Seafood Watch
Seafood Report

MONTEREY BAY AQUARIUM®

Mirugai
Pacific Geoduck
Panopea abrupta

Final Report
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Casson Trenor
Independent Consultant

&

Stephanie Danner
Fisheries Research Analyst
Monterey Bay Aquarium

About Seafood Watch® and the Seafood Reports

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid". The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch®'s sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer

Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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I. Executive Summary

The Pacific geoduck *(Panopea abrupta)* is a large, burrowing clam native to the Pacific Northwest of the United States and to coastal areas of British Columbia with additional populations existing as far south as Baja California. The market for geoduck has generally been based in Asia, but the expansion of the American sushi industry has spurred a rise in domestic demand for geoduck (known as *mirugai*). Geoduck is moderately resilient to fishing pressure. The species exhibits high fecundity and a moderate age at sexual maturity, but has a presumably low intrinsic rate of increase, a long life span, and is easy to harvest. The two primary wild-caught geoduck fisheries occur in Washington and British Columbia. Neither of these fisheries is overfished nor are they undergoing overfishing; however, in British Columbia, only moderately uncertain fishery-dependent data are available. As such, the stock status of Washington geoduck is healthy, whereas the status of the British Columbia stock is a moderate conservation concern. Geoduck is generally harvested with hand-held water jets (stingers), which are thought to cause minimal damage to impacted areas, especially because geoducks inhabit sandy, dynamic areas of the benthos. High-grading of geoducks occurs in the Washington and British Columbia fisheries, but the extent of this practice is unknown. Horse clams (*Tresus spp.*) are commonly found in commercial geoduck tracts. When they are harvested in the commercial geoduck fisheries, they are retained, accounted for and well-managed. As such, Seafood Watch® deems bycatch in Washington and British Columbia to be a low conservation concern. Both Washington and British Columbia have robust stock assessments, management measures to rebound stocks from previously overfished conditions, and strict monitoring and enforcement; therefore, management is deemed to be highly effective in both fisheries. The combination of individual criteria results in an overall recommendation of "Best Choice" for both wild-caught Washington and British Columbia geoduck.

About the Overall Capture Fisheries Seafood Recommendation:

- A seafood product is ranked **Best Choice** if three or more criteria are of Low Conservation Concern (green) and the remaining criteria are not of High or Critical Conservation Concern.
- A seafood product is ranked **Good Alternative** if the five criteria "average" to yellow (Moderate Conservation Concern) OR if the "Status of Stocks" and "Management Effectiveness" criteria are both of Moderate Conservation Concern.
- A seafood product is ranked **Avoid** if two or more criteria are of High Conservation Concern (red) OR if one or more criteria are of Critical Conservation Concern (black) in the table above.

Table of Sustainability Ranks: Wild-caught geoduck

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Inherent Vulnerability		√		
Status of Stocks	√ **Washington**	√ **British Columbia**		
Nature of Bycatch	√			
Habitat & Ecosystem Effects	√			
Management Effectiveness	√			

Overall Seafood Recommendation:

Washington and British Columbia:

Best Choice ■ Good Alternative ■ Avoid ■

II. Introduction

The Pacific geoduck, *Panopea abrupta* (also known as *Panopea generosa),* is the largest burrowing clam in the world. In sushi restaurants, geoduck is known as *mirugai*, a product that is growing in popularity across the United States (US). It is usually available as *nigiri* (raw or cooked fish served atop a small serving of seasoned rice) sushi or as *sashimi* (slices of raw or cooked fish served alone) at sushi establishments, but it is generally listed as "giant clam," "jumbo clam," or "long-necked clam" on menus. Pictures of the animal itself are virtually non-existent at these restaurants, thus it is doubtful that patrons are aware that they are in fact eating geoduck.

The commercial geoduck fishery began in Washington in 1970 and in British Columbia in 1976 following the discovery of extensive subtidal populations. Market demand was initially limited, but grew substantially with the establishment of a major new market in Japan. By 1980, US geoduck harvest had increased as the demand in Asian markets expanded to include whole live and processed geoducks (WDNR 2001a).

Although the majority of the market for geoduck has historically been in Asia, domestic demand for geoduck is on the rise (Tom Hayes, Taylor Shellfish Farms, pers. comm., October 2006). The two primary wild-caught geoduck fisheries occur in Washington and British Columbia. Alaska also harvests geoduck for domestic consumption and export. The Alaskan market share has grown in the past several years, but remains much smaller than those of Washington and British Columbia. Due to logistical constraints, Alaskan harvesters have a difficult time supplying the live geoduck market and often export the product as prepared siphon meat; this decreases the overall value of the geoduck. Due to its relatively small size and the preference of the US sushi market for live product, the Alaskan geoduck fishery is not evaluated in this report.

Harvest Methods

Geoduck is generally harvested using a small hydraulic pump attached to a length of PVC or metal pipe. This device, known as a stinger, is used to liquefy the sand around the geoduck. When the geoduck's surrounding habitat has reached a quicksand-like consistency, the harvester simply reaches down and pulls the geoduck free. Both harvesters of wild geoduck and geoduck farmers use this approach, as it is precise and inexpensive.

Basic Biology

The Pacific geoduck is native to the Pacific Coast of North America from Alaska to Baja California and coastal Japan, but is most abundant in Puget Sound of Washington and British Columbia (Figure 1). It generally weighs between one and three pounds (0.5 – 1.5 kg) when fully mature, with a maximum recorded weight of 7.16 pounds (Goodwin and Pease 1987).

