft long. Pumps and compressors on the boat provide divers with both air to breathe (through hoses that are approximately 300 ft long) and pressurized water for the water-jet nozzle. Boats are allowed to have up to two harvest divers in the water at the same time (WAC 220-52-019(7)). A tender stays on the harvest vessel to monitor pumps and compressors and to haul harvested geoducks aboard. The tender and divers are in constant contact via a surface to diver communication system.

Within each of the six management regions, the geoduck tracts to be harvested are selected by DNR , WDFW and Tribes from those that have met commercial criteria. Depending on the particular management agreement negotiated between the State and Tribes within a region, some tracts may be fished by both State and Tribal divers during the harvest year; in other cases, the State and Tribes harvest on separate tracts. In the case of State harvest, the right to harvest the geoducks is auctioned to private companies. DNR, WDFW and the Tribes are working toward accounting for all fishing-related mortalities, ensuring these combined mortalities do not exceed the annual Total Allowable Catch (TAC), and facilitating effective monitoring and enforcement of the fishery.

Within a given management region, tracts selected for harvest are typically concentrated into a single geographical area to facilitate enforcement. This clustering allows DNR and WDFW personnel to concentrate survey efforts and to focus on mitigating concerns of local residents and local governments. Harvest sites in the past were usually rotated every one to two years. Harvest sites are rotated regionally throughout the year in accordance with State/Tribal harvest agreements. Presently DNR, through harvest contracts with the commercial divers, limit the number of boats that can harvest geoducks in Puget Sound at any one time. Typically eight to ten boats are in operation at any one time.

Figure 2: Map of Identified Geoduck Tracts in Washington

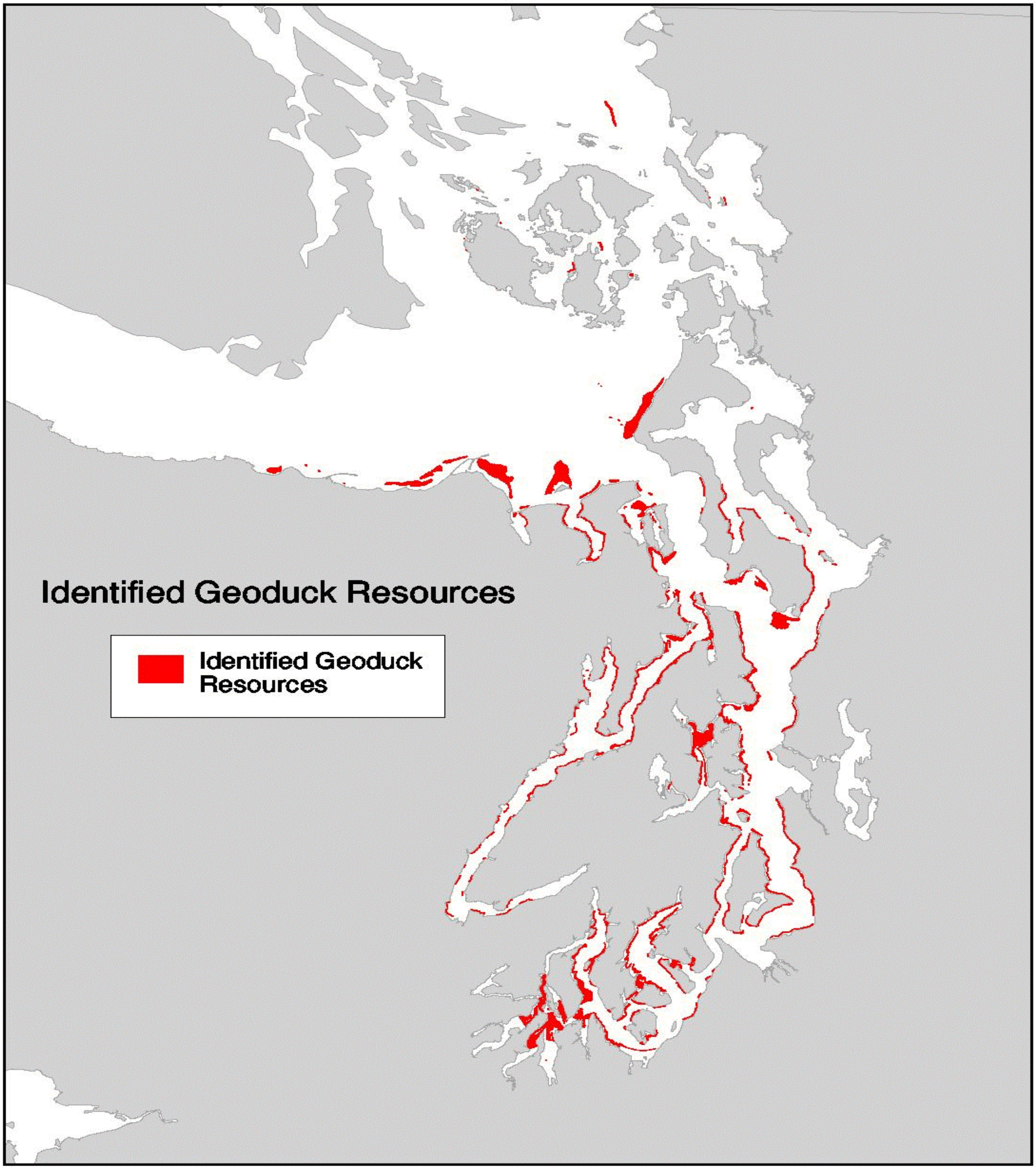
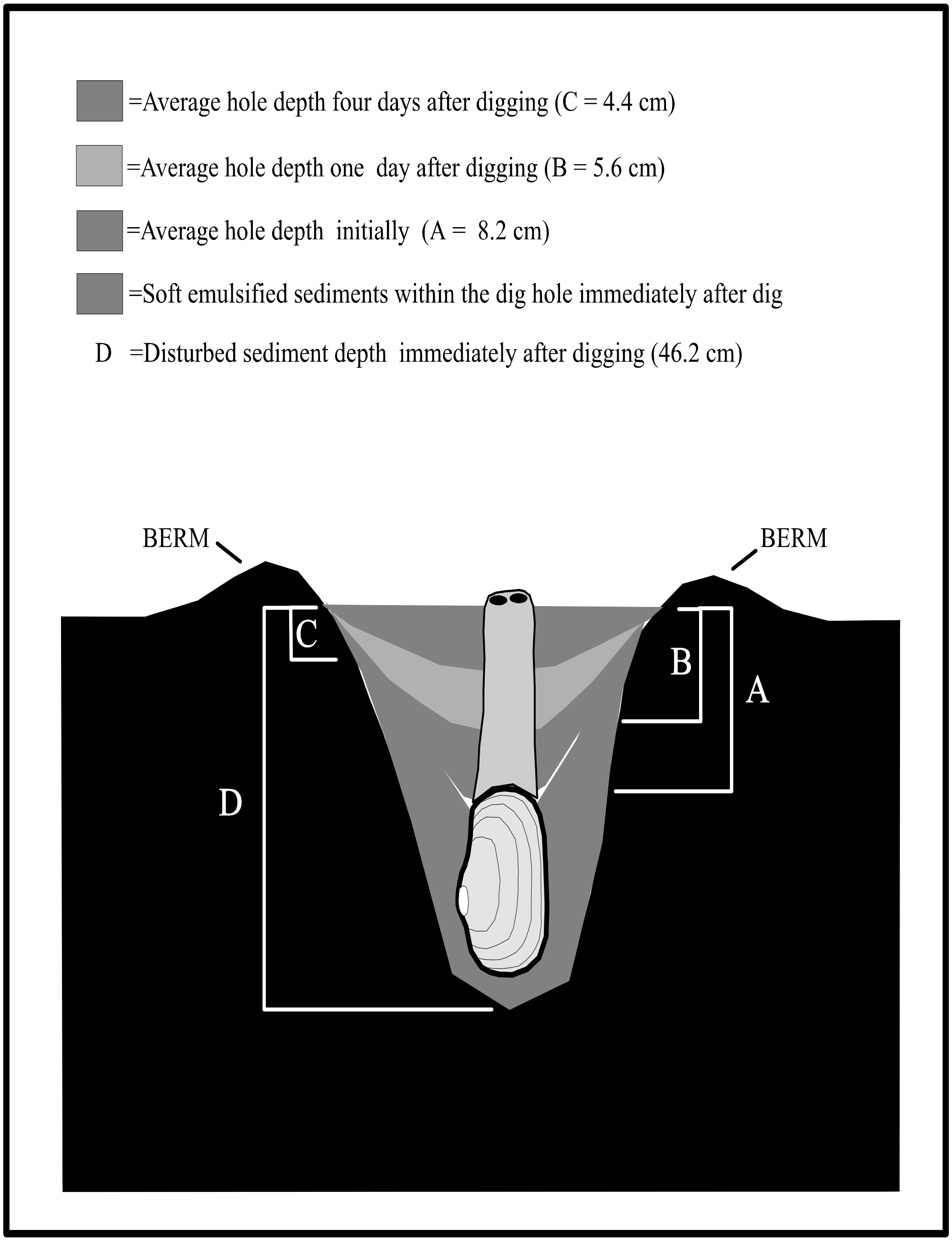


Figure 3: Cross-section of a geoduck harvest hole



2.2 Current Mitigation Measures

The impacts of harvest are disturbance of the substrate (it appears pock-marked where geoducks have been removed), disturbance of other organisms, short-term increases in water turbidity, long-term reduction in the number of geoducks in the harvested tracts, and to a lesser degree, impacts of harvest operations on shoreline residents. The current State-Tribal management agreements and harvest plans include several mitigation measures to minimize these effects:

- Harvest is limited to the use of water-jets. This is the most efficient and environmentally benign harvest method known, disturbing only the area immediately around the geoduck. The hole produced is the result of having removed the large clam and having displaced sediment. To further reduce impacts, nozzles are limited to an inside tip diameter of 5/8-inch (WAC 220-52-019(2a)). The nozzles are hand held and controlled by divers; the nozzle pressure is limited to about 100 psi measured at the pump.
- Geoduck harvest is not allowed in eelgrass beds, which are identified by dive surveys prior to fishing, and is restricted in time to prevent harvest in sensitive areas during herring, salmon, true cod, or other important fish spawning and rearing seasons, as well as eagle nesting periods.
- Limits set on the number of geoducks that can be harvested, pre-harvest environmental surveys, assessments of the effects of harvest, and on-site harvest monitoring by DNR and Tribes also serve to identify and reduce any adverse long-term impacts.

DNR enforcement boat crews weigh all geoducks from all tracts being fished by state divers (State divers are not actually state employees. "State divers" refers to the subcontract divers that are hired by the private companies that purchase geoduck harvest rights from DNR. The subcontract divers harvest the State's share of geoducks). This is normally done on the water before the fishers leave the harvest site for the day. Enforcement boats have cellular phones making DNR staff available to shoreline residents to answer questions or respond to possible violations. The cellular phone numbers are made available to the public through the local shoreline administrator or Aquatic Resource Division staff. Tribal staff are responsible for accounting for the harvesting done by Tribal fishers.

Other concerns center around the impacts of harvest operations on shoreline residents. Harvest generally occurs in rural or sparsely developed areas. Some shoreline residents have expressed concern that the noise and commotion from harvest is disturbing to the tranquility of the shoreline area. To minimize such problems, DNR and WDFW may conduct meetings with county officials at least six months prior to DNR's geoduck auction in order to identify potential problems. DNR and WDFW, if requested by local government, can conduct a public meeting in the neighborhood of the proposed harvest to explain what residents can expect; whom to call if there are any problems; and to learn of possible conflicts with sport fishing, boating, or other uses.

To directly reduce the impacts of harvest on local residents, all State harvesters must remain at least 200 yards from shore (measured from mean high water line) or seaward of the -18 ft (MLLW) depth contour, whichever is further from shore (RCW 77.24.100). Tribal harvesters currently must remain seaward of the -18 ft (MLLW) depth contour. Under terms of the DNR harvest agreement, all State geoduck vessels must operate with noise levels of less than 50 decibels (dBA) measured at 600 ft from the source. The State noise standard for residential areas is 55 dBA (WAC 173-60-040). Currently, the State harvest is limited to daylight hours (typically 8:00 a.m. to 5:00 p.m.) Monday through Friday. WAC 220-52-019 prohibits harvest on week-ends and State holidays. DNR can further restrict hours for State divers in its harvest agreements.

The major impact resulting from harvest is the reduction of numbers of geoducks on the harvest tracts. This reduction includes juvenile geoducks. Small geoducks living next to adults are often inadvertantly displaced by the harvest activities.

Based on post-harvest surveys and landings data from 1985 to 1998, an average of 72 percent of the harvestable-sized geoduck population is removed during one harvest cycle from the individual tracts being fished. If a tract were to be 100 percent harvested (in reality, harvest management does not permit 100 percent harvest of a tract) an estimated 11 to 73 years may be required for the geoduck population on the tract to return to pre-harvest levels. An estimated average of 39 years is needed for full recovery after 100 percent removal due to the slow rate of natural recruitment (see Appendix 2). The annual harvest of geoducks is currently limited to 2.7 percent of the commercial biomass in a region (see Figure 1) on commercial tracts throughout surveyed portions of Washington. The annual 2.7 percent annual harvest rate is the sustainable harvest rate calculated using a fishery age-based equilibrium yield model titled Stock Assessment of Subtidal Geoduck Clams (*Panopea abrupta*) in Washington (Bradbury and Tagart 2000; Appendix 3).

The geoduck population as a whole is further protected because only a small portion of the total population is available for harvest. A large unharvested population remains inshore and offshore of the harvest tracts and in other areas where legal commercial harvest cannot take place. This large unharvested area contains roughly three-quarters of the total geoduck biomass in the State, but is not considered in estimating the Total Allowable Catch (TAC). It therefore serves as a *de facto* "refuge" which may contribute to the sustainability of stocks in harvested areas.

2.3 Alternative harvest methods

The water depths at which geoducks are harvested (-18' MLLW to -70' uncorrected) is mandated in RCW 77.60.070. From a physical standpoint, the deep water boundary and the geoducks depth in the substrate make a hydraulic harvest method (versus a suction dredge) necessary. Alternative mechanical methods include use of a hydraulic escalator harvester, such as is used for the harvest of soft-shelled clams on the Atlantic coast of north America, and hand-held suction harvesters. Geoducks are dug in intertidal areas by recreational diggers with hand tools at low tide. The hydraulic escalator harvester operates by liquefying the sediment in its path down to the depth of the clam and separating the clam from the sediment. Large amounts of material are disturbed, as are all of the organisms in the path of the harvester. In the process, large amounts of silt are also released into the water.

The diver-operated suction harvester vacuums all the sediment from around the geoduck and eventually vacuums up the geoduck. Although it affects less area than the escalator harvester, suction harvest still removes the sediment from the bottom resulting in an obvious hole, and releases silt into the water. The time needed to harvest a geoduck with the suction harvester is much greater than the water-jet.

In comparison, the water-jet method only incidentally removes material from the bottom and produces a small hole of about 0.32 ft^3 for each geoduck harvested. Fewer organisms are affected and only small amounts of silt are released into the water.

Hand harvest using a shovel on intertidal beaches, which is a common method used by recreational harvesters, may result in the removal of 10 to 20 ft^3 of sediment from around and above each geoduck harvested. The use of post-hole diggers or tubes to prevent substrate sloughing can reduce the substrate disturbance during the intertidal hand harvest.

Based on the different levels of disturbance, the diver operated water-jet is the most environmentally benign method for subtidal geoduck harvest. Because this is also the most economically feasible method, Washington harvesters all use it instead of suction harvest. The suction harvest method is presently used only as a research tool by biologists. No other feasible method of subtidal geoduck harvest is known.

2.4 Additional Environmental Review

All geoduck tracts categorized for harvest have been surveyed by WDFW and/or the Tribes. Tracts that meet all the requirements for harvest comprise the list of commercial tracts. As new tracts are discovered they are added to the list. Tracts or portions of tracts classified by DOH as polluted within closure zones, or found to be in conflict with other water-dependent uses are removed from the list.

Before harvest, tracts are resurveyed to better evaluate the geoduck population and the tracts' suitability for harvest. Observations are made of geoduck size, distribution, abundance, and the prevailing sediment type; other factors which are recorded in all surveys and may be recorded during Tribal surveys include ease of digging and associated flora and fauna. Although all commercial geoduck tracts basically conform to the typical tract described in this SEIS, these re-surveys are intended, in part, to identify potential harvest impacts and to produce site-specific environmental information. Prior to harvest on tracts designated by State/Tribal agreement for State harvest, DNR and WDFW may meet with the local government and with the affected residents, to identify other potential impacts, conflicts, and concerns.

The proposed harvest is also reviewed internally with WDFW fishery, habitat and wildlife biologists, as well as enforcement staff. Other county, State and federal agencies, and Tribal representatives are consulted. All reviewers are asked to identify possible conflicts with sport and commercial fishing and possible threats to important species or their habitat. The results of the surveys, comments from the public, and comments from other agencies are included in an Environmental Assessment written for all geoduck tracts proposed for State fishing. This assessment is sent to DNR for use in adoption of existing environmental documents as required by the State Environmental Policy Act (SEPA).

The environmental review work is used to develop special harvest restrictions. These may include changes in the hours and days of operation, location of off-load sites, and changes in tract boundaries to minimize conflicts with sport fishing, commercial vessel traffic, sensitive habitats (e.g., eelgrass), naval operations, etc. In addition, DOH conducts a separate review to ensure that State and federal water quality standards and are met and harvested geoduck are suitable for human consumption.

2.5 Benefits of Reserving Decision

With the exception of the removal of geoducks themselves, the impacts of the geoduck fishery are temporary, and with time the affected environments and the other species in a harvest area return to their preharvest condition, except that harvestable geoduck biomass is reduced. Reserving a decision (i.e. suspending harvest) would eliminate the State's fishery and all associated benefits that are funded by geoduck generated revenues, which include:

- clean-up and restoration of contaminated sediment in the Puget Sound,
- inventory of all nearshore aquatic habitat in the Puget Sound,
- control of the invasive aquatic weed spartina,
- geoduck fishery management, enforcement and harvest compliance programs
- State/tribal shellfish negotiations
- operating and capital improvement monies for Washington's Department of Fish and Wildlife.
- intertidal shellfish enhancement, and
- grants to local governments for the purchase, development and restoration of aquatic lands and public access

The current State/Tribal management agreements and annual harvest plans permit site-specific changes and overall management changes as necessary to protect the geoduck resource and the associated species and habitat.

2.6 No-Action Alternative

A no action alternative would mean that the State of Washington would discontinue harvest of its' share of the geoduck resource. There would be an associated reduction in harvest mortalities, and therefore more geoducks remaining in the wild, but the benefits (identified in section 2.5) that are generated from the harvest would be lost to the citizens of the State. Implementation of a no-action alternative by the State would not impact the Tribes' right to harvest 50 percent of the geoduck resource. In addition, implementation of the no-action might result in the Tribes asserting a right to harvest all or part of the State's share of the geoduck resources if the State does not harvest them, as long as the total harvest did not exceed the biological sustainability of the resource. In this case the same amount of geoduck would be harvested with or without a State harvest.

2.6.1 Impact Assessment

Current studies have not identified any long-term fishery-wide environmental impacts associated with the management of a sustainable commercial geoduck. In addition, long-term provisions for protecting water, infauna, epifauna, fish, marine mammals, birds, marine plants and the built environment are integrated into the 2001 SEIS.

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3.0 AFFECTED ENVIRONMENTS

3.1 Earth

3.1.1 Existing Conditions

Geoducks live in a variety of substrates ranging from soft silt to coarse gravel. Sand or sand and silt substrates support the highest geoduck densities and largest geoducks and are the most common commercial tract substrate (Goodwin and Pease 1987). Substrates may also contain clay, silt, shell, and rock.