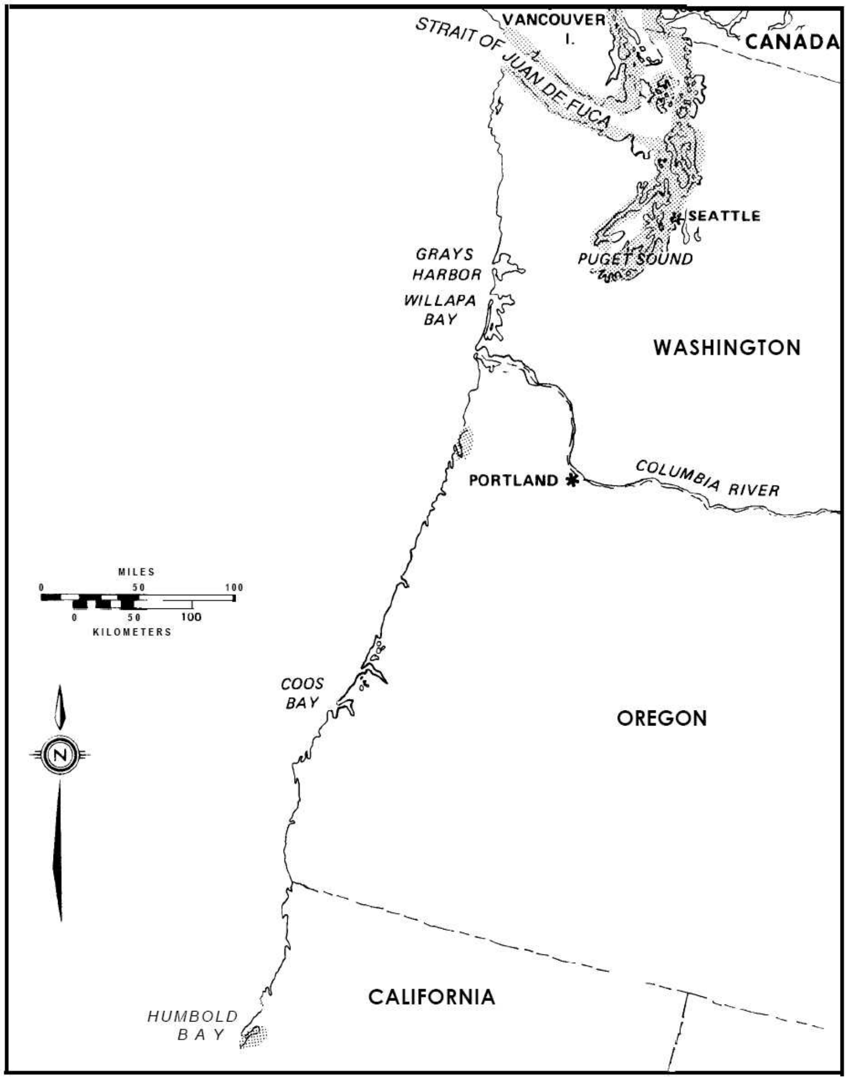


Figure 1. Geoduck distribution in the US (Goodwin and Pease 1989).

The geoduck is an exceptionally long-lived animal, with a potential lifespan of well over one hundred years (Goodwin and Pease 1989). The geoduck's longevity is a result of its hermitage within the substrate of the inter- or sub-tidal ocean floor. Such an existence leads to very little outside influence interfering with the welfare of the geoduck; under normal conditions, the only exposed part of the geoduck is the siphon, a muscular tube through which the geoduck feeds and expels its waste. Moreover, the geoduck has many natural predators early in life, while adult geoducks find refuge in the substrate from most large predators; however, sea otters have been known to unearth shallowly-buried adults, and the sea stars *Pisaster brevispinus* and *Pycnopodia helianthoides* have been observed consuming juvenile and adult geoduck clams (Bradbury 1989; Straus et al. 2008). Dogfish (*Cirrhigaleus spp.* and *Squalus spp.*), cabezon (*Scorpaenichthys marmoratus*), and halibut (*Hippoglossus stenolepis*) have been found with pieces of geoduck siphon in their guts, the result of behavior known as "siphon grazing" (Goodwin 1987; Goodwin and Pease 1989). Geoducks in inter-tidal areas are also preyed upon by crabs and moon snails (Bradbury 1989).

Upon reaching sexual maturity, geoducks become prolific and frequent spawners, spawning from March through July. Female ovaries contain millions of eggs, but only release 1-2 million eggs during each spawning event (Goodwin and Pease 1989).

There are seven distinct stages to the life history of the geoduck, as is the case with most pelecypod (bivalve) species. Fertilization occurs in the water as free-floating eggs and sperm are released by mature geoducks. Fertilized eggs are spheres about 80 µm in diameter and are slightly negatively buoyant; only a very slight current is necessary to keep the egg suspended in the water (Goodwin and Pease 1989).

The embryonic stage sees cell division of the original zygote which eventually forms into a top-shaped larval trochophore (Figure 2). This larva is now mobile, propelling itself through the water by using cilia. Within 48 hours, this phase is followed by the development of a straight-hinged shell, as well as a swimming and feeding organ known as the velum. At this point, the larvae is known as prodissconch I, with a shell approximately 110 pm long. At 165 pm, umbones – rounded ridges on the shell hinges – appear and the larvae enters the prodissconch II stage (Goodwin and Pease 1989).

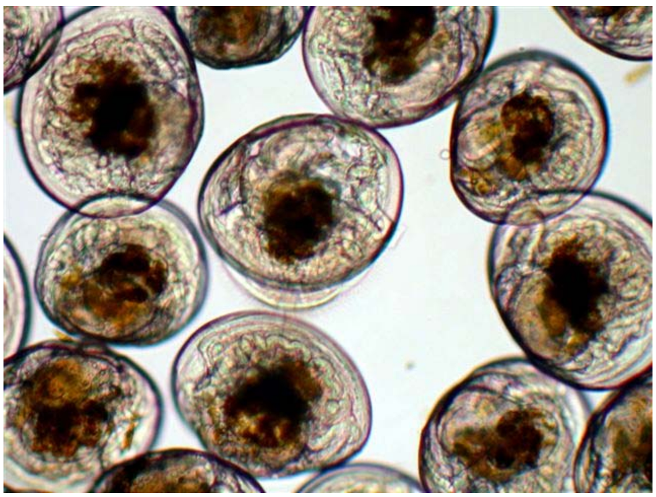


Figure 2. Geoduck larvae, pre-metamorphosis (Taylor Shellfish Farms).

At this point, the geoduck enters what is known as the "metamorphosis," signaling the end of the clam's free-swimming life. External factors may affect or delay the onset of metamorphosis, but under typical conditions, metamorphosis commences between the ages of 16 and 35 days (Cooper 1989). For 2-4 weeks, geoducks pass through the dissoconch stage (Figure 3). This part of the geoduck's life sees the clam attain a shell length of 350-400 µm. Moreover, it loses the velum and is no longer able to swim. Spines begin to develop on the shell edge, and a foot appears that allows the geoduck to crawl. The foot is also used in the "pedal-palp" feeding process (Goodwin and Pease 1989).

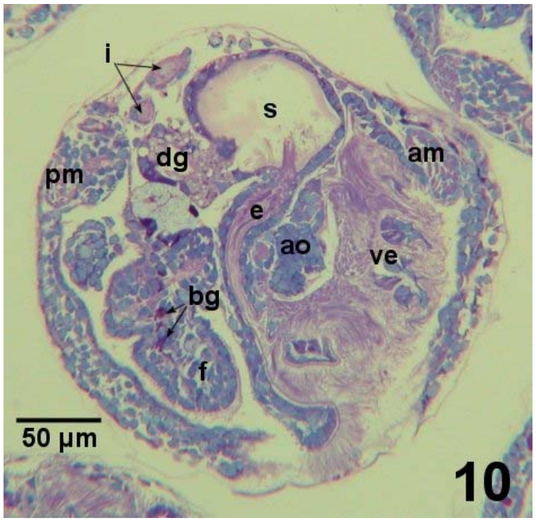


Figure 3. Sagittal section through a geoduck clam larvae on day 17 and at about 305 µm in shell length. The foot (**f**) with developing byssal glands (**bg**) is evident and the retracted velum (**ve**) is taking less space within the larva in comparison to younger larvae. As in younger larvae, the digestive system (esophagus (**e**), stomach (**s**), digestive gland (**dg**) and intestine (**i**)) predominate the internal organs. However, the anterior (**am**) and posterior (**pm**) adductor muscles have developed and the apical organ (**ao**) is beginning to differentiate (Bower and Blackbourn 2003).

Once a geoduck larvae has developed a foot, it is known as a postlarvae. At this stage, the organism is able to crawl along the substrate using its new appendage. Additionally, a postlarval geoduck is able to produce byssal threads, which serve to attach the clam to the seabed. The postlarvae will begin to burrow into the substrate at this point, but only to a very shallow depth, most likely because of the lack of a developed siphon. As the clam burrows into the sand, it generates numerous byssal threads to secure it in place (Goodwin and Pease 1989).

At 1.5-2.0 mm, the geoduck has taken on the general morphology of an adult clam. The siphon is developed enough to allow the clam to begin its final descent into the substrate. A geoduck this size is known as a juvenile and will remain so until reaching sexual maturity, generally at a shell length between 64 and 75 mm (Figure 4) (Goodwin and Pease 1989; Campbell and Ming 2003; Vadopalas unpub. data). The geoduck loses its digging proficiency as it ages; the speed at which the animal is able to fully cover itself decreases as its shell increases in size. The depth to which the animal digs into the substrate is directly related to the lengths of the shell and siphon (Goodwin et al. 1985).

Figure 4. Juvenile geoducks (DNR 2006).

A sexually mature geoduck is considered to be an adult. Adult geoducks are sedentary organisms with poor digging capabilities. They are major contributors to their local benthic communities and are often found in high densities in their native habitat; in Washington's Puget Sound region, the average abundance in non-harvested areas is 1.7 clams per square meter with an average per clam whole wet weight of 872 g (Goodwin and Pease 1987).

Scope of the analysis and the ensuing recommendation:
The following analysis encompasses the wild-caught geoduck fisheries in Washington and British Columbia. These fisheries comprise the majority of US landings (77%) and imports (71%). (See the Import and Export Sources and Statistics section for further explanation.)

Availability of Science

Data concerning fisheries management and quotas are collected by the respective oversight agency or agencies of the given fishery: the Washington Department of Fish and Wildlife (WDFW), the Washington Department of Natural Resources (WDNR), and the Canadian Department of Fisheries and Oceans (DFO). Information on geoduck life history is taken in large part from the numerous in-depth, peer reviewed journal articles.