Substrate density affects the ease of digging geoducks. Very compact substrates and those with large amounts of shell and rock are difficult to work in. Geoducks in soft silt or sand are more easily harvested. Coarse material found in geoduck tracts include pea-gravel, gravel, cobble, boulders, and solid bed rock. However, material larger than cobble is uncommon. Gravel and shell are often found at the substrate surface or buried below a sand and silt layer. Geoducks wedged into shell or gravel deposits can be extremely difficult to remove.

The topography of harvest tracts varies, but most are flat or gently sloping. Some tracts slope more than 30 degrees in places. Substrate surfaces are often rippled by the action of waves and currents. Lighter sand sediments sometimes form unstable dunes which can be several feet thick. The dunes, as they slowly move across the tracts, can smother benthic organisms including geoducks.

3.1.2 Impact Assessment

During geoduck harvest, divers insert water-jets into the bottom next to the geoduck siphons to liquify the substrate, which allows the divers to remove the clams. As geoducks are harvested, holes are created by the removal of the clam, by displacement of sediments, and by the suspension of fine particles (Figure 3). Thousands of geoducks are harvested from each tract, producing an equal number of holes. The number of holes dug per acre is dependent on the density of geoducks. The average density on unfished tracts in Washington is 1.7 geoducks/m^2 (Goodwin and Pease 1991), which is equivalent to 6,880 geoducks/acre. The biomass removed from a tract averages 72% (Sizemore et al. 1998), which means that roughly 4,954 holes are dug per acre on an average tract. Geoduck densities on commercial tracts in Washington range from a high of 0.56 geoducks/ft^2 (at Herron Island 7; Appendix 1) to a low of 0.01 geoducks/ft^2 (at Jamestown 1; Appendix 1). Assuming the same 72% average removal rate per tract as above, the number of holes dug per acre could therefore range between 17,563 and 314. An estimate of 10,000 holes per acre was calculated based on geoduck landing records at high-density commercial tracts fished in the late 1970s and early 1980s (State of Washington 1985).

Goodwin (1978), in small experimental plots in Hood Canal, studied the effects of geoduck harvest on the substrate, the size of the harvest holes, and the length of time required for the holes to be filled in by natural processes. In this study, a control and a treatment plot, each 3 m X 30 m and separated by a space of 20 m, were established in a sandy, flat bottom with little slope and a high abundance of geoducks. The plots were sampled to characterize prefishing geoduck abundance, sediment size distribution, and benthic flora and fauna. Next geoducks were harvested in the treatment plot using standard commercial gear and techniques. The water-jet techniques and equipment used in commercial geoduck harvest have remained essentially unchanged since the start of the fishery. The plots were then re-sampled to assess the effects of the geoduck removal. Newly created harvest holes averaged 37.3 cm (14.7 inches) in diameter and the disturbed depth (soft emulsified material within the hole) averaged 46.2 cm (18.2 inches) (Figure 3). The average depth of the hole (distance from the undisturbed substrate surface to the emulsified material filling the hole) was 8.2 cm (3.2 inches) initially, 5.6 cm (2.2 inches) one day later, and 4.4 cm (1.7 inches) four days later. The average measurable disturbed depth decreased from 45 cm (17.1 inches) one day after harvest to 29.8 cm (11.7 inches) four days later due to compaction of the emulsified material. A berm of sand and shell that was lifted from the substrate by the water-jet surrounded the holes. The hole dimensions and shapes varied depending on the individual diver, substrate composition and compactness, water pressure, and other factors. The hole shown in Figure 3 depicts the average hole in the most abundant and important substrate type (sand and silt).

Immediately after harvest was completed, the treatment plot substrate surface was uneven and pockmarked with holes. A large amount of clam shell and shell fragments was exposed at the surface. Very few geoduck siphons or holes left by retracted siphons could be found. After two months, the control and treatment plots were very similar in appearance. Seven months after harvest, the visual differences which were so pronounced immediately after harvest were gone, and the plots were identical in appearance.

In substrate samples taken randomly throughout the plots, the median grain size of the treatment plot increased from 627.3 microns before harvest to 651.7 microns immediately after harvest. However, this change was not statistically significant. The average percentage of silt and clay found in each plot before and after harvest was not significantly different and no changes to this ratio due to the harvest were detected.

When samples taken directly from harvest holes immediately after being made were compared to those taken adjacent to the holes, statistically different sediment sizes were found. The median grain size declined from 615 microns in the undisturbed substrate to 515 microns in the harvest holes. Silt and clay in the undisturbed substrate averaged 3.5%, while in the harvest holes the fines averaged only 2.3%. Coarse material was lifted from the holes and was deposited in the surrounding berm, which accounts for the decrease in median grain size of the material left in the holes. Silt and clay material was suspended in the water column and carried down current, which explains the decrease in fines. The natural layering of sediments is obviously disturbed by the harvest.

The overall effects of harvest on the sediment size within the treatment plot were not statistically significant, and the visual differences between the treatment and control plots were only temporary. Breen and Shields (1983) in a similar study in British Columbia found no differences between sediment structure of harvested and undisturbed substrates.

By comparison, the scale of disruption of sediments from a hydraulic clam dredge and hydraulic escalator harvest would be expected to exceed that of water-jet geoduck harvest due to the large volumes of water used by these dredges. Kyte et al. (1975) in a study in the Harraseeket River, Maine, found no significant changes in sediment sizes in intertidal clam beds harvested with a hydraulic clam dredge. Goodwin and Shaul (1978) found no significant effects on the percentage of fine sediments in a subtidal hardshell clam bed harvested by a hydraulic clam dredge in Puget Sound. Kyte and Chew (1975) reported a loss of a portion of finer sediments in the tracks of the hydraulic escalator when used to harvest soft-shell clams, *Mya arenaria,* in intertidal areas of Chesapeake Bay and Washington. Results also indicated a "loss or redistribution" of organic material in these sediments. It should also be noted that mechanical harvesters are most often if not always used for intertidal clam harvest while commercial geoduck harvest uses a hydraulic harvest method and only occurs in subtidal areas.

3.1.3 Significance of Substrate Impacts

Geoduck harvest has limited impacts on the substrate. Clams are removed individually, so only the immediate area around the clam is affected, and only small amounts of sediment leave the hole. The biggest impact to the substrate is the creation of harvest holes, which give harvested tracts a pock-marked appearance. These holes are temporary, refilling within several days to seven months depending on substrate composition and the strength of the local water current. Holes in sandy substrates with swift currents refill most rapidly. Harvest has no significant effects on the substrate sediment size but does change the natural stratigraphy in harvest holes. The water-jet introduces well-oxygenated water into the substrate. In substrates that are devoid of oxygen (anaerobic), the oxygenated water can temporarily oxygenate the reduced substrates within the harvest holes.

3.1.4 Mitigation

Substrate impacts are minimized by the use of water-jets for harvest. Restrictions on nozzle diameter (5/8 inch or less diameter; WAC 220-52-019(2a)) further reduce any impacts. Additional reduction in impacts could be achieved by limiting the amount of harvest on each tract and/or allowing harvest only in sandy, high current areas. Both actions would significantly reduce harvest.

3.2 Air

Exhaust from harvest vessel engines and auxiliary equipment have no measurable or significant impact. The limited number of boats that harvest an area results in rapid dissipation of carbon monoxide levels. By comparison, geoduck boats would have no greater impact than recreational boats or other working boats on ambient air quality.

3.3 Water

3.3.1 Existing Conditions

Geoduck harvest is conducted in estuarine waters of Washington in depths of -18 ft. (MLLW) to -70 ft. uncorrected. The waters of Washington are generally of very high quality. Dissolved oxygen levels seldom fall below 5 milligrams/liter (mg/1) and salinity is usually greater than 25 grams/liter (g/l). Temperatures at the depths of harvest are relatively stable and usually range from about 8 C to 12 C. Temperatures can be as high as 20 C in the shallow harvest depths of bays that stratify in the summer, such as Dabob Bay in Hood Canal and in South Puget Sound. Water current velocities are usually weak or moderate. Currents over 2 to 3 nautical miles/hour (knots) may preclude harvest in some areas. Clear water occurs rarely while very turbid water is common and results naturally from algal blooms, silt due to river runoff, and material suspended by wave action during strong wind events. Suspended solids usually vary from 8 to 25 mg/l.

Geoduck harvest requires waters of very high quality. Fecal coliform bacteria (FCB) are used to indicate the presence of septic contamination and as indicators of possible human pathogens. Commercial shellfish growing areas are monitored by DOH and must meet the following criteria: The fecal coliform or geometric mean (MPN) of the water may not exceed 14 per 100 ml, and the estimated 90th percentile may not exceed an MPN of 43 per 100 ml for a 5 tube serial dilution test (Terry Walker, DOH, March 9, 1995). DOH monitors paralytic shellfish poison (PSP), known commonly as "red tide." PSP is caused by a naturally occurring chain-forming dinoflagellate, *Alexandrium catenella*, which produces a toxin very dangerous to humans but which does not usually affect fish or shellfish. All bivalve shellfish (clams, oysters, mussels, scallops, and others) may feed on these dinoflagellates and become toxic for human consumption. Shellfish containing over 80 micrograms of toxin per 100 grams of shellfish tissue cannot be harvested or sold.

Due to these health standards, many geoduck tracts are closed to harvest. Sources of fecal coliform contamination include stormwater runoff, agriculture runoff, marinas, feces from seals and sea lions, and point sources from sewage treatment plants. The DOH establishes closure zones around sewage treatment plant outfalls, which vary in size depending upon the plant and its discharge. Non-point pollution prevents harvest in many otherwise pristine areas. In 1999, 47.706 million pounds of geoducks were considered uncommercial due to point and non-point septic contamination (Appendix 1). This represents roughly 22% of all the surveyed geoduck biomass in the State, and includes extensive geoduck tracts along the eastern shore of Puget Sound between Tacoma and Everett.

Because septic contamination generally accompanies any intensive development of the shorelines, harvest is prohibited near major industrial and commercial areas. Thus, harvest is already prevented in most areas where industrial pollution could be a problem.

3.3.2 Impact Assessment

Any effects of geoduck harvest on water quality would result from suspension of bottom sediments in the water column. During harvest, some material is suspended by the action of the water-jet. Most of this material -- the coarser sediments -- settles immediately to the bottom and forms a berm around the harvest hole, while the fine material (particle size less than 63 microns) settles much more slowly and remains in the water for longer periods. Another source of suspended fines is the action of harvest divers walking or swimming near the bottom and dragging hoses and bags of geoducks. The time the particles remain in the water column depends on their size (small particles remain suspended longer), the amount of mixing and lifting, and water current speed.

If chemicals, organics, and other materials are present in the sediments, they may also affect water quality. Because geoducks are only harvested from unpolluted areas, the possibility of suspending polluted sediments is low. DOH monitors the water quality of all geoduck harvest tracts, and areas known to contain toxic sediments are not approved for harvest. However, naturally occurring materials may affect such things as the amount of nutrients in the water and the amount of dissolved oxygen.

When a geoduck is dug from the substrate with a water-jet, about 0.01 m^3 (0.32 ft^3) of material is displaced from the hole (Goodwin 1978). About 10% of the displaced material is the geoduck itself. Most of the material settles within 0.3 m (1 ft) of the hole in weak water currents. At current velocities of 3 knots most of the material settles within 1.5 m (4.9 feet) down current of the hole.

SEDIMENTATION STUDY

Short and Walton (1992) conducted a study along the Nisqually River delta in south Puget Sound on the transport and fate of suspended sediment plumes associated with commercial geoduck harvest (Appendix 4). In this study, a model to simulate the behavior of suspended sediment plumes associated with geoduck harvesting was developed. The model was adjusted to achieve maximum agreement between model output and actual measurements of TSS (total suspended solids) gathered during a field experiment conducted in conjunction with an actual harvest operation.

Geoducks were harvested by a commercial geoduck diver using standard commercial water-jet gear in a 900 m^2 plot. The model plume generated by a diver digging a geoduck every 50 seconds for 20 minutes was small. At a current speed of 0.05 m/sec the plume (1 mg/l above background) extended down-current of the plot only 60 m, and was about 10-15 m wide. The 10 mg/l plume extended down-current about 30 m. The dense plume (100 mg/l above background) was confined to a small area (less than 5 m) around the diver. At greater current speeds the plume lost its integrity, and at 0.5 m/sec and 1.0 m/sec the sediment down-current was segregated into small self-contained clouds, each representing the material released during the digging of one geoduck. After 20 minutes at 1.0 m/sec current speed, the clouds with up to 10 mg/l of TSS were 170 m down current from the diver.

The concentration of material settled on the bottom was also modeled. For the 0.05 m/sec current speed, virtually all deposition occurred within the first 100 m down-current from the diver. At high current speeds small quantities were deposited as far as 200 m down-current. Most of the material settled within 1 m of the harvest hole. The average thickness of the deposited layer, after digging 25 geoducks, ranged from 0.0039 cm at a current speed of 0.05 m/sec to 0.0048 cm at a current speed of 1 m/sec within the total affected area (5,427 m^2 to 7,047 m^2). The authors of this study also estimated the cumulative effects of digging out the entire fishable geoduck crop (assuming a liberal estimate of 10,000 holes/acre). Their estimate was an average layer 0.4 cm thick if all the material suspended were to resettle on the tract. This estimate includes all grain sizes. This material can be resuspended and transported again if current speed or wave action is sufficiently strong. Fine grain material less than 63 microns can be eroded at currents greater than 0.28 m/sec, which is within the typical range of tidal current speed encountered in geoduck tracts. Thus, resuspension of fines from geoduck plumes is likely to occur. Resuspension of fines due to wave action is also possible in Washington waters during strong wind. Fine grain sediment can regain most of its shear strength within one to two days of deposition. Thus, within a few days of deposition the material would be no more susceptible to erosion than original substrate.

Shoreline owners often express the concern that material suspended by offshore geoduck harvesting is being transported and deposited on intertidal beaches. Short and Walton (1992) addressed this problem (Appendix 4). The authors calculated the average thickness of deposited material from digging 75 geoducks in a 30 m x 30 m area situated 200 m from shore, with currents directly on-shore. Thickness varied from 0.00004 cm at a current speed of 0.05 m/sec to 0.003 cm at a current speed of 1 m/sec. This scenario is very unlikely to occur in nature, since water currents near shore nearly always run parallel to shore, rather than directly on-shore. If fine material is deposited in the intertidal, it is highly unlikely that it would stay there. Most beaches along Puget Sound are composed of sand or gravel, which means that the typical wave and current climate is inconsistent with the deposition and retention of fines.

Another estimate of the amount of deposition from geoduck harvest can be calculated from Goodwin's (1978) measurements. The typical geoduck harvest hole is 37.3 cm in diameter, 8.2 cm deep and is disturbed down to 46.2 cm. Assuming the hole is a cylinder, then the volume of the hole is πr^2 multiplied by the depth, or 3.1416 X 18.65 cm^2 X 8.2 cm = 8,960.3 cm^3. If 10,000 holes are made per acre, the total volume of material deposited in the acre would be 8,960.3 X 10,000 = 89,602,971.6 cm^3 or 89.603 m^3 (assuming all material stays within the acre). One acre = 4,046.7 m^2, thus 89,603/4,046.7 m^2 = 0.022m, or 2.21 cm, which would be the thickness of the layer from 10,000 holes if all material stayed within the acre. An average layer of 2.21 cm never occurs. Instead, most of the material from the holes ends up as berms around the holes, with very little material between the holes. The berms then erode back into the holes due to current, wave, and animal activity.

A third way to estimate deposition of sediment from geoduck harvest involves estimating the volume (or thickness) of a layer of just the fines from 10,000 holes/acre if all the fines settled on one acre. The volume of the average hole is 8.96 liters. If we assume that all the fines from the holes are put into suspension, then 8.96 liters X 0.0351 (the proportion of substrate which is less than 63 microns; Goodwin 1978) = 0.314 liters. The amount of fines lost from the emulsified portion of the hole is available from the same study where the fines decreased from 3.51% to 2.29%. Therefore, 3.51% - 2.29% = 1.22%. The volume of the emulsified portion lost to suspension would be π X 18.6 cm² X 38 cm = 41,301 cm^3 ,or 41.3 liters; 41.31 liters X 0.0122 = 0.504 liters; 0.504 liters + 0.312 liters = 0.816 liters of fines for each hole. If 10,000 holes are dug per acre, then 8,157.72 liters or 8.16 m^3 of fines are put into suspension. This would create a layer 0.2 cm thick if all the material settled on one acre. Short and Walton (1992) estimated that the average cumulative thickness of all grain sizes from commercial geoduck harvest settling on one acre would be 0.4 cm (Appendix 4). The authors stated that since their estimate represents all grain sizes (not just fines), their estimate is not inconsistent with the estimate calculated above of 0.2 cm for fines only, and that depositional thicknesses of this magnitude are extremely small.

One way to view these figures is to compare them to natural sedimentation rates. As a yardstick for comparison, natural deposition of sediments along the Nisqually River delta in south Puget Sound measured 1.7 cm/yr (Brundage 1960), far greater than the 0.2 - 0.4 cm/yr estimates for geoduck harvesting mentioned above. Natural sedimentation at 26 sites throughout Puget Sound accumulates at rates ranging from 2,600 to 12,000 $g/m^2/yr$ (Lavelle *et al.* 1986). By comparison, Short and Walton (1992) estimated that even if all grain sizes put in suspension by commercial geoduck digging were to settle on the tract, the deposition would range from 7,900 to 8,830 $g/m^2/yr$ (Appendix 4). It should be noted that, unlike natural sedimentation or land-based human activities (construction, logging, etc.) geoduck harvesting adds no new sediments to the marine environment.

WATER CHEMISTRY

No studies have been done on the effects of geoduck harvest on water chemistry. However, Tarr (1977) studied the effects from hydraulic clam dredges on water chemistry. These machines were used to harvest subtidal and intertidal clams, and they disrupt large amounts of substrate compared to geoduck harvest. Observations by Tarr (1977) of plumes down-current from these clam harvesters showed no significant effect on dissolved oxygen, organic and inorganic phosphates, suspended solids, or turbidity beyond 150 yards (135 m). The major effect was the suspension of fine material which at 100 yards (90 m) down-current increased turbidity (suspended solids) by an average of 1 mg/l above the background (8 to 25 mg/l).

The geoduck fishery may have an indirect beneficial effect on water quality. Due to the commercial fishery, geoduck tracts have a high economic value. The value of this resource as a "crop" provides State and local agencies with the incentives and justification to protect the tracts from any activity which would impact water quality. The Washington State Growth Management Act requires that local governments designate and protect all naturally occurring shellfish beds as critical areas.

Pollution or septic contamination is a primary concern. DNR, WDFW and the Tribes oppose projects which will degrade water quality near geoduck tracts, and will encourage State and local agencies to control such activities.

DOH monitors the State's shellfish growing waters and prohibits harvest in polluted waters, and thus provide an early warning of declining water quality well before it has actual adverse biological impact on fish or shellfish. Consequently, the presence of commercial geoduck tracts increases the chances that local water will be protected and remain clean.

3.3.3 Significance of Water Impacts

Tarr (1977) noted no significant impacts on water quality from hydraulic clam harvest, which disturbs much greater volumes of substrate and would be expected to have proportionately greater impacts than water-jet geoduck harvest. Observations of clam harvest and channel dredging (Stickney 1973, Westley *et al.* 1975, Morton 1977) have not detected significant biological impacts or any associated water quality changes. Any impacts are confined to the immediate area under harvest, and should have no effect outside the harvest tract boundaries. Short and Walton (1992) have shown that the turbidity plumes associated with geoduck fishing are small, short lived, and contain minor amounts of material (Appendix 4). The amount of material that settles out of suspension from harvest plumes is minor, and has no significant impact. Deposition of plume material intertidally is also very minor and would not be expected to remain, due to the active current and wave climate on most Washington beaches.

A beneficial impact of the fishery is the governmental protection afforded the tracts preventing activities in the area which would degrade water quality. Water around geoduck tracts will receive high priority for protection, helping to maintain high water quality in the general area and throughout Puget Sound.

3.3.4 Mitigation:

Any measures which reduce the amount of silt released into the water will reduce impacts on the water. These measures are discussed in section 3.1.4.

3.4 INFAUNA

3.4.1 Geoducks

3.4.1.1 Existing Conditions

Geoducks are found from California to Alaska. They are the most abundant in the Puget Sound and the coastal waters of British Columbia. Geoducks range from the low intertidal zone to at least 360 ft in water depth. Geoduck biomass often dominate the weight of animals per unit of area within commercial geoduck tracts. They are the world's largest burrowing clam. Geoducks in Puget Sound average 1.9 pounds each, but size and density vary geographically. They are larger and more numerous in southern Puget Sound compared to northern Puget Sound (Goodwin and Pease 1991).

Geoduck distribution is patchy (contagious). The patchiness may be partly due to substrate type. Geoducks are found in a variety of substrates, but are most abundant and largest when growing in sand or mixtures of sand and silt. The average pre-fishing density on all identified commercial tracts Statewide is 1.7 geoducks/m^2 (0.16 clams/ft^2) although in some small areas densities as high as 22.5 clams/m^2 (2.09 clams/ft^2) occur (Goodwin and Pease 1991). Average density in southern Puget Sound, central Puget Sound, and Hood Canal is 1.9 geoducks/m^2 (0.18 geoducks/ft^2) (Goodwin and Pease 1991). Geoduck density is directly related to water depth between 0 and 25 m(82 feet). Size, however is inversely related to water depth.

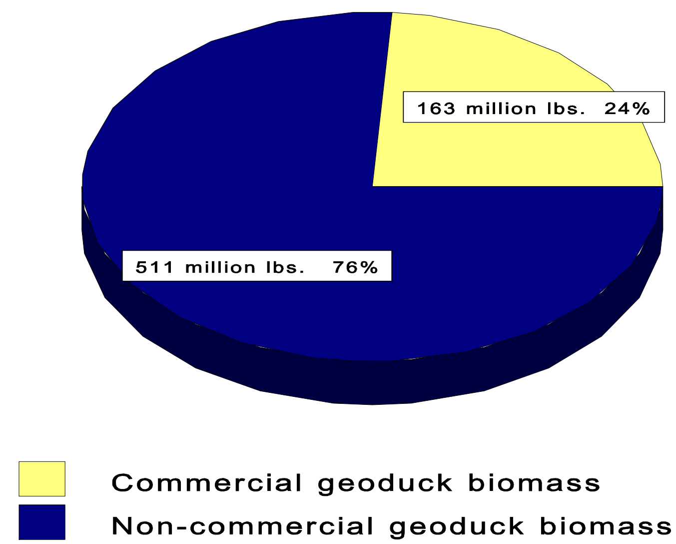
Geoducks grow rapidly and can reach an average harvestable size of 1.5 pounds in four or five years (Hoffmann *et al.* 2000, Goodwin 1976; Appendix 3). Even faster growth occurs in some tracts. Geoducks attain their maximum size and weight within 15 to 25 years in all tracts where growth has been studied (Hoffmann *et al.* 2000).

Geoducks reproduce by releasing their sperm and eggs into the water where fertilization occurs. They spawn primarily from April to June, when increased water temperatures and plankton blooms trigger release of sex products. The microscopic larvae drift with the currents for a period of up to 47 days (based on laboratory observations; Goodwin *et al.* 1979), after which they settle to the bottom and metamorphose into non-swimming juveniles. In the hatchery, with elevated water temperatures, larvae settle and metamorphose in as short a time as 16 to 18 days after fertilization. Due to their long planktonic larval period, the young may be carried by water currents many miles from their parents before settlement. If the larvae settle on suitable substrate they may survive, but settlement on less favorable substrate greatly reduces the chance of survival. Geoduck larvae may be able to choose the appropriate location for settlement by detecting the presence of objects or substances in the environment. Cooper and Pease (unpublished WDFW manuscript) have shown that the tubes of various polychaete worms will trigger metamorphosis in geoduck larvae. In a study at Tala Point, Hood Canal, juvenile geoducks were found clustered around adults (Goodwin and Shaul 1984), and Fyfe (1984) also found that the nearest neighbors of juvenile geoducks were usually full grown adults. Clumping of juveniles around adults may result from selective larval settlement or increased juvenile survival next to adults. Geoduck larvae in the swimming stage are suspension feeders and utilize planktonic algae (phytoplankton). The algae is captured by the larvae's ciliated swimming organ called the velum. After the larvae settle and lose the velar feeding apparatus, but before the adult gill feeding apparatus (ctenidia) develops, they are pedal palp feeders. This means that they feed by protracting the foot into the sediment and then withdrawing it along with adherent depositional material. Food is brought near the mouth during pedal retraction when the foot brushes against the labial palps (King 1985, Cole 1991). Since the newly post-settled larvae have not developed a siphon, they stay at or near the substrate surface where they remain several weeks until the adult siphon and ctenidial apparatus develop, allowing the animal to bury into the substrate. For a more complete life history discussion, see Goodwin and Pease (1989).

In 1999, the total geoduck biomass in Washington tracts which was considered commercial was estimated to be 162.797 million pounds (Appendix 1). All the surveyed commercial tracts listed in the 2000 Geoduck Atlas (Appendix 1) are included in this total. This biomass of 163 million pounds on commercial tracts underestimates the actual geoduck biomass, because not all of the area between the -18 ft MLLW to -70 ft level has been searched. Undiscovered tracts in these depths will be surveyed in the future. Other large areas between the -18 ft. MLLW to -70 ft depth range have been surveyed, but are not commercial due to pollution (47.706 million pounds, Appendix 1), an uneconomically low density of geoducks (8.684 million pounds, Appendix 1), or other miscellaneous reasons (0.198 million pounds, Appendix 1). These surveyed, uncommercial tracts thus contain a total of 56.588 million pounds, bringing the total biomass of geoducks in surveyed tracts between -18 ft. MLLW and -70 ft to 219.385 million pounds.

Moreover, the total geoduck population in Washington in all water depths and locations may be much greater than the surveyed population of 219.385 million pounds within the -18 ft. MLLW to -70 ft depth range (the legal depth range for the State commercial geoduck fishery). Large numbers of geoducks are known to occur inshore and offshore of the legally fishable depths. A very rough quantitative estimate of the total geoduck population in Washington can be extrapolated from survey work conducted in waters outside the -18 ft. MLLW to -70 foot range. Remote video observations in deep water show that geoducks occur as deep as 360 ft (Jamison *et al.* 1984). In Case Inlet, the estimate of geoduck biomass below 70 ft from these video counts was 64.5 million pounds, compared to the 41 million pounds estimated from diver surveys in the legally fishable depths. If this ratio of deep-water to legal-depth biomass (64.5/41 = 1.573) is reasonably consistent throughout the rest of Washington, then the total deep-water biomass adjacent to surveyed tracts in Washington can be roughly estimated as 1.573 x 219.385 million pounds = 345.093 million pounds. The geoduck biomass shallower than -18 ft MLLW can also be roughly estimated, using dive survey data. Data from seven commercial tracts surveyed by WDFW

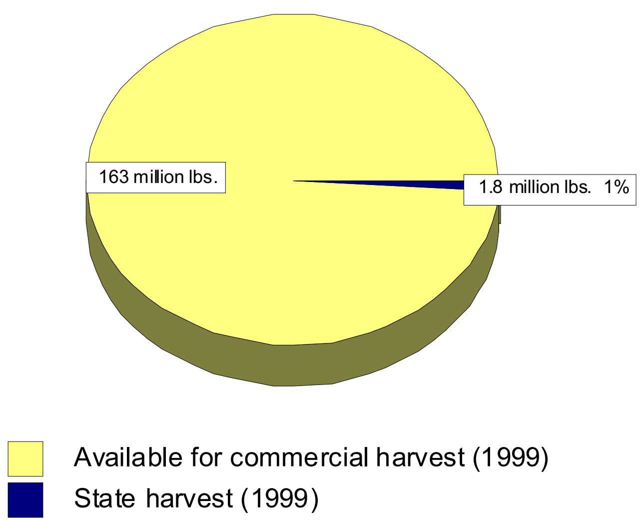
Figure 4: State-Wide Geoduck Resources



in 1998 and 1997 were used to calculate the average geoduck density within the shallow half of the commercial zone (i.e., between -18 and -30 ft). This density was assumed to be roughly equivalent to the density shallower than -18 ft. MLLW. Computer-generated maps of the tracts were then used to calculate the total area shallower than -18 ft MLLW which was adjacent to the tracts. Shallow-water biomass was then calculated for each of the seven tracts (as the product of average density and total shallow area adjacent to the tract). On average, shallow-water geoduck biomass amounted to 59% of the biomass in the legally-fishable depth range from -18 ft. MLLW to -70 ft. uncorrected. A more conservative estimate of shallow-water biomass would be 50% of the legally-fishable biomass. The total shallow-water biomass in Washington waters adjoining surveyed tracts can then be roughly estimated as 0.50 x 219.385 million pounds = 109.693 million pounds. Summing these figures (162.797 + 56.588 + 345.093 + 109.693=674.171), state-wide geoduck resources in Washington are estimated to be 674 million pounds.

(Note: The State's TAC in 1999 was 1.8 million pounds. In reality, the State's harvest for the last eight years has averaged 1.6 million lbs./year)

Figure 5: Annual state commercial harvest



Presently, the total commercial biomass is approximately 163 million pounds (24%) (figure 4). The very rough estimate of state-wide geoduck resources is provided for context purposes. This estimate should never be used to establish fishing quotas or for any other fishery management purposes.

COMMERCIAL FISHERY

The Total Allowable Catch (TAC) is the total weight of geoducks which may be harvested during the year. Currently, separate TACs are calculated for each of the six geoduck management regions on an annual basis. The TAC for a region is the product of two numbers: 1) The estimated commercial biomass within commercial tracts in the region, and 2) The recommended harvest rate. Figure 5 shows the State's fishing quota for 1999 (the State quota is 50% of the TAC) in relation to the commercial geoduck biomass. The State's actual average harvest between 1990 and 1999 was1.6 million pounds per year.

Commercial biomass is estimated by dive surveys on commercial tracts within the region. Detailed survey methods are described in Appendix 3. Regional biomass estimates are the sum of all surveyed commercial tract estimates within the region. Tract estimates are adjusted annually whenever a tract is surveyed or commercially harvested. Whenever a tract is fished, the known weight of the catch is subtracted from the tract's biomass estimate. These adjusted biomass estimates for a tract are used by managers until the tract is re-surveyed.

The recommended harvest rate is the proportion of the commercial biomass which is expected to provide a sustainable high-yield fishery over the long term. This proportion, usually expressed as a percentage, is determined based on the predictions of mathematical yield models which forecast the long-term consequences of various harvest rates on geoduck populations. Such models rely on estimates of growth, natural mortality, sexual maturity, harvest selectivity and other life history parameters to make their long-term predictions.

WDFW developed the first yield model for geoducks in 1981, based on Ricker's yield-per-recruit model (Ricker 1975) and biological data from unfished geoduck tracts in Washington. An annual harvest rate of 0.020 (2%)of the unfished, "virgin" biomass was recommended based on the model results. Estimating virgin biomass based on current surveyed biomass proved unwieldy, however, particularly given the switch to regional geoduck management mandated by Tribal entry into the fishery.

In 1995, WDFW biologists developed an age-based equilibrium yield model for geoducks which is currently used as the basis for the recommended harvest rate (Bradbury and Tagart 2000). The equilibrium yield model is similar to the original Ricker model, but utilizes more of the available biological data on geoducks, and frames its harvest rate predictions in terms of current biomass, not virgin biomass. This feature makes the calculation of regional TACs much easier and relies on fewer assumptions about virgin biomass levels. Because the TAC is based on a fixed proportion of existing biomass, it automatically adjusts to changes in the geoduck population (caused by both fishing and environmental changes). Finally, the new model also allows managers the option of choosing a harvest rate which preserves the reproductive potential of the population rather than simply achieving the maximum yield. This feature of the new model is consistent with federal fishery management plans, which increasingly rely on spawning biomass as a basis for setting fishing targets, rather than yield-per-recruit (National Research Council 1998).

On March 26, 1997, State and Tribal biologists agreed to an annual harvest rate of 0.027 (2.7%) of current commercial geoduck biomass in each region. This recommendation was based on the results of the equilibrium yield model (Bradbury and Tagart 2000; Appendix 3). The 2.7% harvest rate is predicted to preserve 40% of the unfished spawning potential of the commercial population, a risk-averse policy now widely used by federal fisheries managers (Clark 1993). For purposes of comparison, the harvest rate which is predicted to produce the maximum yield per recruit is 0.075 (7.5%) (Bradbury and Tagart 2000). The 2.7% annual harvest rate is applied to the estimate of commercial biomass in each region based on the annual Geoduck Atlas. The TAC within a region therefore changes annually with changes in the estimated commercial biomass; changes resulting in a net increase in biomass (newly surveyed areas, for example) will result in an increased TAC, while a region with a net decrease in biomass (due to harvest, or loss of tracts from pollution, for example) will have a reduced TAC.

In the past, the annual TAC has served as a fishing target, but in practice, the entire TAC is not always taken. The TAC is sometimes underfished for several reasons: Paralytic Shellfish Poisoning (PSP) closures of commercial tracts by DOH, market conditions, time constraints for harvesting an area and problems obtaining shoreline permits for harvest. In 1996 and 1997, for example, the combined TACs for all management regions were underfished by 619,000 pounds (19% below the combined TAC) and 150,000 pounds (4% below the combined TAC), respectively. Much of the annual underharvest was due to PSP closures of tracts in the central Puget Sound management region. The actual landed harvest rates in 1996 and 1997 were therefore 2.2% and 2.6% respectively, instead of 2.7%. State/Tribal agreements stipulate that unharvested portions of the TAC in one year may not be "added" to the following year's TAC.

This 2.7 % annual harvest rate may change in the future as research continues on the biology of geoducks. For example, research is currently underway to independently refine the estimated rate of natural mortality, an important factor in the yield model. Research is also underway to determine if growth rates differ among the six management regions, another factor which might influence the yield model predictions. State and Tribal biologists will continually update the model and its input to reflect the latest information on geoduck life history. Other models, such as the empirical recovery study discussed below may also be used in the future to refine geoduck harvest rates.

WDFW is performing a study to independently compare the yield model predictions to geoduck populations which have been fished in the past (Appendix 2). This study estimates the length of time that commercially fished geoduck tracts require to regain their prefishing densities (recovery time). Geoduck density estimates are made before fishing, soon after fishing, and then again after several years of population recovery. The amount of increase in the population which occurred during the two post-fishing surveys is extrapolated into the future to estimate the time needed for complete recovery. This research is being done in 15 tracts located throughout Puget Sound. Based on preliminary data gathered thus far, the estimated recovery time of the tracts varies from a low of 11 years to a high of 73 years. The average projected recovery time for all tracts with statistically significant density data is 39 years, meaning that on average 2.56% of the biomass lost to fishing is replenished each year. At this annual recovery rate, it is possible to preserve 40% of the harvestable population's unfished spawning biomass with a harvest rate as high as 5.7 %. Therefore, the recovery study data thus far suggest that the current 2.7% harvest rate is conservative, and will preserve more spawning biomass than is predicted by the equilibrium yield model.

These preliminary recovery study results have been used only to check the predictions of the equilibrium yield model. They are not currently used by managers to adjust biomass estimates on fished tracts. As noted earlier, catches are subtracted from the surveyed biomass on all fished tracts, and no adjustments are made to the resulting biomass estimate until a new survey is performed. As this study is continued in the future, and enough tracts are studied, then regional recovery times may be calculated and used to manage the geoduck harvest if significant differences exist among management regions. In fast recovery regions the recommended harvest rate may be higher than 2.7%, and in slow recovery regions lower than 2.7%. For the present time, the overall Washington harvest rate of 2.7% appears to be conservative, but should continue to be used until enough information is available to indicate that a change is appropriate.

To ensure that the catch is distributed throughout Washington, no more than 2.7% of the commercial biomass for each of the six management regions (Figure 1) is currently allocated to total fishing mortality each year. Tracts which have been fished once may not be re-fished until a new survey demonstrates that geoduck density has reached or exceeded pre-fishing density.

The time period for recovery is relatively long due primarily to the low rate at which geoducks naturally recruit or repopulate. Mortality of the eggs, larvae, and post-settled juveniles is extremely high, and very few young geoducks survive the onslaught of predators (Goodwin and Shaul 1984). The recruitment rate of geoducks is low, but some recruitment appears to occur every year. If the young clams survive their first year of life, they are normally buried in the substrate deep enough to have reached a predator depth refuge and suffer very little predation thereafter (Sloan and Robinson 1983).

Geoducks are extremely long-lived, a characteristic which is linked to their low rate of recruitment and low rate of natural mortality as adults. Subtidal unfished geoducks in Washington average 46 years of age, and the oldest live animal aged from Puget Sound was 131 years (Bradbury and Tagart 2000; Goodwin and Shaul 1984). Strom recently aged a geoduck from the Strait at 163 years (Strom 2000). The oldest geoduck from British Columbia was reported to be 146 years (Harbo *et al.* 1983). Canada's Department of Fish and Oceans more recently aged a 168 year old geoduck.

Geoducks are a renewable resource which, if properly managed, can provide a sustained harvest. The annual TAC in each management region is based on a conservative harvest rate and a conservative estimate of commercial biomass. Fishing at any sustainable harvest rate will result in a gradual reduction of the unfished, "virgin" commercial biomass until a new fishing equilibrium is reached. Most stocks of animals produce the greatest harvestable surplus when they are at an intermediate level of abundance (Ricker 1975). Recruitment and growth of geoducks add to the biomass each year, while fishing and natural mortality subtract from the biomass. When fishing and natural mortality are balanced with recruitment and growth, the population is relatively stable over the long term. The 2.7% harvest rate developed for geoducks is currently the best estimate of the largest proportion of commercial biomass which can be removed each year while maintaining the spawning stock at a stable intermediate level.

The geoduck harvest in the future could be expanded by five different methods. This could be done on a sustained basis as long as no more than 2.7% of the stocks being fished are taken annually.

The first potential expansion could be to harvest tracts in water deeper than that presently being fished. The present policy of DNR, WDFW and the Tribes is to allow no harvest deeper than -70 ft of water uncorrected by tides. This depth restriction is set by WAC 220-52-019, as well as by current State/Tribal agreements and harvest plans. Deep-water harvest is feasible now, but is more expensive and would require more complicated diving. Harvesters would probably switch to decompression diving to extend their bottom time; this would require onboard decompression chambers and mixed gas rather than compressed air for the divers' air supply. The deep-water expansion could logically extend to 100 ft, which would significantly expand the commercial biomass now being fished. Geoduck density increases with increased depth to at least 80 ft, but geoduck size decreases (Goodwin and Pease 1991). The deep water expansion would probably occur in areas where water currents are sufficiently strong to maintain a sand/silt substrate. Likely areas for large deep water stocks would be the Nisqually Delta area, Dana Passage, Colvos Passage, the main body of Puget Sound from the Tacoma Narrows to Whidbey Island, Admiralty Inlet, and portions of the Strait of Juan de Fuca. Harvest of geoducks in the deep areas by State harvesters would require a change of WAC 220-52-019 (11).