Market Availability

Common and market names:
Pacific geoduck (pronounced "goo-ey-duck") is generally referred to simply as geoduck or geoduck clam. It also has been called the Methuselah's clam (Orensanz 2004), but this name is rarely used. In sushi restaurants, geoduck is known as *mirugai* and is often translated as "giant clam," "long-necked clam," "jumbo clam," or "horseneck clam."

Seasonal availability:
Geoduck is available year-round.

Product forms:
Geoduck is generally sold live, but is also available as *mirugai sashimi* – raw geoduck cut into thin slices – in Japanese restaurants. Geoduck is often available in upscale Chinese restaurants and is prepared in various ways. Frozen or dried siphon meat is also available in small quantities (Hayes, pers. comm., October 2006)

Import and export sources and statistics:
Geoduck import and export data is provided by the National Marine Fisheries Service (NMFS 2006a; NMFS 2006b). In 2006 in the US, geoduck was landed in Washington (77%) and Alaska (23%) (Figure 5). Approximately 70 mt of geoduck (68 mt fresh/live and 2 mt frozen/dried/salted/brine) were imported into the US in 2006, coming from Canada (71%) and New Zealand (29%) (Figure 6). In 2006, 2,102 mt of geoduck were exported (2,008 mt live/fresh and 94 mt frozen/dried/salted/brine), primarily to Canada (78%) and Asia (21%) (NMFS 2006b).

According to the NMFS data, the total amount of US export of geoduck is greater than the total amount landed and imported. This is because a substantial amount of the geoduck that is exported is from aquaculture (farmed geoduck), and data on farmed geoduck are not included in the NMFS landings and trade databases. Therefore, NMFS does not have data on the percentage of wild geoduck consumed in the US from each country of origin (A. Lowther, NMFS, pers. comm., August 26, 2008).

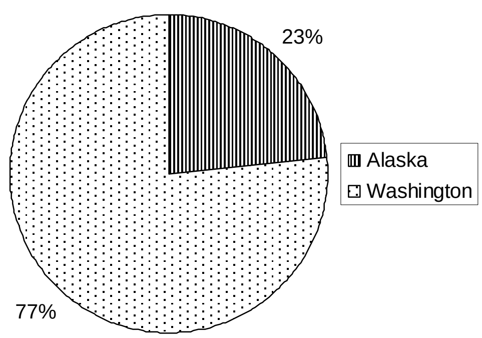


Figure 5. US geoduck landings in 2006 (data from NFMS 2006a).

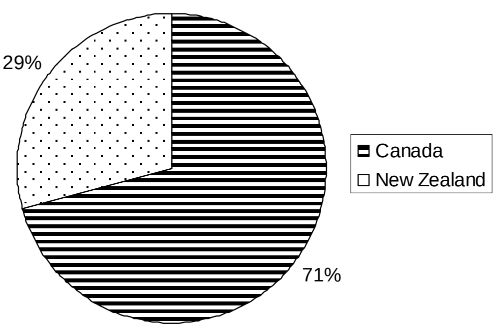


Figure 6. Geoduck imports into the US in 2006 (data from NMFS 2006b).

III. Analysis of Seafood Watch® Sustainability Criteria for Wild-caught Species

Criterion 1: Inherent Vulnerability to Fishing Pressure

Though the intrinsic rate of increase ('r') for *Panopea abrupta* is unknown, it is presumed to be low (Bradbury et al. 2000). When geoducks from different areas and habitats are compared, the von Bertalanffy growth coefficient 'k' averages to 0.16, but k has been shown to vary by as much as 0.12 (Hoffmann 2000). Age at sexual maturity (~75 mm in length) varies from 2-8 years of age (Goodwin and Pease 1989; Bradbury et al. 2000). The maximum age reported for geoducks also varies, ranging from 100-146 years. Female geoducks have large ovaries that contain millions of eggs; however, they only release 1 to 2 million eggs per spawning event (Goodwin and Pease 1989).

P. abrupta range from Alaska to Baja California and coastal Japan, but are most prevalent in Puget Sound and British Columbia (Goodwin and Pease 1989). Geoduck habitat is increasingly altered each year due to construction of piers, jetties, marinas, and pipelines (Goodwin and Pease 1989).

The sedentary nature of the geoduck and their easily identifiable siphon increases their vulnerability to capture by commercial harvesters. This may be buffered, however, by the large geoduck population (~75% in WA) that is not exploitable at diver depths (greater than 20 meters) (WDNR 2001b; DFO 2008a). In addition, geoduck harvesting is also prohibited during spawning periods and in marine protected areas. These factors allow for a reservoir of broodstock in deeper waters. In Washington, geoduck harvesting is also prohibited in marine parks, and there are unharvestable beds (due to rocky substrate, contamination, or other factors), which serve to protect a certain amount of breeding clams (WDNR 2001b). In British Columbia, a large numbers of geoducks are also located in marine protected areas and/or gravel-or shell-packed substrates, making it too difficult for harvesters to extract them (DFO 2008a).

Table 1. Life history characteristics of *Panopea abrupta*.

Intrinsic Rate of Increase ('r')	Age at Maturity	Growth Rate	Max Age	Max Size	Fecundity	Species Range	Special Behaviors	Sources
Unknown, but presumably low	2+ years	Variable	100-146 years, varying by region	200+ mm	As high as 5 billion eggs	Alaska south to Baja California, coastal Japan	Fully sedentary upon reaching maturity; easily identifiable siphon	Goodwin and Pease 1989; Bradbury et al. 2000; Hoffmann 2000; WDNR 2001b; DFO 2008a

Synthesis
P. abrupta benefits from its low age at sexual maturity and high fecundity. These qualities are tempered, however, by its presumably low intrinsic rate of increase and extremely long life span. As such, geoduck is considered moderately vulnerable to fishing pressure according to Seafood Watch criteria.