The second method would be to harvest the stocks shoreward of the -18 ft. MLLW line. This is likely to add a lesser amount than the deep water expansion. Geoducks are less dense in shallow water, but are larger than those in deeper water. Geoduck harvest in the shallow water is complicated by the fact that most eelgrass and herring spawning areas in Puget Sound are shoreward of the -18 ft. MLLW level. Herring spawning substrates and eelgrass will have to be avoided by any future geoduck harvest if it were to occur in shallow water. Harvest of geoducks in the shallow areas by State harvesters would require legislative action to change RCW 77.60.070.

The third potential expansion would be to areas which lie within the current legal depth ranges, but which have never been surveyed for geoducks and therefore have an unknown geoduck biomass. For example, the San Juan management region and the western portion of the Strait of Juan de Fuca management region contain known geoduck beds which have commercial potential, but these have not been surveyed to date, except on an exploratory basis.

The fourth method would be to harvest geoducks that are in polluted water which DOH will not currently certify. This could be done by future water pollution abatement which reduces pollution, or by harvesting geoducks from restricted areas and moving them to clean water or depuration plants, where the clams can rid themselves of dangerous pathogens and toxins, making them safe for human consumption. This kind of operation increases the cost of production, and would have to be carefully regulated by DOH. The DOH does not authorize or support depuration plants.

The fifth method would be to create a commercial (crab) bait fishery where geoduck fishing would be expanded to occur in areas that are not currently health certified for human consumption.

Expansion into any of these above-mentioned areas would require surveys to estimate geoduck biomass. Surveyed tracts then could be added to the commercial biomass within a region and may be fished as part of that biomass. If the deep- or shallow-water expansions were to occur, and the potential geoduck catch from these areas were significant, then the biological characteristics of deep- and shallow-water geoducks should be studied. If significant differences exist between these stocks and those currently being fished, separate harvest rates may have to be developed for these stocks.

WDFW developed a geoduck hatchery and the technology required to spawn geoducks and raise the larvae and juvenile clams to a size that could be planted in Washington subtidal tracts and intertidal beaches (Beattie and Goodwin 1993). Survival in most experimental subtidal plantings was less than 1% after one year in the field. The low survival made these large-scale unprotected plantings in subtidal waters uneconomical, and therefore they were terminated. Predator-protection devices may increase survival, but they also increase costs and labor, and for these reasons no subtidal plantings are currently being considered. Neither the annual TAC for geoducks nor the 2.7% annual harvest rate is dependent upon, or in any way influenced by hatchery re-seeding of geoducks. The recovery of geoducks in harvested tracts occurs naturally, albeit very slowly, and this is the mechanism upon which the sustained-yield commercial fishery is based.

3.4.1.2 Impact Assessment

The major impact of geoduck harvest is a reduction in the local geoduck population on harvested tracts. Since 1985, the reduction within individual tracts has averaged 72%, ranging from a low of 48% to a high of 94% (Sizemore *et al.* 1998). The removal of geoducks is a significant change in the biological community, since geoducks often represent the greatest biomass of any single species in an area. The removal of geoducks might affect phytoplankton levels since geoducks are an important suspension-feeding species. This possibility is discussed in further detail in Section 3.9.3.

Harvest reduces the geoduck population on fished tracts for many years, and permanently reduces the overall abundance of harvestable geoducks. The 2.7% annual harvest rate discussed in section 3.4.1.1 is predicted by the equilibrium yield model (Bradbury and Tagart 2000) to preserve 40% of the unfished spawning biomass throughout all tracts (Appendix 2). For an individual tract, the preliminary data from the recovery study suggest that an average of 39 years may be required for recovery following complete removal of all harvestable geoducks. Recruitment of young geoducks is spatially patchy and nearly always occurs at low rates (Goodwin and Shaul 1984). Recruitment appears to be slower on harvested tracts than on unharvested tracts. The authors took random venturi dredge samples within six different tracts, with roughly half the samples taken in portions of the tracts which had been commercially fished, and the other half taken in portions of the same tracts which had not been fished. The average density of recruits (ages 0-4 yr) was 0.78 recruits/m^2 in the unfished portions, and 0.54 recruits/m^2 in the fished portions. The authors speculated that the decreased number of juveniles in the fished portions was probably due to an adverse effect of fishing on recruitment. The implications of lower recruitment on fished tracts and its possible relationship to the results of the recovery study are discussed on page 7 of Appendix 2. We speculate that lowered recruitment on fished tracts may account for the difference between empirically-based harvest rates reliant on recovery time and model-based harvest rates predicted to maximize yield-per-recruit (i.e., reliant on the assumption of constant recruitment at all stock levels). The long-term management solution was to look at harvesting less than the target 80% of a tracts biomass to increase recruitment. In response to this, the State and Tribes adopted a target harvest rate of 65% or .04 geoduck per square foot in

2001.

Young geoducks living near adults are often washed out of the bottom during the harvest for adults and are injured, killed, or left exposed to predators. Despite the low recruitment, the recovery research described in section 3.4.1.1 and Appendix 2 shows that harvestable geoduck density has increased from the post-fishing level on all study tracts following commercial harvesting.

The State and the Tribes have recently acknowledged that undocumented fishing mortalities have been a recent problem in the geoduck fishery. To the extent that these non-landed harvest mortalities cause the annual TACs to be exceeded, they could represent a risk to the level of sustainable harvest opportunities for the State and Tribes from commercial tracts. The parties have been jointly pursuing additional geoduck management measures to both reduce and account for undocumented harvest over the past year, while the State has been steadily improving its monitoring and enforcement activities in the geoduck fishery for several years. A description of these problems is presented in this section, while measures taken by the State to avoid and mitigate un-landed fishery mortalities is presented in section 3.4.1.4.

The following are sources of current fishery mortality that have not been routinely estimated and managed as part of the regional TACs, with some notable exceptions:

- inadvertent wastage during normal harvest operations
- intentional discards/wastage occurring because of price differentials (can occur either on- or off-tract)
- unreported catch - could be take home or sold geoducks that don’t show up on fish tickets or official weigh-out receipts - from tracts that are open by regulation for commercial harvest

- poaching - to the extent that poaching occurs on commercial tracts, it is a fishing mortality that is part of the TAC

Inadvertent wastage also can occur as a normal part of harvest operation, e.g., clams might miss a diver's bag or not be found after extraction. While the magnitude of this wastage is usually considered small, it can be affected by diver experience, conditions, and speed of harvest operations. As with other deliberate wastage and poaching, inadvertent wastage is a portion of the total allowable fishing mortality represented by the TAC.

The practice called "high grading" or selective harvest could in some cases result in exceeding the annual harvest rate and TAC for geoducks. High grading is the selection through observation or physical touch of only those geoducks which are of the highest quality. Divers commonly high grade by selectively harvesting particular areas within a commercial tract containing higher-quality geoducks, while harvesting other areas within the tract at a lower intensity. This practice is a natural consequence of the fact that geoduck quality is correlated with substrate composition and depth (Goodwin and Pease 1991). As long as all geoducks which are removed from the substrate are weighed and counted against the TAC, however, the TAC cannot be exceeded by this form of high grading. This form of high grading is therefore legal.

High grading of another form is referred to as wastage and occurs if low-quality geoducks are deliberately sorted and discarded after harvest. This practice violates State laws against shellfish wastage (RCW 77.15.170) and civil contracts between DNR and harvesters, and also violates annual State-Tribal geoduck harvest plan. However, discarding is not easy to accomplish aboard the harvest boats, which are under surveillance by DNR enforcement crews. Thus, this form of high grading must take place underwater to reduce the chance for detection. Discarded geoducks cannot dig back into the substrate and will die from predation or harvest-related injuries. Thus, to the extent that discarding occurs and is not estimated, it represents an unreported harvest which is not counted against the regional TAC.

Discarding was not well documented prior to 1996. In recent years changes in market conditions have promoted grading of geoducks for quality, based on color and size, and created incentives to discard less marketable geoducks. Grading has increased pressure on the harvesters to discard lower quality geoducks. Discarding of harvested geoducks takes many forms. DNR monitors have observed, and adjusted their monitoring program to deal with many methods of discarding including; re-insertion into the substrate, dumping on and off tract before being accounted for by monitors, and pulverizing the geoducks on the harvest vessel and clandestinely disposing them overboard. WDFW conducted five dive surveys on seven commercial tracts in 1999 in an attempt to quantify the impact of discarding on geoduck mortalities. Four of the six dives were confined to small areas where harvest was observed on a given day (which may have introduced bias into the estimate of the discard rate). Discard estimates for these five dives ranged from 2 to 10 %. The other two surveys were done systematically and covered the entire tract. Discard rates were 28% and 9 % on these two tracts. Discard rates of 9% and 28% , if occurring on all tracts harvested within a management region, would translate into an actual annual regional harvest rate of 3.0% and 3.7% respectively. These fishing rates exceed the recommended sustainable harvest rate of 2.7% for commercial geoduck stocks (between -18 ft. MLLW and -70 ft. uncorrected).

Since discarded geoducks are not landed, they are not counted on WDFW fish tickets as harvest. Annual landings from a tract are subtracted from its pre-fishing biomass estimates each year to calculate adjusted biomass estimates. Discarding, then, results in actual harvest rates that are higher than those calculated based on landings. Unaccounted for harvest impacts, such as discards, also inflate estimates of regional biomass to which the 2.7% harvest rate is annually applied to compute TACs.

Still a third form of illegal high grading occurs if divers partially dig a geoduck in order to ascertain its quality (based on the texture or size of the siphon) without removing it completely from the substrate. This form of high grading is reportedly preferred by some divers because it is not easily detected with SCUBA or underwater video surveys. If the partially-exposed geoduck is left in the substrate because it does not meet the diver's quality criteria, it may die from predation or harvest-related injury.

Poaching is a recognized problem in the geoduck fishery, but the level of poaching can be difficult to estimate unless poachers are caught and convicted. Nevertheless, it is possible to provide examples of the potential impact of poaching based on information from recent federal prosecutions. The most recent poaching cases prosecuted were the Narte/DeCourville and Mok conspiracy cases, which involved an estimated 161,151 pounds illegally harvested over a 10 to 15-month period in 1995 and 1996. The poaching occurred in the South Sound, Hood Canal, and Central Sound management regions. If this poached amount had occurred from commercial tracts and was annualized, it would represent about 7.2% of the combined annual TACs in these regions during 1996. In these particular cases, this documented poaching did not directly result in the TAC being exceeded because the State and Tribes landed 619,000 pounds less than the combined 1996 TACs for these three regions (due to PSP closures and permit problems). If estimated poaching results in an overharvest in any given year, however, State and tribal managers are obligated by agreement to reduce the future annual TAC (2.7% minus the poached amount) to compensate for it.

Uncovering poaching and being able to estimate its biological impacts is dependent on WDFW enforcement, ideally working with DNR and Tribal enforcement authorities and with assistance from an alert public by reporting suspicious activities. Poaching levels largely will depend upon the effectiveness of the enforcement effort. As long as geoduck prices remain high, the incentive for poaching is significant and can only be deterred by enforcement activities combined with more stringent penalties and other measures that would increase the difficulty of finding market channels for illegally harvested geoducks.

In section 3.3.2 the amount of turbidity created during geoduck harvest was discussed. No studies on the effects of turbidity on geoducks have been published; however, many studies are available for other bivalve species. The amount of suspended sediments created by geoduck fishing is small. The dense plume (100 mg/l above background) was confined to a small areas less than 5 m around the diver (Short and Walton 1992; Appendix 4). The 10 mg/l plume extended down current about 30 m. The suspended turbidity could adversely affect geoduck eggs, larvae, and adults (or other important bivalves), either by decreasing growth or increasing mortality. Davis (1960) studied the effects of silt on the embryonic development of the clam *Mercenaria mercenaria* and found that concentrations of silt below 750 mg/l did not adversely affect eggs from developing normally; however, when silt levels rose above 3,000 mg/l, no eggs developed normally. Loosanoff and Davis (1963) reported that the eggs and embryos of the oyster *Crassostrea virginica* were more sensitive to silt than *Mercenaria mercenaria* eggs and embryos. At 250 mg/l of silt, 75% of the oyster eggs survived and 95% of the clam eggs developed to the straight-hinge stage. Davis and Hidu (1969) found that *Crassostrea virginica* eggs were adversely affected in silt concentrations as low as 188 mg/l.

Larvae appeared to be more tolerant of turbidity than eggs. Growth of clam larvae (*Mercenaria mercenaria*) was normal in 750 mg/l, and at lower concentrations was actually faster than in the controls (Davis 1960). Loosanoff and Davis (1963) reported that silt was more harmful to oyster larvae than clam larvae. At silt levels of 705 mg/l, oyster larval growth was decreased, while clam larvae grew normally even in 1,000 mg/l of silt and survived for 12 days in 3,000 to 4,000 mg/l. Davis and Hidu (1969) found similar larval responses. Seaman *et al.* (1991) found that mussel larvae (*Mytilus galloprovincialis*) growth was greater than controls in silt concentrations of up to 500 mg/l, but was reduced at higher concentrations. Huntington and Miller (1989) found no significant effect on the growth of *Mercenaria mercenaria* larvae with silt concentrations at or below 560 mg/l.

Juvenile and adult bivalves appear to be less tolerant of silt than larvae. Compared to controls, growth of juvenile *M. mercenaria* was reduced in silt at 44 mg/l, but were not affected below 25 mg/l (Bricelj *et al.* 1984). Silt at 100 mg/l will reduce the pumping rate of adult *C. virginica* and *M. mercenaria*, and silt concentrations as low as 40 mg/l reduced clearance of algal cell numbers by adult *M. mercenaria*. Growth of the mussel *Mytilus edulis* was not affected by concentrations of silt less than 100 mg/l, and at higher concentrations growth was increased (Winter 1975).

Increased growth of adult clams (*Spisula subtruncata*) in 25 mg/l of silt was shown by Mohlenberg and Kiorbae (1981). The growth of mussels, *M. edulis*, was also increased in low levels of silt (5 mg/l; Kiorbae and Mohlenberg 1981). At higher concentrations (100 mg/l) Robinson *et al.* (1984) have shown a decrease in the ingestion of food by the clam *Spisula solidissima*.

Considering the low levels and short duration of turbidity caused by geoduck harvest, it is highly unlikely that significant adverse effects on bivalve eggs, larvae, or adults (including geoducks) occur during normal geoduck harvest.

3.4.1.3 Significance of Geoduck Impacts

The impacts of harvest on geoduck populations within tracts which are fished are localized but significant due to the high within-tract harvest rate (since 1985, averaging 72% of the commercial biomass within a tract; Sizemore *et al.* 1998). These impacts are long-term due to the low rate of natural recruitment. The impacts of long-term harvest on the State-wide population of commercially harvestable geoducks are smaller and incremental when only 2.7% of the commercial biomass is removed each year, and recovery occurs on fished-out tracts.

Nevertheless, there is an expected gradual decline (until the sustainable rate is reached) in commercial biomass throughout the State as fishing proceeds at this or any sustainable level until equilibrium is reached. This decline occurs because as fishing proceeds, a greater proportion of tracts join the ranks of those in "recovery." This impact is long-term because the current 2.7% harvest rate is expected to eventually reduce the spawning biomass on commercial tracts to 40% of the unfished, "virgin" level. At that point the harvestable population will reach a new fishing equilibrium (40%) and fluctuate around this lower level indefinitely. The impact on total geoduck biomass will be of a much lower magnitude, however, since the biomass on commercially-harvestable tracts represents only about 24% of the total geoduck biomass (Appendix 1; section 3.4.1.1). Of the total biomass in all areas (estimated to be 674 million pounds; section 3.4.1.1), roughly 76% (511 million pounds) remains unfished in deep water, shallow water, and polluted or otherwise unfishable areas.

If we assume, for simplicity's sake, that the 2000 Geoduck Atlas estimate of commercial biomass (162.797 million pounds) represents the unfished, "virgin" commercial biomass, then the expected 60% reduction of commercial biomass would result in a long-term decrease of 97.678 million pounds of commercial biomass (if no recovery occurred). This amounts to a reduction in total geoduck biomass of 14% (97.678 /674.171 = 0.14). Assuming that current biomass on commercial tracts is roughly 80% of the unfished level, the reduction in total geoduck biomass would amount to 17%. Thus, the reduction in total geoduck biomass is expected to be between 14-17% of the unfished "virgin" level. However, this reduction could be greater if management changes are made in the future allowing harvest in deep-water, shallow-water, or polluted areas or if all fishing-related impacts (e.g., wastage, unreported catch and poaching) are not being estimated and accounted for.

The fishable stocks are being harvested at a sustainable rate, based on both a mathematical model of geoduck population dynamics and surveys of commercially harvested tracts which are recovering from fishing. The wide dispersal of geoduck larvae by currents, and the proximity of unfished geoducks to commercial tracts limits harvest effects on the reproductive population in any particular area and on the nearby intertidal geoduck stocks. The presence of a viable geoduck fishery gives existing geoduck populations protection from other human activities. The economic value of geoducks strengthens State and local agencies justification to oppose activities which would pollute or damage the tracts.

3.4.1.4 Mitigation

Reduction of the geoduck population is the direct result of harvest. The long-term impacts on the population are controlled to remain within planned levels by current management policies which limit total annual fishery related mortalities to not exceed the TAC, protect shallow and deep water stocks from harvest, and require ongoing monitoring of stocks and their biological parameters. Identification of commercial tracts allows resource agencies and local governments to protect them from adverse impacts due to shoreline development and other human activities.

High grading that involves discarding, is illegal under State and civil contract law, as well as State/Tribal management agreements. Discarding can be minimized by effective monitoring and enforcement, involving SCUBA or underwater video surveillance of commercial tracts at periodic intervals as they are being fished. DNR enforcement crews use SCUBA and underwater video surveys to detect discarded geoducks on the bottom if high grading of this form is suspected. Inspections of both the harvest areas and harvest vessels are conducted by DNR enforcement staff on a routine basis in order to reduce the amount of wastage that occurs on State monitored harvest areas. DNR divers conduct investigative dives to check for wastage and other harvest violations, and in order to reduce the opportunity for wastage, enforcement crews perform on water weigh outs prior to harvest vessels leaving the harvest area. DNR's "on-the-water" enforcement program includes the following activities to deter illegal discarding of harvested geoducks:

- Enforcement staff are on tract at all times during harvest with exception of emergency and operational requirements (ex. fueling, getting geoduck samples in for analysis, taking crew to shore, mechanical problems). If the monitor boat must leave the tract a monitor will be left on the tract if weather and staffing permits,
- DNR accurately marks the boundaries of the tract using dGPS and maintaining the markers throughout the harvest period,
- DNR regularly conduct enforcement dives on the tract, including along the deep-water boundary, and inspection of harvest holes to check for discarded geoducks,
- DNR enforcement staff conduct on the water weigh-out of geoducks before harvesters can leave the tract
- Harvesters are required to check in with the monitors before entering or leaving the harvest area,
- DNR enforcement staff conduct vessel inspections before and after

harvest,

- DNR enforcement staff maintaining up-to-date enforcement logs on monitoring activity,
- State and tribal managers spot check each others monitoring programs and harvest activities.

DNR under-harvested the State TAC by 2 million pounds between 1996 and 2001. The under-harvest greatly reduced the fishery mortalities during that time period and minimized the possibility to exceed the TAC. DNR will also set aside up to 2% of the State TAC in each region as a conservation measure to account for possible wastage that might occur during harvest.

In addition to DNR's enforcement program, the following measures will be utilized to keep track of the general biological health and sustainablity of the geoduck fishery:

- State and Tribal managers may choose to conduct post-harvest surveys on fished tracts in order to estimate the accuracy of the reported catch,
- Regular coordination occurs between Tribal and State enforcement officers,
- Managers will develop a method for estimating the amount of geoduck discarding and adjust the TAC to accommodate this under reporting.
- The Department and the majority of the Tribes adapt their on the water monitoring programs to deal with new methods of discarding by harvesters.
- State and Tribal managers began a series of meetings in 2000 to discuss the issue of discarding, and to increase the level of enforcement and monitoring necessary to minimize the amount of discarding that occurs. These discussions will continue in 2001 and consider the possibility of adjusting landed catch allowances to a value less than the TAC to account for other fishing mortalities, e.g., from discarding, poaching, unreported

catch and inadvertent wastage. In addition, we will review harvest levels since 1996 to determine the amount of the TAC that was not harvested for each year. This information will provide us with a more precise method for quantifying the need for adjustments to the TAC. All fishery related mortalities, whether landed and reported as harvest or not, will be estimated and counted against the TAC and deducted annually from estimated commercial biomass, as appropriate.

High grading which involves partial digging may not be easily detected by standard enforcement methods, however. A simple experiment using "tagged" geoducks could be performed to estimate the level of delayed mortality from partial digging. Photographs of randomly sampled geoducks could be compared to commercial catches to determine if high grading is occurring on a particular tract. High grading losses will be estimated and accounted for as fishery mortalities and will be counted against the respective regional TACs.

Hatchery cultured geoduck seed can be planted in the field and protected from predators. This technique can be used to mitigate the loss of geoducks intertidally, or subtidally on a very small scale. Subtidal enhancement has yet to be proven to be economical on a large scale. If geoduck enhancement with hatchery seed is done in the future, care should be exercised to prevent damage to possible discrete genetic stocks. Genetic stock identification research should be evaluated before any movement of cultured stock occurs.

Further mitigation would necessitate reduced harvest or no harvest by the State (the Tribes can still fish). This would reduce short-term impacts on the population proportionally, but would also reduce the benefits of the fishery (trade, food, jobs, and other benefits). Impacts to the geoduck stocks are unavoidable. No other methods of harvest are available which produce less incidental impact. Reducing the size of the fishery would reduce impacts but also reduce the benefits of the fishery.

3.4.2 Horse Clams

3.4.2.1 EXISTING CONDITIONS

Two species of horse or "gaper" clams (*Tresus capax* and *Tresus nuttallii*) commonly occur with geoducks in the subtidal waters of Puget Sound, although *T. nuttallii* is more abundant subtidally than *T. capax* (Campbell *et al.* 1990). The two species cannot be reliably distinguished while still in the substrate, and are hereafter referred to collectively as "horse clams." Horse clams were the fifth most commonly occurring species of the plants and animals that occur with geoducks (Goodwin and Pease 1987). These clams are not nearly as abundant as geoducks in most of the major geoduck tracts shown in Figure 2. Horse clams prefer coarser substrates (pea gravel and gravel and shell) with lesser amounts of sand and silt than do geoducks. In these coarse substrates, horse clams are more apt to be mixed with hardshell clams, native littleneck (*Protothaca staminea*) and butter clams (*Saxidomus giganteus*). Horse clams found in the silt and sand substrates of most geoduck tracts have not been systematically surveyed and population estimates are not available. The presence or absence of horse clams has been recorded routinely in geoduck surveys since 1984.

Large numbers of horse clams were seen in recent geoduck surveys on tracts at Arcadia, Steamboat Island, Fox Island, and Pitt Passage in southern Puget Sound, Agate Passage in central Puget Sound, northern Hood Canal, and the Admiralty Inlet area. In these surveys, geoducks are routinely sampled with water-jets. Horse clams are sometimes taken by mistake. Horse clams can normally be identified visually by a diver, and are seldom harvested by mistake. In some cases, however, positive identification is not possible and horse clams are removed from the substrate. These mistakes are probably also made by commercial divers on occasion, although no information on the magnitude of this problem is available.

Horse clams are large and can grow to over 1 kg (Campbell *et al.* 1990; Breed-Willeke and Hancock 1980; Bourne and Smith 1972). At mature sizes they are buried as deep as 50 cm in the substrate. They are easily harvested with geoduck water-jets and, since they normally rest slightly shallower in the substrate, can be taken in less time than geoducks. Horse clams are found in relatively deep water in Puget Sound. Goodwin and Shaul (1978) reported horse clams in water as deep as 42 ft, and they are reported in British Columbia to depths of at least 150 ft (Campbell *et al.* 1990).

Horse clams, when they occur in geoduck tracts, could be harvested by commercial geoduck divers. This harvest, in addition to geoduck harvest would increase the total catch of clams, harvest holes, turbidity plumes, and reduce horse clam populations, but limit it to the areas where geoduck harvest occurs. Harvest hole sizes and turbidity plumes will be similar to those of geoduck harvest, but may be slightly smaller since horse clams are normally not buried in the substrate as deeply as geoducks.

A commercial fishery for subtidal horse clams using water jets has existed in British Columbia since 1979. Annual landings averaging about 285,000 pounds. In Washington, horse clams were fished from the mid 1960s to the mid-1980s with hydraulic clam dredges. The catch was 432,000 pounds in 1966, gradually increased to 523,000 pounds in 1977, and dropped to 2,000 pounds in 1985. Landings averaged 108,000 pounds per year during the entire period. The catch was reduced and finally halted due to the intense public opposition to the use of clam dredges. Shifts in population structure in harvested areas between horse clams and hardshell clams were often seen due to the aggressive recruitment of horse clams after fishing (Goodwin 1979). No information exists on the possible shift in clam species in tracts with horse clams and geoducks that are fished exclusively for geoducks with water-jets.

Markets for horse clams exist in North America for bait in the Dungeness crab fishery and in Asia for human consumption (personal communication, January 1995, Tom Bettinger, Taylor United).

An equilibrium yield model for horse clams was completed by WDFW in 1996 (Appendix 5). Based on the results of the yield model, an annual harvest rate of 13.5% of estimated annual biomass is expected to preserve at least 50% of the unfished spawning biomass of horse clams. This harvest rate is five times higher than the harvest rate recommended for geoducks, primarily because horse clams have a much higher rate of natural mortality and grow faster than geoducks.

Because the recommended annual harvest rate for horse clams is five times the harvest rate for geoducks, it is reasonable to assume that horse clam populations which are fished concurrently with geoducks will recover to pre-fishing densities more quickly than the geoduck population. For this reason, horse clam harvest is currently allowed by the Tribes within commercial geoduck tracts with no quota (per State/Tribal management agreements in Central Puget Sound, South Puget Sound and Strait management regions). The Tribes have agreed to limit commercial horse clam harvest to those tracts open for commercial geoduck harvest. Presently there is little or no commercial harvest of horse clams. Additional management issues will be addressed if the fishery is expanded. WAC 220-52-019 (6) makes it unlawful for State harvesters to harvest horse clams, or any other species of marine life during the State's commercial geoduck harvest.

The impact assessments and mitigation sections given previously for geoducks would apply in most part to the potential horse clam harvest.

3.4.3 Other Infauna

3.4.3.1 EXISTING CONDITIONS

Geoduck tracts support a wide variety of animals that are either buried or partly buried in the substrate including anemones, flat worms, ribbon worms, peanut worms, mollusks, crustaceans, and cnidarians. These animals are collectively called the benthic infauna. The structure of marine bottom-dwelling (benthic) communities is largely dependent on sediment composition and hydrographic conditions (depth, current velocity, etc.). The abundance and diversity of species found on each geoduck tract will differ. The tracts all contain representatives of the same groups and are similar enough for generalizations to be used to describe typical tracts.

One of the most abundant and widespread groups of animals of the infauna are the polychaete tube worms (*Spiochaetopterus sp*. and *Phyllochaetopterus sp*.). These polychaetes live in long, thin leathery jointed tubes (<1 mm diameter) which form dense root like mats in the sediment. These animals are ranked number one on the list of plants and animals that occur most often in geoduck tracts (Goodwin and Pease 1987). Preliminary observations indicated the worms' presence may accelerate and facilitate the development and settlement of geoduck larvae to the substrate (Cooper and Pease, unpublished WDFW manuscript). Worm tubes may also serve as spawning substrate for herring. Several other worms are found in lesser abundance on geoduck tracts. These include other polychaetes, as well as the relatively abundant ribbon worms (nemerteans), the less abundant flatworms (turbellarians), and peanut worms (sipunculans). Many of these worms feed on organic material in the sediments, while others feed on food particles in the water. Several species are carnivorous, often feeding on other worms.

Perhaps the next most characteristic animal on geoduck tracts, especially in southern Puget Sound, is the orange sea pen (*Ptilosarcus gurneyi*). Sea pens are ranked third in the above mentioned list. Sea pens are particularly common in sand substrates, partially buried with their feather-like polyps extended to filter plankton from the water. Other common cnidarians are burrowing anemones (*Pachycerianthus fimbriatus*) which are frequently found in muddy substrates, plumose anemones (*Metridium senile*), and sea-whips (Family Virgulariidae).

Where gravel patches occur on geoduck tracts, the butter clam (*Saxidomus giganteus*) and the native littleneck (*Protothaca staminea*) are found. These two hardshell clam species are ranked fifteenth on the above mentioned list. The cockle (*Clinocardium nuttallii*) is frequently found on geoduck tracts but is present only in low numbers and is ranked thirty-ninth on the above mentioned list. A small clam called *Macoma inconspicua* may be present in high numbers. The shells of these clams rarely exceed 1.5 cm (5/8 inch) and they are found buried close to the substrate surface. A very small clam (4 mm or 5/32 inch) called *Transennella tantilla* is abundant on many geoduck tracts. It may be present in high numbers but contributes little to total biomass. The same is true for *Cryptomya californica*, a small clam which lives in ghost shrimp burrows. A medium sized close relative of geoducks called the false geoduck (*Panomya sp.*) is common, and was ranked twelfth on the above-mentioned list. They can be confused with juvenile geoducks, but are much smaller than adult geoducks.

The ghost shrimp (*Callianassa sp.*) is among the many crustacean species which are found on geoduck tracts. Ghost shrimp inhabit many, but not all, of the tracts. They are often present in high numbers, especially in Hood Canal. Ghost shrimp build tunnels in the substrate and feed on organic detritus. A variety of small crabs, worms, and fish populate its burrows. In dense populations, their burrowing and turbidity-producing activities can limit the distribution of many important bivalves such as oysters and clams (Posey 1986; Posey *et al.* 1991). Ghost shrimp are anecdotally thought to produce an adverse effect on geoduck distribution. WDFW divers, in 30 years of subtidal geoduck surveys, have never seen significant quantities of geoducks in tracts where ghost shrimp are abundant. Small isopod, amphipod, and copepod crustaceans also live within geoduck tract substrates.

The burrowing sea cucumber (*Leptosynapta clarki*) is also sometimes found and attains a length of 2.4 inches (6-7 cm). It feeds on organic detritus.

3.4.3.2 IMPACT ASSESSMENT

Harvest of geoducks disrupts the sediment around each geoduck and the animals that live within the sediment. The area actually dug within a commercial tract depends on the density of geoducks. Average density on unfished tracts in Washington is 1.7 geoducks/m^2, and 1.9 geoducks/m^2 in central Puget Sound, southern Puget Sound, and Hood Canal (Goodwin and Pease 1991). Assuming an average density of 1.9 geoducks/m^2 and an average hole size of 1,093 cm^2 (1.18 ft^2), digging will affect 21% of the area within a harvest tract if all geoducks are removed. A liberal estimate of the amount of area affected by digging would be 25% (State of Washington 1985). Soft-bodied animals may be damaged by the water-jets while many are exposed to predation by fish, crab, other predators, and other scavengers. Tubeworms in the disturbed sediments may also be broken apart. Very small animals may be suspended and carried away by currents. Most of these animals repopulate the harvested tract rapidly (see the studies summarized below). Animals not in the immediate vicinity of harvested geoducks are not affected directly, although they may be indirectly affected for a short period by silt and displaced substrate material.

The impact of geoduck harvest on benthic organisms was assessed at an experimentally harvested plot in Hood Canal (Goodwin 1978). Estimates of the abundance and diversity of bottom animals were first obtained from two previously unfished plots, after which one of the plots (the "treatment" plot) was fished using the standard commercial water-jet method. The other plot ("control" plot) was not fished on. Both plots were then re-sampled roughly seven months after harvest of the treatment plot. The before and after samples were compared at both plots to assess the effects of harvest. All samples were taken with a venturi suction dredge, which removed material as deep as 50 cm below the substrate surface, and with a sediment core sampler which retained smaller animals.

The dominant organisms (in terms of both numbers and weight) found in the substrate samples were small clams, ghost shrimp, and polychaete tube worms. Core samples washed on 1 mm screens had high numbers of the tiny clam *Transennella sp*. Ghost shrimp were the most numerous animals in the 6.35 mm mesh suction dredge samples, followed by the small clam *Macoma inconspicua*. Natural seasonal changes in the size of infaunal populations complicated interpretation of the data. The biomass of the tiny clam *Transennella sp.*, for example, increased significantly in the "after" samples on both the fished and unfished plots, and so these increases were probably due to seasonal variation rather than fishing. The author reported that total biomass of the infauna (excluding geoducks) sampled in the 1 mm screens showed no statistically significant change within the treatment plot seven months after fishing. Total biomass of the infauna (excluding geoducks) captured in the 6.35 mm mesh suction dredge samples increased significantly on the treatment plot seven months after fishing, but no corresponding statistically significant increase was found in the unfished control plot. Of individual species captured on the 6.35 mm mesh sampler, only the small clam *Macoma inconspicua* underwent a significant increase during the seven-month period after fishing on the treatment plot; no statistically significant changes were noted seven months after geoduck fishing in the populations of ghost shrimp, moon snails, polychaete tube worms, or other bivalves.

Breen and Shields (1983) also studied the effects of geoduck harvest on associated fauna at three experimental plots at Brady's Beach, British Columbia. Core samples were taken from a control plot from which geoducks had never been removed, and two treatment plots from which all geoducks were harvested. The authors considered their experimental harvest to be more disruptive of the substrate and infauna than commercial geoduck fishing. Core samples were taken from the three plots. One of the treatment plots as sampled nine months after fishing, and the other sampled two years after fishing. The authors found no evidence of changed sediment structure caused by geoduck harvest, and only one animal taxon was significantly affected; these were copepods of the order Harpacticoida, which increased significantly following geoduck harvest. Species diversity was reported to be higher in the experimental plots from which geoducks had been most recently harvested.

The relative abundance of some of the major infauna was compared before and one year after fishing at 11 commercial tracts in Washington (Appendix 6). Of the seven tracts containing polychaete tube worms (*Spiochaetopterus sp.* and *Phyllochaetopterus sp.*), only two tracts showed a significant change following fishing (a decrease on one tract and an increase on the other). Of seven tracts containing sea pens (*Ptilosarcus gurneyi*), only one tract showed a significant difference (an increase) following fishing. On the three tracts containing sea whips (Family Virgulariidae), no significant differences were found after fishing. Of the eight tracts containing plumose anemones (*Metridium senile*), only one tract showed a significant change (an increase) following fishing. Of six tracts on which tube-dwelling anemones (*Pachycerianthus fimbriatus*) were observed, only one showed a significant change (a decrease). Of the seven tracts containing horse clams (*Tresus sp.),* two tracts showed significant post-fishing increases, while one decreased significantly.

Several authors have recently studied the infaunal effects of commercially harvesting clams with suction pumps, a more severe form of harvesting than used for the commercial geoduck fishery. Unlike geoduck fishing, which leaves the disturbed sediment *in situ*, suction pumps remove the upper layers of the substrate as well as the infauna. Kaiser *et al.* (1996) found that the infaunal community was restored within seven months after suction harvesting Manila clams from commercial beds on the southeast coast of England, beds which were characterized by coarse sediment. Spencer *et al.* (1998) conducted a similar experiment in fine muddy sand substrates and found that the benthic community was restored within nine to 12 months after suction harvesting.

Coen (1995) found that harvesting clams using a mechanical hydraulic dredge causes some mortality of infaunal and epifaunal organisms directly in its path. However, the community effect was found to be short term because many of the small benthic organisms regenerate rapidly, recolonize quickly and have high fecundity. Direct and indirect evidence showed that the short term and localized depressions of infauna cause by a mechanical clam dredge do not appear to have a primary influence on subtidal habitats.

3.4.3.3 SIGNIFICANCE OF OTHER INFAUNAL IMPACTS

Goodwin (1978) concluded that geoduck harvest had little effect on the benthic infauna. The only statistically significant effects which could be attributed to geoduck fishing were slight increases in the biomass of some small clam species seven months after fishing. The report concluded that harvest did not cause biologically significant decreases in standing crops of major organisms, and that the effects noted probably would not be evident after a year or two. Breen and Shields (1983) found very little effect on benthic infauna due to geoduck harvest in British Columbia. Before- and after-fishing dive surveys at 11 commercial tracts in Washington (Appendix 6) showed few significant infaunal effects a year after harvest. Of 38 tests performed (one test for each tract containing the species in question), only eight showed a change after fishing, five of which involved increased abundance.

3.4.3.4 MITIGATION

Herring use tube worm mats as spawning substrate. Geoduck harvest activities could disrupt and cover some of these mats, smothering or damaging attached herring eggs. To avoid this problem, geoduck fishing is not allowed by State/Tribal harvest agreements in documented herring spawning beds during the herring spawning season. (see Section 3.6).

3.5 EPIFAUNA

3.5.1 Existing Conditions

Epifauna are animals that live on, not in, the substrate. These animals are generally large compared to most infaunal species, and many feed on small infaunal species or detrital food particles.

Various species of crab are common in geoduck tracts. The large and commercially important Dungeness crab (*Cancer magister*) is common on geoduck tracts north of Vashon Island. Dungeness crab are often associated with sand/silt substrate, especially near beds of eelgrass (*Zostera marina*). Dungeness crab are predators/scavengers on the benthic infauna. Their prey includes small clams, worms, and probably juvenile geoducks.

Red rock crab (*Cancer productus*) are common on geoduck tracts and are widely distributed throughout Puget Sound. They are normally more associated with rock/gravel substrates than Dungeness crab. The graceful crab (*Cancer gracilis*) is another abundant crab species, especially in southern Puget Sound where it is found on most of the geoduck tracts. The red rock crab is ranked ninth, the graceful crab thirteenth, and the Dungeness crab twenty-ninth on the list of species that occur most often with geoducks (Goodwin and Pease 1987).

A variety of smaller crabs are also seen, including small spider crabs (*Pugettia producta* and *P. gracilis*). The commensal pea crabs (*Pinnixa faba* and *P. littoralis*) inhabit the mantle cavity of larger clams, including geoducks. Their presence does not appear harmful to the clam.

Various pandalid shrimp are present on most geoduck tracts, especially if algae is abundant to provide cover, hiding places, and food. On any one tract, ocean pink shrimp (*Pandalus jordani*), northern pink shrimp (*P. borealis*), spot shrimp (*P. platyceros*), or coonstripe shrimp (*P. goniurus*, *P. hypsinotus*) may be found. Members of the Families Crangonidae and Hippolytidae are also found on geoduck tracts. Other small crustaceans (copepods, isopods, and amphipods) are common.

Several species of epibenthic mollusks occur in geoduck tracts including the carnivorous moonsnail (*Polinices lewisii*) which may reach 5 inches (12.7 cm) in diameter and the closely related, but smaller, *Natica sp*. These snails attack buried clams by drilling a hole through the shell and sucking out the tissue. They are probably major predators on juvenile geoducks or adults which are shallowly buried due to layers of shell, rock, or hard pan below the softer surface sediments. On tracts where boulders, rock outcroppings, or objects discarded by humans occur, the large gumboot chiton (*Cryptochiton stelleri*) and octopus (*Octopus dofleini* and *O. rubescens)* may occasionally be found.