Inherent Vulnerability Rank:

Resilient | **Moderately Vulnerable** | Highly Vulnerable

Criterion 2: Status of Wild Stocks

The Puget Sound region of Washington and the southern coastal areas of British Columbia boast the largest geoduck populations in the world. Although these two populations are thought to be genetically homogenous, they are managed as separate stocks and under different regimes. Other outlying populations – most notably in the Queen Charlotte Islands of British Columbia – are thought to be genetically distinct from the central group (Dewey, pers. comm., October 2006).

Washington

In Washington, status of the geoduck stock is based on stock assessments and other fishery-dependent and independent data. The most recent publicly available stock assessment for geoduck in Washington dates from 2000; however, the geoduck stock assessment is an ongoing activity. The results are summarized every year and form the basis for setting annual quotas, but this information is generally not distributed to the public. Instead, it is shared with state and tribal fishery managers and incorporated into state and tribal annual harvest agreements.

According to the Washington Department of Fish and Wildlife (WDFW), the 2008 commercial biomass estimate of geoduck in Washington is 183,125,000 pounds (B.Sizemore, WDFW, pers. comm., May 8, 2008). Approximately three-quarters of the total geoduck biomass in Washington is located inshore and offshore of the harvest tracts and in other areas where commercial harvest cannot occur. This biomass is not considered when estimating the annual harvest rate; therefore, it acts as a refuge, which may contribute to the sustainability of the stocks (WDNR 2001b).

From 1975 until 1995, there was a long-term decreasing trend in geoduck landings; however, landings have been increasing since 1995 (Figure 6) (WDFW 2008a).

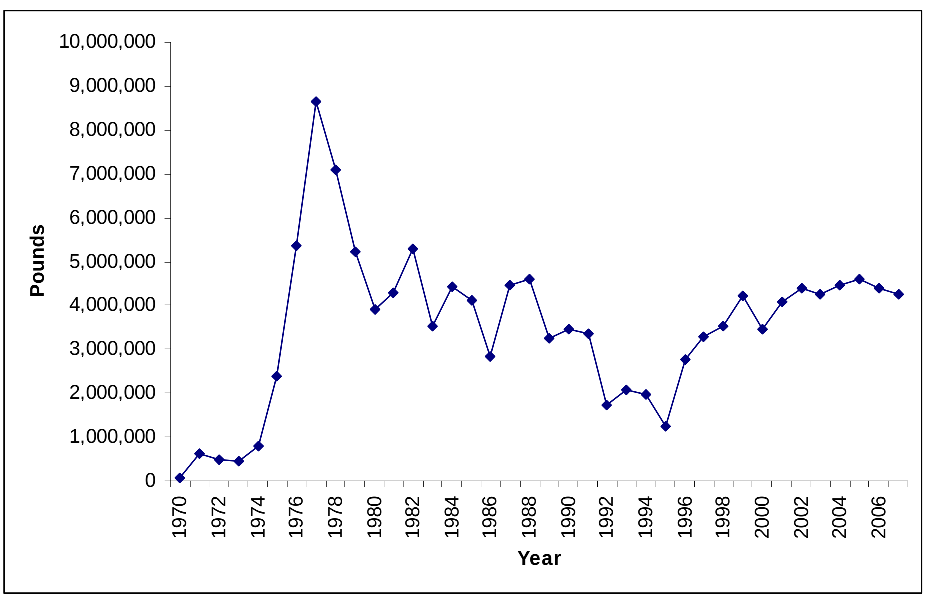


Figure 6. Historical commercial geoduck landings in Washington. Note: 2007 data are preliminary (WDFW 2008a).

When managing the fishery, Washington commercial geoduck managers do not use the standard biological reference points such as target or threshold fishing mortality rates and biomass levels, but rather focus on harvest rate strategies. Manager do this because geoducks have a low instantaneous natural mortality rate, so small differences in annual harvest rates can greatly affect stock size, especially if the harvest rate is set too high. Also, biomass estimation errors of individual geoduck beds are assumed to be reasonably unbiased and unlikely to result in substantial long-term degradation of the stock, whereas an error in setting the annual harvest rate will have substantial effects on stocks leading to underharvesting or overharvesting. As such, choosing a harvest strategy is the most critical aspect of geoduck management.

The Washington geoduck fishery uses a spawning biomass per recruit (SPR)-based strategy, which seeks to preserve some minimum level of spawning biomass while producing yields close to the maximum sustainable yield (MSY). Washington specifically uses an $F_{40\%}$ yield strategy for geoducks in all six management regions, which is achieved with an instantaneous fishing mortality rate (F) of 0.028. Clark (1991) showed that fishing at $F_{35\%}$ would achieve at least 75% of MSY for a wide range of stock-recruit relationships. $F_{35\%}$ has been adopted as a target rate for a number of fish stocks in Alaska and the U.S. Pacific coast. Clark (1993) later revised his recommendation to $F_{40\%}$ after considering variability in recruitment (Bradbury and Tagart 2000).