Echinoderms are also abundant. The sea cucumber *Parastichopus californicus* is common on most geoduck tracts and other silt/sand habitats. These large (16 inches, or 40 cm) echinoderms feed on organic material in the sediment and may be important in recycling these nutrients. Several species of sea star are also common, including *Pisaster brevispinus*, *Pycnopodia helianthoides*, *Solaster stimpsoni*, *Mediaster aequalis*, *Luidia foliolata*, and *Henricia leviuscula*. Sea stars are carnivorous on clams, especially small clams near the surface. *Pisaster* and *Pycnopodia* in particular may consume large numbers of geoducks including shallowly buried adults (Sloan and Robinson 1983). The green sea urchin (*Strongylocentrotus droebachiensis*) which feeds primarily on algae, occasionally inhabits geoduck tracts.

3.5.2 Impact Assessment

Epifaunal animals, being mobile, are not affected by geoduck harvest in the same way as infauna, which live in the substrate. Snails, crabs, and sea-stars are not likely to be damaged by water-jets or carried away with currents and can move to undisturbed, adjacent areas. During geoduck harvest, their food supply may increase as they forage on exposed organisms in and around the harvest holes. This will also attract predators from adjacent areas. After a few days, there may be less food available on the harvested tract until the infaunal animals repopulate the tract. The experimental harvests conducted in Hood Canal and British Columbia indicate that harvest-related reductions in the standing crops of benthic organisms are slight and temporary (Goodwin 1978; Breen and Shields 1983). Some epifaunal animals are largely protected from the effects of geoduck fishing because, if they occur at all within a geoduck tract, they tend to inhabit areas which contain few or no geoducks. Octopus and gumboot chitons, for example, are associated with boulders, rock outcroppings, and discarded metal or rubber debris, habitats which rarely contain geoducks.

Concerns about the possible adverse effects on crab stocks from geoduck harvest have been raised many times from concerned shoreline owners, sport crabbers, and others. WDFW responded to these concerns with a study in northern Hood

Canal to determine if there was a significant effect of commercial geoduck fishing on Dungeness and red rock crab fishing catch rates (Appendix 7). Crabs were sampled using baited pots at one site before, during, and after commercial geoduck fishing, during which 1.8 million pounds of geoducks were removed from the site. Concurrently, crabs were sampled at a nearby unfished site. Both sites were sampled using 30 commercial crab pots on 20 occasions over a period of 4.6 years. The specific objective of the study was to determine if significant changes in the crab catch rate occurred following geoduck fishing in the harvested site, and if any such changes could be attributed to geoduck fishing. Results of the study indicated that the average Dungeness crab catch rate at the site fished by geoduck divers was 1.70 crabs per pot prior to geoduck fishing, and 2.96 crabs per pot during the post-fishing period. At the unfished site, crab catch rates also increased during the same time period. None of these changes were statistically significant, however. The authors concluded that the extremely high natural variability of Dungeness crab populations would tend to mask all but the most extreme increases or decreases in catch rates due to geoduck fishing. Red rock crab (*Cancer productus*) were also sampled during the research. Although there was a decrease in catch rates for this species during the geoduck fishery, a similar decrease occurred at both the fished and unfished sites, meaning that the decrease was likely the result of a natural fluctuation rather than geoduck fishing.

Dive survey data provides additional information regarding the effects on Dungeness, red rock, and graceful crabs (Appendix 6). Of seven commercial tracts containing Dungeness crabs which were surveyed before fishing and one year after fishing, only one tract showed a significant change after fishing (an increase). Of the eight tracts containing red rock crabs, only one tract showed a significant change following geoduck fishing (an increase). Of five tracts containing graceful crabs (*Cancer gracilis*), two tracts showed significant changes following geoduck fishing; graceful crabs increased in relative abundance on both tracts.

The apparent lack of adverse effects on Dungeness and red rock crab may be due to the low percentage of potential crab habitat which is normally disturbed in an area during a normal geoduck fishing event. WDFW, in consultation with Dr. David Armstrong of the University of Washington, has determined that Dungeness crab in Puget Sound utilize the substrate bottom from the +1 ft tide level down to -330 ft(MLLW). If geoduck harvest is liberally assumed to be 85% of the estimated population on a tract (in fact, the average removal since 1985 is 72% of the biomass; Sizemore *et al.* 1998), and the size of each harvest hole is assumed to be 1.2 ft^2 (section 3.4.3.2), then the amount of substrate disturbed can be given as a percentage of the total available to crabs in any given site. These calculations are shown for six different sites in Table 2. The amount of disturbance to potential crab habitat is low, ranging from 1.1% to a high of 2.6%, and suggests that geoduck harvest in most situations has a low chance of causing major adverse effects on Dungeness crab.

On ten tracts containing sunflower stars (*Pycnopodia helianthoides*) prior to fishing, no significant changes were observed a year after fishing (Appendix 6). Likewise, no significant post-fishing effects were observed on the nine tracts containing pink short-spined stars(*Pisaster brevispinus*).

3.5.3 Significance of Epifaunal Impacts

Geoduck harvest has not been observed to have demonstrable long-lasting impacts on the epifauna of the harvested tracts. These effects are temporary and do not appear to be significant.

Table 2. Crab Habitat Disturbed by Geoduck Harvest

Location	Percentage of total crab

	habitat disturbed by geoduck harvest
Jamestown (Strait of Juan de Fuca)	1.4
West side Hood Canal north of the floating bridge	1.4
Hood Canal (Lofall, Vinland, Thorndyke Bay)	2.0
Agate Passage (west side) Sandy Hook Point Bolin	 1.1 2.6
East side, Bainbridge Island	1.1

3.6 FISH

3.6.1 Existing Conditions

The principal fish associated with geoduck tracts are flatfish (Families Bothidae and Pleuronectidae) such as flounder and sole. Some of these flatfish are commercially important. Dover sole (*Microstomus pacificus*), rock sole (*Lepidopsetta bilineata*), sand sole (*Psettichthys melanosticus*), English sole (*Parophrys vetulus*), starry flounder (*Platichthys stellatus*), and sand dab (*Citharichthys stigmaeus*) are all found on geoduck tracts. These fish eat invertebrates that live on and in the substrate. Various sculpins (Family Cottidae), cabezon (*Scorpaenichthys marmoratus*) and greenling (*Hexagrammos sp.*) will be present on tracts where algae, rock, or human refuse provide cover. Ling cod (*Ophiodon elongatus*) may be present on tracts with substantial rock material or human refuse. On many tracts, various gobies (Family Gobiidae) can be found living in small holes. Perch (Family Embiotocidae) do not live permanently on geoduck tracts but are often seen passing over them. The dogfish (*Squalus acanthias*) is a frequent visitor to the tracts. Dogfish and cabezon graze on siphon tips; the stomach of one cabezon was found to contain the siphon tips from 14 geoducks (Anderson 1971). Various trout and salmon species may feed in or pass over geoduck tracts. These highly migratory fish do not live permanently in one area.

Though rarely observed during dive surveys, salmon may be in the vicinity of geoduck tracts during juvenile rearing, juvenile emigration to the ocean, and adult migration to spawning grounds.

Many of the commercial geoduck tracts are adjacent to, or coincident with areas where Pacific herring (*Clupea harengus pallasi*) spawn. Pacific herring spawning is usually limited to depths between +3 ft and -15 ft; but in some areas, spawning occurs as deep as -40 ft to -60 ft. Herring spawn on or near 55 geoduck tracts in water deeper than -15 ft (WDFW 1995; Appendix 1). Herring deposit eggs on eelgrass, algae, hard substrate, and occasionally on polychaete tube mats. Many other species of fish pass over geoduck tracts at various times either feeding in the water column or migrating over the tracts, notably Pacific cod (*Gadus macrocephalus*) in Agate Pass and Port Townsend. Pacific cod may also use geoduck tracts near Agate Passage and Port Townsend for spawning.

3.6.2 Impact Assessment

Fish are able to swim away from the harvest area. Fish which feed on the benthic infauna and epifauna may remain in or near the harvest areas. In the past 30 years of geoduck surveying, divers have often observed flatfish and perch attracted to and feeding in areas that were being experimentally fished for geoducks with water jets. Fish swimming above the plume of turbid water created by the harvest are generally unaffected except that some may feed on small infaunal organisms which become suspended in the water while others may avoid the plume of turbid water immediately downstream of the harvest operation.

Dive survey data were used to compare the relative abundance of flatfish (Family Pleuronectidae) observed on geoduck tracts before and after fishing (Appendix 6). Of the nine tracts on which flatfish were observed, only two tracts showed significant changes a year following fishing; the relative abundance of flatfish increased on both these tracts.

Portions of commercial geoduck tracts used by fish for spawning may be affected by geoduck harvest. Herring eggs deposited on tube worm mats or vegetation could be damaged directly, or indirectly if covered with sediment and smothered.

The potential exists for the presence of divers to interfere with fish spawning or feeding activity.

3.6.3 Significance of Fish Impacts

Based on biological surveys of geoduck beds and study results (Appendix 6) as well as 30 years of observation, geoduck harvest does not appear to have demonstrable impacts on local fish abundance. Some fish may be attracted to the tracts to feed on exposed organisms, while others may avoid the commotion and silt plume. These effects however, appear to be limited to the time when harvest is actually underway. Studies discussed earlier have shown that, except for geoducks themselves, recovery of benthic organisms is rapid.

The status of salmon populations along the Pacific Rim, including runs in Washington State, has received considerable review in recent years (Myers *et al.* 1998, Johnson *et al.* 1997, Gustafson *et al.* 1997, Hard *et al.* 1996, Weitkamp *et al.* 1995). Within the waters of the Strait of Juan de Fuca, Hood Canal and Puget Sound, two salmon populations -- Puget Sound chinook salmon (*Oncorhynchus tshawytscha*) and Hood Canal summer run chum salmon (*O. keta*)-- were listed by NMFS on March 16, 1999 as threatened species under the federal Endangered Species Act (Dodge, 1999). Puget Sound coho salmon *(O. kisutch*) are at historically high population levels, but due to concerns about intensive artificial propagation, high harvest rates, upland development trends, unfavorable ocean conditions, and recent declines in adult size, Puget Sound/Strait of Georgia coho were designated as a “candidate” species on July 25, 1995 by NMFS (Weitkamp *et al.* 1995). Sockeye salmon (*O. nerka*) and pink salmon (*O. gorbuscha*) populations are healthy, and are not considered at risk in areas where known geoduck beds are found.

During smoltification, salmon change from a freshwater to a marine existence.

Juvenile survival strategies vary widely depending on the salmon population. Chum and "ocean-type chinook" salmon have a limited freshwater residence with extensive nearshore rearing (Healy 1982). Sockeye and "stream-type" chinook salmon have an extended freshwater residence period (Healy 1991), and may on occasion migrate up to their third year and move quickly off-shore. Kokanee, which are sockeye that live their entire existence in freshwater, never migrate to saltwater (Burgner 1991). Juvenile salmon rearing areas encompass the top few meters of the water column in marine waters (Bax 1983).

Under most circumstances, commercial geoduck tracts are geographically separated from salmon spawning streams (Figures 5, 6 and 7). Geoduck tracts are also deeper (>18 ft MLLW (~5.5 m)) than juvenile rearing areas, including migratory corridors. Most young fish (30mm) entering the Puget Sound are generally observed in shallow shoreline areas at a depth of 1 meter or less (Shepard 1981). Eelgrass beds, commonly used for juvenile salmon rearing habitat, are excluded from commercial geoduck harvest. All commercial geoduck harvest must occur at least two vertical feet seaward and deeper from eelgrass beds. A 180- ft horizontal buffer zone between eelgrass beds and geoduck harvest areas may be used when the slope is very gradual. This optimizes harvest area and still provides a protective setback based on results of the Pentec study (Appendix 4 to the SEIS). The common practice is to establish tract boundaries using a 2 ft vertical buffer between eelgrass and geoduck harvest areas. In addition, geoduck tracts represent only a small area (1.3 %) within the marine environment (Appendix 1). During a geoduck fishery, the use of selective harvest gear and the harvest of one geoduck at a time per diver allows for behavioral avoidance by juvenile and adult salmon. Following geoduck harvest, tracts are not disturbed for several decades during the tract recovery period.

In his review of the methods and practices used to harvest geoducks and their potential impact on salmon (see DSEIS scoping review letters), Dr. Charles

Simenstad, with the University of Washington School of Fisheries felt that "the impact to juvenile ocean-type salmon to be comparatively minimal or non-existent." He went on to say the following: "The exclusionary principle of not allowing leasing/harvesting in water shallower than -18 ft. MLLW or 200 ft (sic yds) distance from shore (MHW); 2 ft. vertically from elevation of lower eelgrass margin, and within any regions of documented herring or forage fish spawning should under most conditions remove the influences of harvest-induced sediment plumes from migrating salmon. As the available information indicates that sediment plumes do not enter the nearshore zone, impacts to juvenile salmon habitat and prey resource should also be protected from impact by these policies if effectively regulated."

Figure 6: Summer Chum Production Streams in Hood Canal and Commercial Geoduck Tracts

Figure 7: Summer Chum Production Streams in the Strait of Juan de Fuca and Commercial Geoduck Tracts

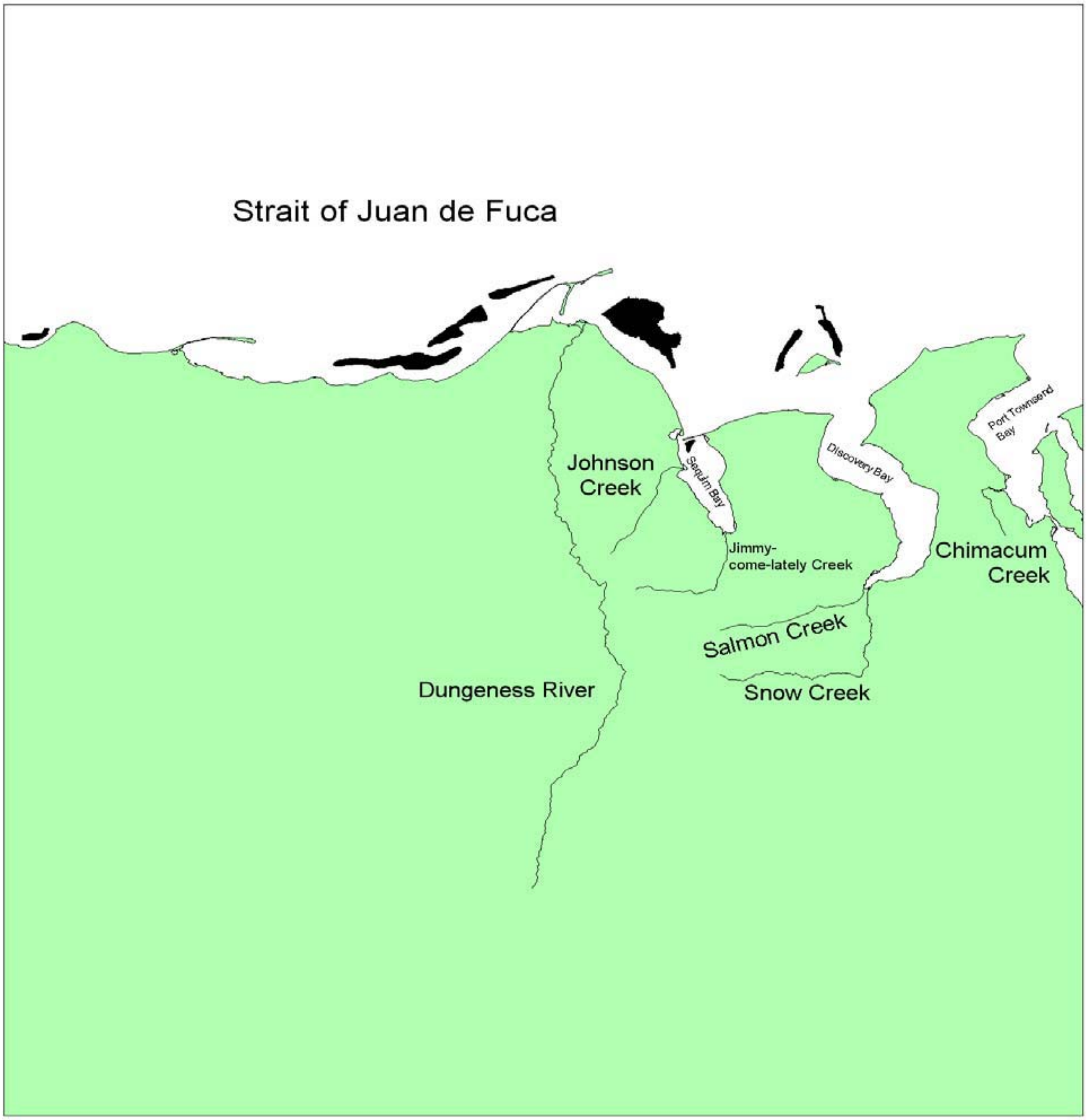
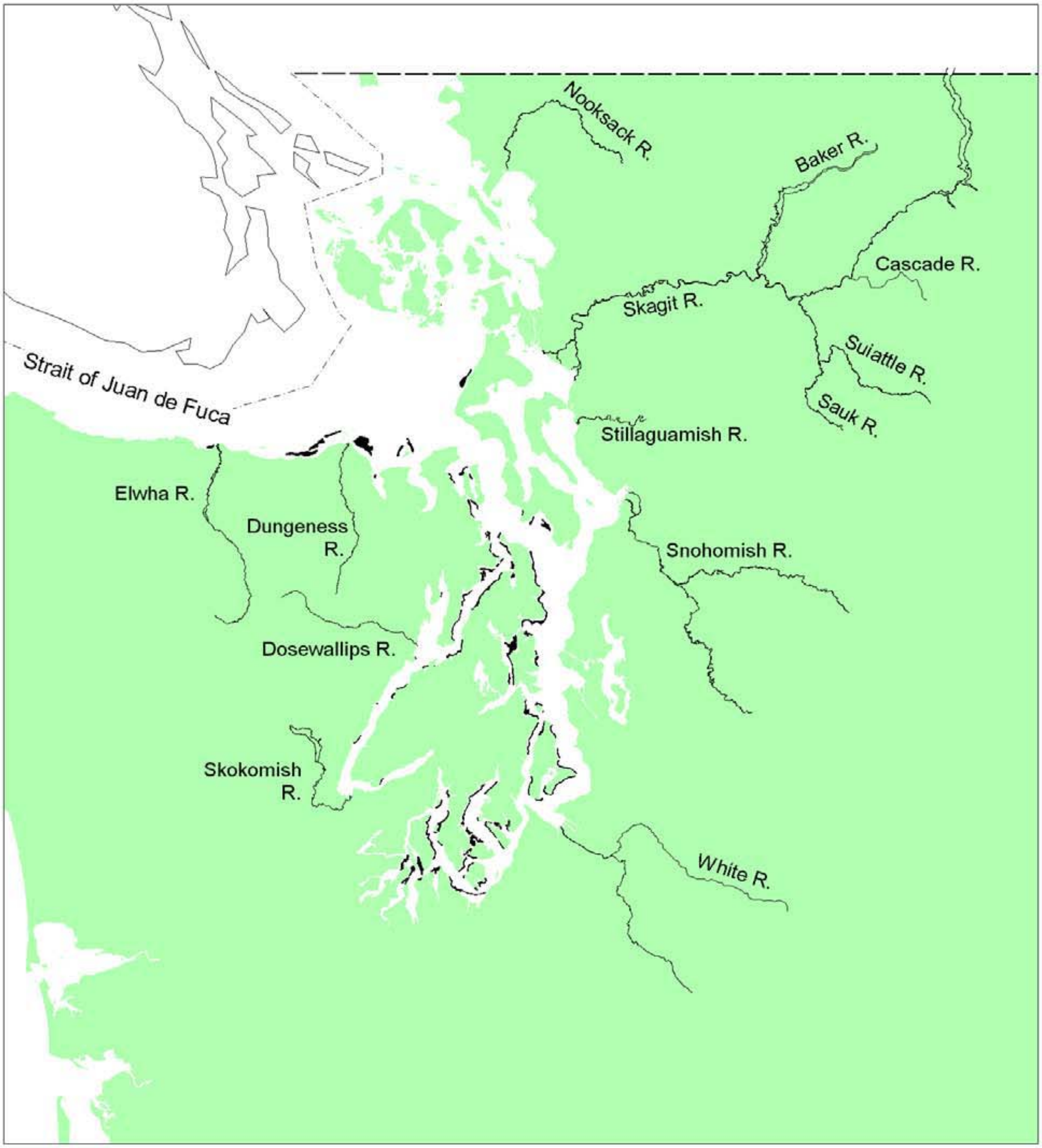


Figure 8: Overview Map: Major Chinook Salmon Tributaries in Puget Sound and Commerical Geoduck Tracts



HOOD CANAL SUMMER RUN CHUM SALMON

The risk of geoduck harvest affecting Hood Canal summer run chum, listed as a threatened species (Dodge 1999), is low due to the behavior of emigrating juveniles and the location of emigrating corridors in relation to the area where geoduck harvest occurs. Subestuary deltas in the Hood Canal, Puget Sound and Strait of Juan de Fuca support the summer chum fry transition from freshwater to saltwater during seaward migration. Summer run chum fry migrate during February and March, and usually occupy the sublittoral seagrass beds (at a depth of between 1.5-5.0 m (Tynan 1997)) that connect subestuary deltas (Wissmar and Simenstad 1988). Seagrass beds, concentrated between +1 m to - 2 m within the nearshore area, are considered the most important habitats. Kelps, macroalgae and mud and sand flats are also prominent migratory corridor habitats linking subestuary deltas (Simenstad 1998). Summer chum have been observed during their first few weeks in the nearshore area to be very close to shore and in the top 6 inches of surface waters. Most of the summer run chum fry maintain a nearshore distribution and rapidly out-migrate northward (at a rate of 7-14 km/day), generally along the east shore of Hood Canal (Schreiner 1977; Bax *et al.* 1978; Bax 1982; Bax 1983). Bax (1983) observed that early run chum fry show little change in length during this migration. The rapid seaward migration of summer run chum fry is thought to be a response to low food availability, predator avoidance, or accelerated surface water flow from prevailing south winds (Bax *et al.* 1978; Bax 1982; Bax 1983; Simenstad *et al.* 1980). With a short smolt residence time, the use of the nearshore area for migration in Hood Canal, and the existing conditions of commercial geoduck harvest, the likelihood of any interaction between geoduck harvesting and migrating summer run chum smolts is greatly reduced.

It should be noted that of the 11 summer chum production streams in Hood Canal, summer chum have been extirpated in three streams; Big Beef Creek, Anderson Creek and the Dewatto River. The Tahuya River is functionally extirpated. Four streams; the Little Quilcene River, the Hamma Hamma River, the Duckabush River and the Lilliwaup River have very low returns relative to historical levels. Only three streams, the Big Quilcene River, the Dosewallips River and the Union River have returns considered stable or rebuilding. The collective average Hood Canal summer chum returns and spawning levels are just three percent of those populations in the 1960s and early to mid 1970s. There are presently three Strait of Juan de Fuca streams with known summer chum populations: Salmon and Jimmycomelately Creeks are at low return levels, but appear stable. The Snow Creek population appears to be declining. There have been no summer run chum escapements observed in Chimacum Creek since 1984, and this run is believed to be extirpated (Tynan 1997).

William et al. (1975) identified the following limiting factors have contributed to the decline of Hood Canal Summer Chum:

- Lack of stream bank cover
- Development within the watershed
- Poor water quality
- Road crossings
- Removal of stream bank cover
- Acceleration of erosion
- Summer temperatures
- Summer stream flows
- Major marine activities of metropolitan centers
- Seasonal flooding
- Construction adjacent to streams

Simenstad (1998) identified shoreline development, including intertidal fills, installation of bulkheads and docks and destruction of shoreline vegetation as having caused direct and “considerable indirect impacts”to important summer chum salmon habitat along in the Hood Canal shoreline.

CHINOOK SALMON

The risk of geoduck harvest affecting Puget Sound chinook salmon, listed as a threatened species (Dodge 1999), is reduced due to the geographic separation of spawning tributaries and commercial harvest areas (Figure 7). The Skagit River and its tributaries -- the Baker, Sauk, Suiattle, and Cascade Rivers -- constitute what was historically the predominant system in Puget Sound containing naturally spawning populations of chinook salmon. Chinook salmon are also present in the North and South Fork Nooksack, White, Stillaguamish, and Snohomish Rivers. No commercial geoduck fishing occurs in the vicinity of these drainages. Fall run stocks of chinook salmon may be found throughout the region in all major river systems (Myers *et al.* 1998).

The likelihood of any interaction between geoduck harvesting and any migrating stream type salmon smolt is minimized due to their short residence time in the shallow subtidal waters where geoduck harvest occurs. Stream-type chinook salmon smolts have a long freshwater residence time, tend to be large as smolts (averaging 73-134 mm), and move offshore quickly (Healy 1991). Ocean-type chinook salmon have a shorter freshwater residence time and tend to utilize estuaries and coastal areas more extensively for juvenile rearing (Myers *et al.* 1998). The ocean-type strategy is predominant in Puget Sound, and may be a response to the limited carrying capacity of smaller streams and low productivity in certain watersheds (Miller and Brannon 1982). In most river systems, fry migrants, which migrate 60-150 days after hatching, and fingerling migrants, which migrate in the late summer or autumn of their first year, represent the majority of ocean-type emigrants (Myers *et al.* 1998).
Juvenile chinook salmon were found in all marine habitats in the Puget Sound from mid-May through September (Shepard 1981). In addition, geoduck harvest

could potentially have direct and indirect impacts to benthic habitat utilized by chinook (primarily adult) salmon. A study by WDFW found that hatchery chinook salmon juveniles released into the Hood Canal were not observed to go beyond 300 yards from the shore line or below a water depth of five feet (Shepard 1981). State harvest of geoducks is limited to no closer than 200 yards from shore. The exact timing and rate of migration for chinook juveniles is not well known for all rivers and streams, but under the existing management conditions of commercial geoduck harvest, juvenile rearing areas for fry and fingerling chinook migrants would not likely be disturbed.

3.6.4 Mitigation

During the preharvest surveys, tracts are inspected for important fish habitats, and the presence of different species of marine fish are noted on a transect-by-transect basis. These data are included in Environmental Assessments and provided to WDFW biologists in the Marine Fish and Freshwater Fish Divisions. These marine fish and salmon biologists review the proposed harvest sites on a site-by-site basis and identify potential conflicts. If spawning areas, or other important habitats are present, these areas maybe closed to harvest or closed seasonally during spawning periods or other critical times. Generally however, open sand/silt habitats are rarely used for fish spawning in the marine environment.

Herring are the species most likely to spawn on or near commercial geoduck tracts. Herring spawning areas are well documented (WAC 220-100-260; WDFW 1995). Spawning occurs between January and June and is usually inshore of the geoduck tracts between +3 ft and -15 ft. water depth contours (MLLW). Geoduck harvest is limited to depths below -18 ft MLLW). Fifty-five of the total 371 identified geoduck tracts, however, have occasional spawning on or near them at depths greater than -15 ft, and in these cases herring spawn may be affected. On these tracts, geoduck harvest will not be allowed during the time of the year when damage to spawners, eggs, larvae, or juveniles could occur. The annual Geoduck Atlas (e.g., Appendix 1) lists all tracts with herring spawning occurring on or near them, and lists fishing closures to coincide with herring spawning based on advice from WDFW and Tribal marine fish biologists. Most algal species that are used as substrate for herring spawning are annuals, with the exception of laminarians and therefore quickly recover if damaged by geoduck harvest.

Geoduck harvest is not allowed during the spawning period of other important fish such as Pacific cod or English sole in areas known to be used for spawning. Ling cod normally spawn in rocky areas with steep vertical cliffs. The egg masses are guarded and maintained by the adult males. Damage to ling cod eggs or direct harm to ling cod from geoduck fishing is unlikely due to the geographic separation of ling cod spawning areas and geoduck harvest areas.

For any areas where "take" of a species listed as “threatened” under the federal Endangered Species Act (ESA) is a possibility, measures will be employed to avoid the "take", or an authorization for incidental take will be obtained from the National Marine Fisheries Service under ESA rules. The Department of Natural resources will consult with NMFS to determine the actions necessary for the commercial geoduck fishery to meet requirements of ESA and ensure protection of endangered fish stocks.

3.7 MARINE MAMMALS

3.7.1 Existing Conditions

Several marine mammals may live near, or pass by, some of the geoduck harvest areas in their normal movements throughout Puget Sound. Harbor seals (*Phoca vitulina*) and California sea lions (*Zalophus californianus*) have been observed swimming in the water over many of the commercial geoduck tracts. Killer whales (*Orcinus orca*) and gray whales (*Eschrictius robustus*) are occasionally seen. Dall's porpoise (*Phocoenoides dalli*) and the harbor porpoise (*Phocoena phocoena*) are infrequent visitors to the commercial tracts. River otters (*Lutra canadensis*) have been seen near at least seven commercial tracts, and are probably present at times near many more tracts.

3.7.2 Impact Assessment

Geoduck harvest has not appeared to have any adverse effects on marine mammal populations. A study conducted at Protection Island indicated that 150 m (about 492 ft) is the critical zone for boat and beach disturbances to harbor seals that are resting on the beach (Gearin 1980). In 1999 DNR, WDFW and the Tribes had discussions with U.S. Department of Fish and Wildlife Staff for Protection and Gertrude Islands. It was acknowledged that the 600 ft offshore harvest limit should provide an adequate buffer zone between harvest activity and seal populations. Seals rapidly adapt to the presence of an anchored vessel, and it is not uncommon for seals to swim through a geoduck harvest area. Occasionally gray whales, killer whales, and sea lions swim through or linger around the harvest operations. Operations normally cease until they leave.

3.8 BIRDS

3.8.1 Existing Conditions

Many species of birds inhabit or visit geoduck harvest areas. Important species include the brant (*Branta bernicla*), Canada goose (*Branta canadensis*), rhinoceros auklet (*Cerorhinca monocerata*), bald eagle (*Haliaeetus leucocephalus*), great blue heron (*Ardea herodias*), and the osprey (*Pandion haliaetus*). There may be large flocks of waterfowl near harvest areas, especially during the winter, including dabbling ducks, scoters, grebes, loons, cormorants, guillemots, puffins, murres, and mergansers. Various species of gulls and terns are very common throughout Puget Sound and the geoduck harvest areas.

3.8.2 Impact Assessment

Geoduck harvest has not been observed to have adverse effects on bird populations or on their use of the water on the harvest tracts. However, public concern was raised regarding the possible impacts of daily geoduck harvest activities in one area, over several months of harvest, on bald eagles behavior. In addition, protection of bald eagles was considered even more critical due to their listing as an endangered species. In response to these concerns, DNR funded a study by WDFW raptor biologists in 1993 and 1994 to examine the issue.

Watson *et al.* (1996) evaluated the temporal and spatial relationships between geoduck harvest operations and the behavior of bald eagles in nesting territories in Puget Sound (Appendix 9). The two-year study was conducted at eight different eagle territories, including two territories on Hood Canal in which commercial geoduck fishing took place. Primary foraging areas of all territories were in the vicinity of marine waters, and all nests were located less than 300 m from the beach. Eagle behavior -- including foraging, search-capture time, perch visits, and number of flights -- was documented during 1,896 hours of observation, and comparisons made between behavior during geoduck fishing days and non-fishing days. The authors concluded that recreational boats, recreational clammers, beachcombers and picnickers presented the most significant source of direct disturbance to eagles. Only a single disturbance due to commercial geoduck harvest was noted during the study. The study concluded that "Geoduck clam harvest is unlikely to adversely impact productivity of bald eagles in Washington State based on the levels and types of eagle behavioral responses that we identified, the current State regulations governing harvest, and harvest tract locations." The report noted that only 8% of 536 occupied bald eagle territories were within 400 m from potential geoduck harvest tracts where there is the greatest potential for impact. Also, geoduck harvest typically is completed at a given tract within three to five years and not conducted again for several decades while the tract recovers. Other activities, such as recreational clamming, beach walking, and recreational boating, create a potential human presence daily throughout the year.

Nevertheless, the report stated that minimizing effects of geoduck harvest on localized eagle populations is important on Hood Canal or other areas that are experiencing chronic reproductive failure. The authors recommended restricting geoduck harvest in eagle foraging territories until after 10 AM, which would eliminate boating presence during the main eagle foraging period.

DNR and WDFW will review all proposed geoduck harvest with WDFW and Tribal raptor biologists prior to fishing. Where necessary, harvest plans will be modified to protect birds and their feeding and nesting areas.

3.9 PLANTS

3.9.1 Eelgrass

3.9.1.1 EXISTING CONDITIONS

Eelgrass (*Zostera marina*) is a perennial vascular seed plant that grows in the shallow subtidal and lower intertidal areas in Puget Sound. The plant has an extensive rhizome and root system and prefers substrates of silt and sand. Light penetration appears to be a limiting factor for eelgrass growth (Phillips 1984). In Puget Sound, south of Admiralty Inlet (including Hood Canal), eelgrass surveys have shown that eelgrass rarely occurs deeper than the -18 ft MLLW contour. Outside of the Puget Sound, in the clearer waters of the Strait of Juan de Fuca, surveys have documented eelgrass growing as deep as the -23 ft MLLW contour (Jamestown tract southeast of Dungeness Bay) and the -28 ft MLLW contour (Point Partridge tract off Whidbey Island).

The eelgrass plant consists of rooted rhizomes which are buried in the substrate. Along the rhizome are bundles of blades which reach up through the substrate into the water column. The number of blades in each group can vary from one to several. Eelgrass is an extremely important part of the total plant and animal community. Eelgrass plays a significant role in the overall primary productivity and provides food to animals by direct grazing or detritus from decaying plants. It serves as a nursery and shelter area for a variety of finfish and shellfish species of commercial and recreational importance, and provides spawning habitat for herring. Eelgrass stabilizes sediments by reducing water current flow and binding sediment materials with roots. Eelgrass is also important in nutrient recycling.

3.9.1.2 IMPACT ASSESSMENT

Geoduck harvest could affect eelgrass by direct physical damage to blades and roots or uprooting the plants with the water-jet. Sediment ejected from harvest holes could also bury or partially bury plants, causing damage.

3.9.1.3 MITIGATION

Due to the recognized importance of eelgrass, the potential damage to eelgrass that could result from geoduck harvest and based on the recommendations of WDFW habitat biologists, geoduck harvest is not permitted in any eelgrass beds. This is stipulated in State/Tribal management agreements and harvest plans, and is accomplished by doing pre-harvest eelgrass surveys along the entire shoreward perimeter of all geoduck tracts to find the deepest growing eelgrass. The shoreward boundary of the geoduck tract is then set seaward of the deepest rooted eelgrass blade. State/Tribal harvest plans stipulate that "... where eelgrass is deeper than -16 ft (MLLW), the shoreward boundary of the tract will be 2 vertical ft deeper and seaward of the deepest occurrence of eelgrass. Alternately, (based on the recommendations in Appendix 4), a buffer zone of at least 180 ft around eelgrass beds deeper than -18 ft (MLLW) can be used when the perimeter of the zone is marked and visible to divers within the tract." This provides a clear margin of safety between geoduck harvest and eelgrass. The shoreward boundary is then enforced by DNR and Tribal enforcement crews.

3.9.2 MACROALGAE

3.9.2.1 EXISTING CONDITIONS

Relatively few species of large benthic algae (macroalgae) grow in abundance on the typical sand and silt substrate of geoduck tracts. The macroalgae need a hard substrate for attachment. They can grow only where rocks, shell, or other hard materials are found. Macroalgae that does occur include *Laminaria sp.*, *Alaria sp.*, *Gracilaria sp.*, *Desmarestia sp.*, and *Neoagardhiella sp*. The bull kelp (*Nereocystis leutkeana*) rarely occurs on commercial geoduck tracts. Sea lettuce (*Ulva lactuca*) is often seen both attached and floating within geoduck tracts. Unattached algae may occasionally be found in large concentrations, deposited there by water currents.

3.9.2.2 IMPACT ASSESSMENT

Some of the small red and brown algae may be uprooted by the water-jets during harvest. Most are perennials and recolonize the tracts during the next season. The Laminarians which cover portions of the substrate of some tracts may impede harvest during summer months. Divers may clean them away to find geoducks, but laminarians will re-establish annually. Because of the selective nature of the water-jet method, kelp and other algae attached to rocks are seldom disturbed.

The impact of geoduck harvest on Laminarian kelp (*Laminaria sp.*) was compared on eight commercial tracts before and one year after fishing (Appendix 6). Of the eight tracts, only one showed a statistically significant change (an increase) after fishing. When data from all eight tracts were combined, there was no significant change to Laminarian kelp following fishing.

3.9.3 PHYTOPLANKTON

3.9.3.1 EXISTING CONDITIONS

The term phytoplankton refers to members of the planktonic community which make their own food via photosynthesis. Virtually all marine phytoplankters in Washington are microscopic algae, and they form the basis of the marine food chain. Phytoplankton is fed on by zooplankton (planktonic animals), which are in turn food for fish, and also by benthic filter feeders (such as oysters, clams, and mussels). Phytoplankton is found in significant quantities (more than 0.2 mg chlorophyll a/m^3) in nearly all parts of Puget Sound and at all times of year. Phytoplankton blooms, however, occur mostly during the spring and summer. The rate of phytoplankton production in Puget Sound ranks among the highest in all saltwater environments (Strickland 1983).

3.9.3.2 IMPACT ASSESSMENT

Changes in geoduck biomass due to commercial harvest may affect phytoplankton levels because of the filter-feeding activities of geoducks. Like other bivalve suspension-feeders such as oysters and mussels, geoducks are capable of filtering large volumes of water and extracting particles of high nutritional value. Microscopic examination of adult geoduck gut contents from Puget Sound suggests that geoducks feed exclusively on phytoplankton (Goodwin and Pease 1989).

A rough estimate of the impact of commercial geoduck harvest on phytoplankton levels may be calculated based on two factors: 1) The decline in total geoduck biomass expected from commercial harvest, and; 2) The degree to which geoducks, as benthic suspension-feeders, may affect phytoplankton levels.

As noted in Section 3.4, fishing is expected to eventually reduce the total commercial geoduck biomass by roughly 14-17% from the unfished, "virgin" level. No data exist on how geoducks may affect phytoplankton levels, but recent studies on other suspension-feeding bivalves (such as eastern oysters, *Crassostrea virginica*) may be used as a comparable substitute. These studies have demonstrated that oysters are extremely effective filter-feeders, and that changes in their abundance may, at least in certain situations, have significant effects on phytoplankton levels. Ulanowicz and Tuttle (1992) used an ecosystem model of Chesapeake Bay, where oyster biomass has declined 99% since the 1870s, to explore the consequences of changing oyster abundance on other ecosystem elements. Their model suggested that a 150% increase in the oyster stock might result in an 11.5% decrease in phytoplankton. Applying this ratio to geoduck stocks suggests that the eventual expected 14-17% decrease in total geoduck biomass might result in a 1% increase in phytoplankton.