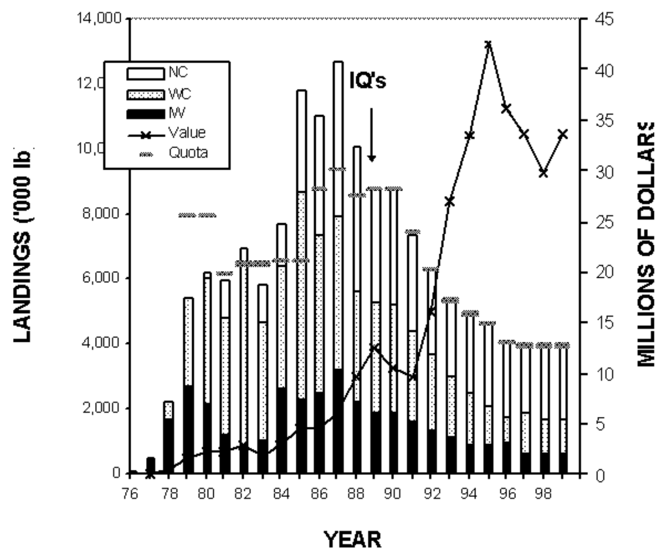
Based on an $F_{40\%}$ yield strategy, the annual harvest rate for the Washington geoduck fishery is 2.7% of estimated commercial biomass (WDFW 2006). The $F_{40\%}$ yield strategy is predicted to preserve 40% of the unfished spawning population (WDNR 2001a). The average estimated time for the geoduck stock to recover to pre-fishing density is 39 years (Bradbury et al. 2000). A biomass dynamics model (Bradbury et al. 2000) was used to compare the recovery time with the annual fishing rate. The model predicted that a recovery time of 39 years and fishing rate of 2.7% annually would eventually reduce biomass to 49% of its unfished level. This is greater than the 40% target level for the $F_{40\%}$ yield strategy; therefore, the current fishing rate of 2.7% is thought to be conservative (Bradbury et al. 2000). Overfishing is not occurring, as the current level of fishing mortality (F_{CURR}) (0.028) relative to the fishing mortality rate that produces the maximum yield per recruit over time (F_{MAX}) (0.075) is 0.37.

WDFW biologists, other federal, state and county agencies, and tribal representatives review the proposed harvest sites and identify potential conflicts. If spawning areas or other important habitats are present, they may be entirely closed to harvest or closed seasonally during spawning periods or other critical times (WDNR 2001a).

For broadcast spawners like geoducks, the reproductive potential in a marine basin may not be affected by isolated localized depletion. In some regions, hundreds of tracts can be rotated into harvest over time, in a relatively open system (allowing for larval drift, mixing, and recruitment across broad areas) (B. Sizemore, pers. comm., August 25, 2008). Many tracts are left unfished in a given year. To prevent localized depletion and aide in assessments, individual tracts that have been fished down 65% or more are not harvested and left to recover (B. Sizemore, pers. comm., August 25, 2008). State and tribal managers conduct post-harvest surveys on fished tracts to verify changes in geoduck density following harvesting, monitor compliance with harvest management agreements, and establish a baseline density level for estimating recovery of the tract. Once the mean pre-fishing density is reached, the bed will again be eligible for harvest (WDNR 2001a).

British Columbia

The commercial harvest of geoducks in British Columbia began in 1976, and has since become one of the province's most valuable fisheries (Figure 7). From the early 1980s to 2007, annual harvest rates for geoduck were set at 1% of the estimated original (pre-fishery) biomass, taking no more than that replaced by recruitment of juveniles into the biomass. Since the beginning of the 2007 fishing season, geoduck quotas have been calculated as 1.2% to 1.8% of the current biomass estimates. The use of current biomass to calculate quotas eliminates the uncertainties around estimating original biomass (DFO 2008b).



Annual quotas, value and catch by region of British Columbia. NC=North Coast, WC= west coast of Vancouver Island, IW=inside waters of Van. Is.

Figure 7. Historic British Columbia geoduck landings and values (DFO 2000).

The most recent stock assessment of British Columbia geoduck populations was conducted in 2005 (Zhang and Hand 2007). The TAC rose by 55,000 pounds in 2001-2002 to a total of 3,965,400 pounds, but dropped to 3,795,000 pounds in 2003 due to stock concerns for geoduck populations on the West Coast of Vancouver Island (WCVI). In 2004, a re-evaluation of geoduck bed status in WCVI abated some of this concern and the TAC was returned to 2002 levels of 3,965,400 pounds. In 2005, after a thorough bed-by-bed review, the TAC dropped to 3,443,800 pounds and has remained at this level since then (Figure 8) (DFO 2008b).