Even phytoplankton increases of this small scale are unlikely in Washington, given the differences between commercial geoduck stocks and oysters. Oyster biomass is concentrated in the shallow euphotic zone where phytoplankton production is highest. Thus, oysters and other suspension-feeders living in intertidal and shallow subtidal depths are generally able to consume a much greater portion of phytoplankton than those living at depth (Gerritsen *et al.* 1994). Therefore, the geoduck stocks which occur shallower than -18 ft MLLW and are not harvested commercially are best situated to consume phytoplankton. In addition, geoducks are only one of many grazers on phytoplankton, and it is likely that these other grazers (including zooplankton, horse clams, oysters, hardshell clams, and mussels) would be able to consume increases (greater than 1%) in phytoplankton produced by a reduction in geoduck stocks. For example, zooplankton became a major consumer of phytoplankton in Chesapeake Bay, a position once filled by oysters before their 100-fold decline (Newell 1988).

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4.0 ASSESSMENT OF IMPACTS TO THE BUILT ENVIRONMENT

Because geoduck harvest is conducted offshore, and is a temporary activity, impacts to the human or the built environment are limited. Those shoreline areas of the built environment which receive some impact, or where concern has been expressed during the scoping process, are described below.

4.1 NOISE

4.1.1 Existing Conditions

All commercial geoduck tracts occur along sparse to moderately developed shorelines. Areas with high residential housing density or commercial development are usually precluded from harvest by the resulting low water quality.

Background noise in these areas is relatively low, consistent with their residential nature. Noise studies conducted by DNR in similar areas showed that average daytime noise levels ranged from 42 to 50 dBA, although increases of 50 to 75 dBA were frequent as the result of vehicular traffic, aircraft, boats, etc. (Vining 1972). In addition, ambient noise levels were quickly affected by increased wind velocity and wave action on the shore. Noise levels of 30 to 40 dBA were recorded during the late evening and early morning. Washington Department of Ecology (DOE) regulations (WAC 173-60-040) permit activities of up to 55 dBA continuous (with occasional higher peaks) next to residential areas.

4.1.2 Impact Assessment

The geoduck harvest operation involves three primary sources of noise; the vessel engine, pump or compressor engines powering the water-jets and life support system (auxiliary equipment), and the two-way diver communication system. The auxiliary equipment and the communication system operate continuously during harvest and is the major source of the noise. Engine noise, similar to other watercraft, occurs only when the boat is entering or leaving the tract or repositioning. The boat remains at anchor in one location when harvesting occurs. Some boats are equipped with air pumps and/or the water pumps that are powered by the main engine.

Auxiliary equipment is usually placed in the boat's hold to provide more working space on deck. If located on deck, it is most often shielded. This equipment is required to be muffled to meet state noise standards and allow for radio communication with the divers. On harvest vessels, the sound of the divers breathing on the surface to water communication radio may be the loudest noise detectable.

Noise levels resulting from various geoduck harvest boats were determined by on-site monitoring. Maximum noise levels of 58 to 61 dBA were measured 100 ft from "Boat A" which had the auxiliary equipment housed on deck. In contrast, another geoduck "Boat B" with equipment in the hold produced maximum noise levels of 53 to 55 dBA measured about 100 ft from the boat. Since that study, vessel noise has generally been reduced as older boats have been replaced, and the need for diver communication has necessitated less onboard noise.

With these data, it is possible to predict the noise levels reaching the adjacent shorelines. Farther than 100 ft from a boat, noise levels will decline 3 to 6 dBA each time the distance doubles. Over semi-turbulent water, the reduction will be about 4.5 dBA. The predicted noise levels at various distances from the boat are shown below. State law (RCW 75.24.100) prohibits harvest within 200 yards of shore.

Table 3. Predicted Harvest Noise Levels

Distance (ft)	Noise Level (dBA)	
	"Boat A" Equipment on deck	"Boat B" Equipment below deck
100	58.0 - 61.0	53.0 - 55.0
200	53.5 - 56.5	48.5 - 51.5
400	49.0 - 52.0	44.0 - 47.0
600 (200 yards)	46.7 - 49.7	42.7 - 44.7
800	44.5 - 47.5	39.5 - 42.5
1600	40.0 - 43.0	35.0 - 38.0

No studies have been conducted of the noise generated in the water as the result of geoduck harvest. WDFW divers report that the only noises heard while using the water-jet harvest gear are the sounds of the boat's propeller while the boat is maneuvering, the bubbles from the divers when they exhale, and the sound of the nozzle when it strikes a rock or other hard object. Except for the diver's breathing, these sounds are occasional and intermittent.

4.1.3 Significance of Noise Impacts

When "Boat A" was not operating, the background noise level on the shoreline was measured and found to be in the range of 39 to 41 dBA. The difference between background and operating noise levels with the boat 200 yards offshore was 5 to 10 dBA. This noise level would be noticeable, particularly if the boat operated in one location for an extended period of time. In comparison, boat "B" with a noise output of 0 to 5 dBA over background levels would be much less noticeable and, at times, not even discernable. Most boats currently participating in the fishery are similar to "Boat B".

Noise increases exceeding 5 dBA above background levels may cause complaints, particularly if the noise interferes with sleep or communication. Increased noise 10 dBA above background levels are likely to cause complaints. Noise from harvest operations has only rarely resulted in complaints from shoreline residents. The geoduck boats normally operate well below the DOE noise standard (55 dBA). Otherwise, harvest restrictions will be will be maintained to meet State and local noise restrictions.

Noise impacts have been minimized by restricting State harvest to daylight hours (Monday through Friday) and by prohibiting harvest within 200 yards offshore. During all State harvest operations DNR enforcement crews monitor sound levels with hand-held noise meters. Vessels found to exceed 50 dBA (measured from 600 ft, which is the DNR harvest agreement level) are suspended from harvest until the vessel is brought into compliance. It is unlikely noise would adversely affect fish or other organisms in the area. Special noise restrictions will be developed for specific wildlife and habitat protection requirements.

4.2 LAND AND SHORELINE USE

Geoduck harvest does not interfere with or preclude other shoreline or upland use. Because of the presence of commercially harvestable geoducks, however, DNR, WDFW, and the Tribes discourage aquatic development which would degrade water quality. DNR and WDFW will also encourage and assist other State and local agencies to protect water quality from upland development. This may limit some activities which would otherwise pollute the water.

Prior to harvest, DNR and WDFW may consult with agencies with interest or jurisdiction in the harvest area. These include: Indian Tribes, U.S. Navy, Washington State Parks and Recreation Commission, local governments, etc.

DNR and WDFW will work with these groups to resolve any conflicts of interests. Concern has been expressed by the Navy about conflicts between naval operations and harvest in Hood Canal near the Bangor Submarine Base and elsewhere. At times, naval operations may necessitate restrictions on harvest. DNR and WDFW will work with the Navy to resolve any conflicts, prior to auction of geoduck fishing rights.

4.2.1 Land Use Plans

The commercial geoduck harvest tracts are identified and allocated for harvest by DNR, WDFW, and the Tribes (see the State/Tribal regional management Agreements). Conflicting uses of these tracts will be discouraged by DNR, WDFW and the Tribes to ensure their future availability for harvest.

These tracts occupy areas subject to the Shoreline Management Act (SMA). Under the SMA, the local county or city adopts a Shoreline Master Program for the orderly and controlled development of the shorelines (defined as all navigable waters and shores up to 200 ft inland of mean high water). The SMA is intended to control construction-type activities, not the harvest of natural resources. However, DNR and WDFW work with the local governments prior to and during harvest to address local concerns.

4.2.2 Aesthetics

Geoduck harvest occurs underwater. The only aspect of harvest visible from the surface is the vessel anchored, at least 200 yards, offshore. Although the significance of aesthetic impacts can only be addressed by the viewer, DNR and WDFW believe geoduck harvest does not present a significant aesthetic impact.

4.2.3 Recreation

The presence of a geoduck vessel with divers in the water means other vessels must use caution. This may require a vessel to change course, but no more than is necessary to avoid other sport or commercial divers or boats. "Rules of the Road" (Federal Boat Safety Act) declare that an anchored vessel must be avoided by other vessels. Commercial geoduck boats must display diver flags to alert other boat traffic of ongoing harvest operations. Geoduck harvest does not result in any significant navigational obstruction. Most harvest is nearshore and out of major traffic routes.

Some commercial harvest will occur in areas which are also popular sport fishing sites. Fishing over divers could cause serious injury to divers. This has not been a problem in the past, even in areas of major, concentrated fishing. Most sport fishing is conducted seaward of the -70 ft contour. Where necessary, DNR and WDFW have worked with local fishing groups to resolve conflicts. Restrictions on harvest hours and days of fishing reduce conflicts between geoduck operations and sport fishing.

4.3 TRANSPORTATION

Some geoduck tracts lie in or near commercial navigating channels. Few conflicts occur due to the wide dispersal of harvest vessels. The depth limitation of the harvest area (-18' MLLW - 70' uncorrected) also keeps harvest nearshore where recreational boating activities occur. Conflicts may occur near some areas, such as entrances to harbors and ferry landings. In these cases, DNR and WDFW prevent conflicts by consulting with the appropriate authority prior to harvest to determine appropriate harvest restrictions.

Geoduck harvesters unload their boats at public or private boat ramps, docks or marinas, depending on the proximity of off-load areas to harvest tracts. Problems can occur when unloading prevents use of these facilities by others. As part of the harvest agreement conditions, DNR approves off-load locations. DNR considers the proximity to harvest tracts, the State's ability to monitor harvest, and the impact to local residents. If particular off-load sites are shown to be inappropriate, they will not be approved or approved only with restrictions. Off-load sites are frequently monitored by DNR enforcement personnel and WDFW Patrol Officers. When conflicts arise during use, the geoduck off-load operations are modified to allow continued public use or the off-load operation is relocated.

4.4 PUBLIC SERVICES

Geoduck harvest has no significant financial impact on State services. Management and enforcement activities of DNR and WDFW are paid from geoduck harvest revenues. No general fund monies are used to manage the geoduck program, therefore the Program does not detract funding from other State programs.

Harvested geoduck are often landed and loaded into trucks at public marinas and dock facilities. These activities have created inconveniences for other (primarily recreational) uses of these facilities. Landing geoduck could cause delays and inconvenience for others who use the facilities, particularly when launching and retrieving boats. However, harvest vessels do have a right to use public facilities. There have also been complaints of inappropriate behavior by State and Tribal harvesters. Some marina operators have restricted or banned State and Tribal harvest boats from using their facilities.

Local public emergency services would be called upon to respond to an emergency situation created by the unlikely possibility of a dive accident, boat accident or other emergencies related to commercial geoduck harvest operations.

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6.0 GLOSSARY

Commercial biomass	The estimated biomass on those tracts that are potentially available to be commercially harvested at some prescribed rate.
Commercial geoduck	A geoduck in a commercial tract.
Commercial tract	A geoduck tract in which geoduck densities are considered high enough to support a fishery and which has no other drawbacks to fishing (e.g., pollution, narrow width, land-use conflicts, poor quality geoducks, difficult digging conditions, etc.) The commercial status of tracts is listed annually in the Geoduck Atlas.
dBA (decibel)	A unit for measuring the relative loudness of sounds equal approximately to the smallest degree of difference of loudness ordinarily detectable by the human ear the range of which includes about 130 decibels on a scale beginning with 1 for the faintest audible sound.
DOH	Washington State Department of Health
DNR	Washington State Department of Natural Resources
DOE	Washington State Department of Ecology
EIS	Environmental Impact Statement
ESA	Endangered Species Act.
Epifauna	Benthic animals which live on the surface of the substrate.
Escalator harvester	A hydraulic clam dredge which delivers the harvested shellfish to the boat with a continuously moving belt.
Fines	Silt and clay less than 63 microns in size.
Harvestable geoducks	Geoducks of a size in which the siphon or "show" is likely to be seen by a diver. Generally geoducks with a total weight > 300 grams and >5 yrs old. Note that "harvestable geoduck is not necessarily a "commercial" geoduck.

Geoduck Atlas	An annual WDFW publication listing all known geoduck tracts in Washington, along with maps of their location, their commercial status, estimates of geoduck biomass, and other summary information.
Geoduck tract	A subtidal area with defined boundaries which contains geoducks.
Harvest rate	The fraction of surveyed biomass at the beginning of a year which is removed by fishing during the year, often expressed as a percentage.
Harvestable Surplus	Term used to describe the assessed commercial fisheries stock available for harvest.
Infauna	Benthic animals which live in the substrate.
Major geoduck tract	A geoduck tract of more than five acres.
MHW	Mean high water; the average of all high tides. This varies from 7.1 ft at Neah Bay to 13.5 ft at Olympia.
Micron	.001 millimeter
MLLW	Mean Lower Low Water; the arithmetic mean of the lower low water heights of a mixed tide observed over a specific 19-year Metonic cycle at a specific tidal reference station used to correct ambient depths (from diver depth gauges) to a standard tidal datum.
MPN	Most Probable Number, a common measure of fecal coliform bacteria levels.
NMFS	National Marine Fisheries Service.
PSI	Pounds per square inch.
RCW	Revised Code of Washington; laws passed by the State legislature.
Quota	See definition for TAC.
Recovery time	Estimated time for a commercially fished geoduck tract to return to the prefishing density (and biomass) level.
Recruitment	The entry of new animals into the harvestable population.

Sediment size distribution	1. Coarse sand greater than 500 microns. 2. Fine-medium sand 63 to 500 microns. 3. Silt and clay less than 63 microns.
SEPA	State Environmental Policy Act of 1971 (RCW 43.21).
SMA	Shoreline Management Act of 1971 (RCW 90.58).
TAC	Total Allowable Catch. The number or weight of geoducks which may be harvested in a specific unit of time. As used here, the TAC is the product
TSS	Total suspended solids.
WAC	Washington Administrative Code; departmental regulations.
WDFW	Washington State Department of Fish and Wildlife.

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7.0 Conversion Table

Metric to U.S. Customary

	Multiply By	***To Obtain***
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
Meters	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.3527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
Celsius degrees (C)	1.8 (C) +32	Fahrenheit degrees

U.S. Customary to Metric

	Multiply By	***To Obtain***
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
ounces (oz)	28350.0	milligrams
ounces	28.35	grams
pounds (lb)	0.4536	kilograms
pounds	0.00045	metric tons
Fahrenheit degrees (F)	0.5556(F -32)	Celsius degrees

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DISTRIBUTION LIST:
THE COMMERCIAL GEODUCK FISHERY DRAFT SEIS

CITIES

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Mr. Gary Robinson
PO Box 547
Anacortes, Washington 98221

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Planning and Community Development
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Bainbridge Island, WA 98110- 1812

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Terry Galvin, Interim Planning Director
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Blaine, WA 98231

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Bremerton, WA 98377

City of Edmonds
250 5th Ave N
Edmonds WA 98020-3146

City of Everett
2930 Wetmore Ave
Everett WA 98201-4044

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City of Gig Harbor
Planning Commission
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Gig Harbor, Washington 98335

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Building & Planning
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City of Port Townsend
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Waterman & Katz Bldg.
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City of Sequim
152 W Cedar Street
Sequim WA 98382-3317

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310 West Cota Street
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1715 Lafayette
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Port Angeles Washington 98362

Island County Planning Department
Island County Courthouse
6th & Main St
Coupeville WA 98239

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Mason County Planning Department
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Shelton WA 98584

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Tacoma, WA 98409

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Mr. Skip Ferrucci
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San Juan County Planning Department
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Friday Harbor WA 98250-8070

San Juan County Parks
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350 Court Street
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Whatcom County Planning and Development Services
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Thurston County Department of Parks and Recreation
Mr. Micheal Welter
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1st & Commercial Ave.
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Bellingham WA 98225

Port of Bremerton
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Port Orchard, WA 98367

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P.O. Box 538
Everett, WA 98206

Port of Olympia
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Olympia, WA 98501

Port of Port Angeles
338 W 1st Street
Port Angeles, WA 98362

Port of Port Townsend
2601 Wash St
Port Townsend WA 98368

Port of Seattle
P.O. Box 1209
Seattle, WA 98111

Port of Skagit County
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Burlington WA 98233-5306

Port of Tacoma
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Center for Marine Conservation
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San Francisco, California 94104

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Seattle, WA 98117-5728

Friends of the San Juans
P.O. Box 1344
Friday Harbor, WA 98250

The Mountaineers' Conservation Division
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Olympic Environmental Council
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Port Townsend WA 98368-0062

People for Puget Sound
1402 Third Ave., Suite 1200
Seattle WA 98101

Protect The Peninsula's Future
P.O. Box 1677
Sequim, WA 98382

Puget Soundkeeper Alliance
1415 W. Dravus
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Puget Sound Water Quality Action Team
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1-800-54-SOUND

Washington Environmental Council
615 Second Ave, Suite 380
Seattle, WA 98104

Washington Foundation for the Environment
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Seattle, WA 98111

The Wilderness Society
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WA State Department of Transportation
Environmental Affairs Office
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Nelson Alaska Seaproducks
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Seabed Harvesting
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Sea World Fisheries
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Bow WA 98232

Pacific Coast Oyster Grower's Association
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Olympia, WA 98501

Washington Association for Fisheries
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Shoreline, WA 98177

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Anacortes American
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901 Sixth St., Anacortes, WA 98221

Bainbridge Island Review
221 Winslow Way W.
Bainbridge WA 98110

The Bellingham Herald
1155 N. State Street
Bellingham WA 98225

The Bremerton Sun (Kitsap County)
545 Fifth Street
Bremerton WA 98310

The Herald (Snohomish County)
Grand and California Streets
P.O. Box 930
Everett WA 98206

Journal of the San Juan Islands
P.O. Box 519
Friday Harbor, WA 98250

The Morning News Tribune
1950 S. State Street
P.O. Box 11000
Tacoma WA 98411

The Mukilteo Beacon
P. O. Box 229
Mukilteo, WA 98275

The Olympian
Federated Publications Inc.
P.O. Box 407
Olympia WA 98507

The Peninsula Daily News (covers the entire Olympic Peninsula)
305 W. First Street
Port Angeles WA 98362

The Peninsula Gateway
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Gig Harbor, WA 98335

Seattle Post-Intelligencer
101 Elliott Avenue W.
Seattle WA 98119

Sequim Gazette
PO Box 1750
147 W. Washington
Sequim, WA 98382

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227 W. Cota
Shelton, WA 98584 PO Box 430

Port Orchard Independent
2950 Mile Hill Drive
Port Orchard, WA 98366

The Port Townsend/Jefferson County Leader
P.O. Box 552
226 Adams St.
Port Townsend, WA 98368

The Seattle Times
Fairview Avenue N. and John Street
P.O. Box 70
Seattle WA 98111

Skagit Valley Herald
1000 E. College Way
P.O. Box 578
Mt. Vernon WA 98273

South Whidbey Record
222 Anthes
Langley, WA 98277

OTHER MEDIA

Seattle Daily Journal of Commerce
83 Columbia Street
Seattle, WA 98104

The Fisherman's News
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Joe Lambert	Secretary	Hood Canal Environmental Council	10458 Seabeck Hwy NW	Seabeck, WA 98380
Tom Corboy			3921 Forest Beach Dr NW	Gig Harbor, WA 98335
John Ahl			24565 Johnson Rd NW	Poulsbo, WA 98370
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Mike O'Connor			2818 Horsehead Bay Dr NW	Gig Harbor, WA 98335
Bob Elsner		Port of Anacortes	PO Box 297	Anacortes, WA 98221
David Winfrey		Puyallup Tribe	2002 E 28th St	Tacoma, WA 98404

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				98404
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Sarrissa Dainel			801 11th St	Bremerton, WA 98337
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Derrick Toba		Tulalip Fisheries Dept	7615 Toten Beach Rd	Marysville, WA 98271
Mark Haupt			1272 NW Comyn Rd	Poulsbo, WA 98370
Don Flora			12877 Manzanita Rd	Bainbridge Island, WA 98110
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Rich Childers	Shellfish Biologist	Jamestown S'Klallam Tribe	1033 Oly Blyn Hwy	Sequim, WA 98382
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David Mascarenas			517 Laurel Dr.	Everett, WA 98201-4130
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