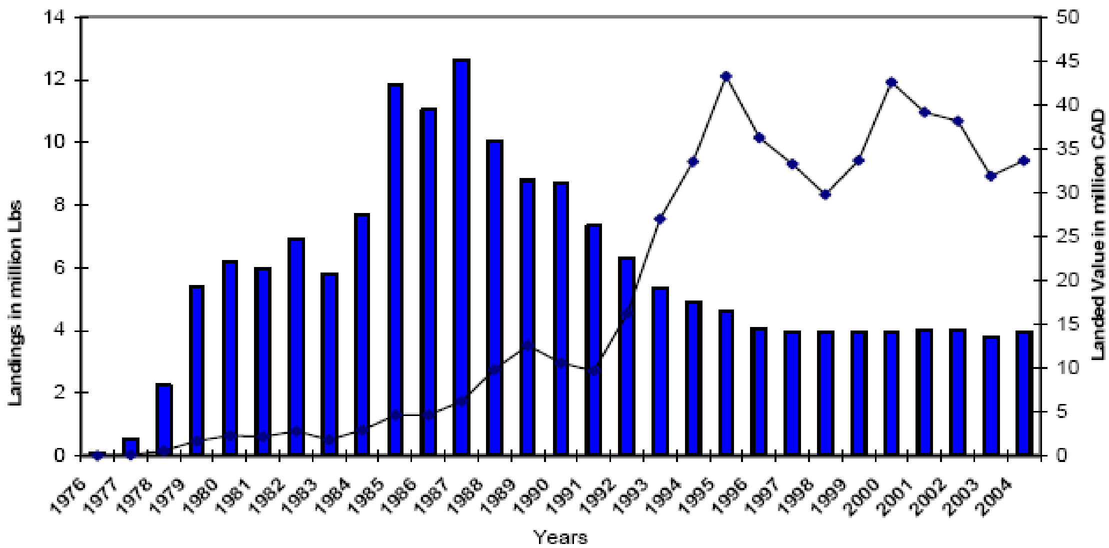


Figure 8. Trends in British Columbia geoduck landings and landing value (Khan 2006).

The current fishing mortality rate is unknown, but overfishing is highly unlikely. Over time, the number of management areas has increased with fewer beds being grouped together in order to spread out fishing effort and reduce the potential for local overharvesting. Approximately 9% of the total British Columbia bed area (26,400 hectares) is believed to have been overharvested and is now closed for recovery (DFO 2008a). Individual beds that have been reduced to 60% or more of the estimated original biomass (the limit reference point is 40%) are no longer available for fishing and are assigned zero quota (DFO 2006).

Sea otters were re-introduced into British Columbia from 1969-1972 (Breen et al. 1982), and since have expanded their range, increasing in numbers to greater than 3,200 in 2005 (Harbo and Rogers 2006). There is debate as to whether this expansion of sea otter populations in the central coast and WCVI is having a negative impact on standing geoduck populations (DFO 2006). The area TAC, individual vessel quota, and the number of individual quotas for geoduck in the WCVI declined in 2007 due to reductions in the biomass estimate. Sea otter predation, earlier intensive harvest, and previous over-estimation of stock abundance and availability to the fishery are likely contributors to the reduction in biomass (Harbo and Rogers 2006; DFO 2008b). The impacts of sea otters are difficult to quantify; however, sea otters cover a geographic area that supports millions of pounds of geoducks. Researchers have documented sea otter impacts on 58 geoduck beds in the WCVI, covering an area estimated to have originally represented greater than 80 million pounds or one-third of the original biomass. Initial calculations suggested that sea otters consumed about 15%-17% of the geoduck population annually in the Mission Group islands, which are part of the WCVI (Harbo and Rogers 2006). Researchers have also documented sea otter impacts on more than 30 geoduck beds in the central coast, covering a geographic area estimated to have originally represented greater than 7 million pounds (13% of biomass) (Harbo and Rogers 2006). It must be noted, however, that this data is from grey literature, and has yet to be published in any peer-reviewed journals.

It is also important to note that not all geoducks are vulnerable to sea otter predation. In many areas, geoducks occupy hard substrates that are too difficult for sea otters to dig through, or depths that are too great for sea otters to dive and forage (Harbo and Rogers 2006). Studies on the effects of sea otter predation on soft-bottom prey communities in Alaska (Kvitek and Oliver 1992; Kvitek et al. 1993) showed that otter-cracked shells of deep-burrowing clams, including *Panopea abrupta*, were rarely found, even at foraging sites where they made up the majority of available prey. This finding supports the belief that geoducks have a partial depth refuge from otter predation.

Table 2. Stock status for the *Panopea abrupta* Washington and British Columbia fisheries.

Stock	Classification Status	B_{CURR}/B_{MSY}	Occurrence of Overfishing	F_{CURR}/F_{MAX}	Abundance Trends/ CPUE	Age/Size/ Sex Distrib.	Degree of Uncertainty in Stock Status	Sources	SFW Rank
WA	Not overfished	B_{MSY} not used; B_{CURR} = 183,125,000	Overfishing not occurring	0.028/0.075 = 0.37	Long-term: decreasing; Short-term: increasing	Unknown	Low	Bradbury et al. (2000); WDNR (2001a&b); WDFW 2006; B. Sizemore, pers. comm. (2008); WDFW 2008a	Healthy
BC	Not overfished	Unknown	Unknown, but likely not occurring	1.2-1.8% of estimated current biomass	Long-term: decreasing; Short-term: stable	Unknown	Moderate	DFO (2000); DFO (2008b)	Moderate

Synthesis
The Washington geoduck stock is not overfished and overfishing is not occurring. The estimated TAC is conservative at only 2.7% of estimated commercial biomass, and three-quarters of the stock is outside harvestable areas. As such, the geoduck stock in Washington is considered to be ‘healthy’ according to Seafood Watch criteria. In British Columbia, geoduck quotas are calculated as 1.2% to 1.8% of the current biomass estimates, and overfishing is not occurring. Population abundance has a decreasing long-term trend, but stable short-term trend. In addition, only moderately uncertain fishery-dependent data are available. Given this information, the status of the geoduck stock in British Columbia is a ‘moderate’ conservation concern according to Seafood Watch criteria.

Status of Wild Stocks Rank:

Washington

Healthy ■ Moderate/Rebuilding ■ Poor ■ Critical ■

British Columbia

Healthy	**Moderate/Rebuilding**	Poor	Critical

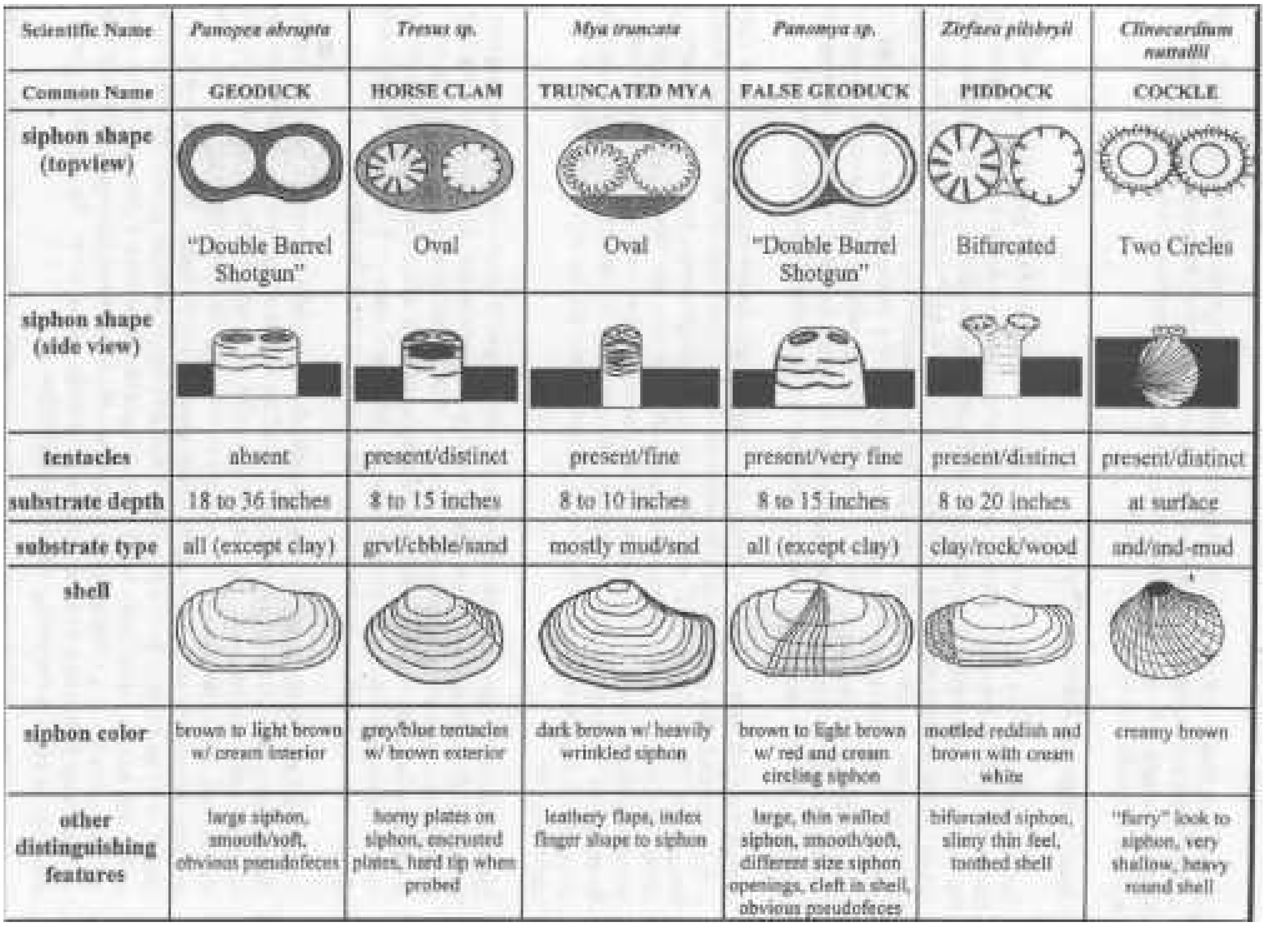
Criterion 3: Nature and Extent of Bycatch

Seafood Watch® defines sustainable wild-caught seafood as marine life captured using fishing techniques that successfully minimize the catch of unwanted and/or unmarketable species (i.e., bycatch). Bycatch is defined as species that are caught but subsequently discarded (injured or dead) for any reason. Bycatch does not include incidental catch (non-targeted catch) if it is utilized, accounted for and managed in some way.

The sedentary nature of geoducks allows for targeted and precise harvesting methods. The presence of a "show" – the recognizable tip of a geoduck siphon, which protrudes slightly above the sand – helps harvesters to locate the clams before digging (Figure 9).

Figure 9. The tell-tale "double-barrelled shotgun" of a geoduck show (Photo Don Rothaus).

Due to the unique shape and proportions of a geoduck siphon, harvesters can use this morphology to differentiate geoducks from other large clams sharing the habitat before they unearth the clam. This greatly reduces habitat disruption and potential bycatch. There are numerous bivalve species sharing the habitat of the geoduck, but clam identification charts allow for careful and accurate harvesting (Figure 10).



Scientific Name	*Panopea abrupta*	*Tresus sp.*	*Mya truncata*	*Panomya sp.*	*Zirfaea pilsbryii*	*Clinocardium nuttallii*
Common Name	GEODUCK	HORSE CLAM	TRUNCATED MYA	FALSE GEODUCK	PIDDOCK	COCKLE
siphon shape (topview)	"Double Barrel Shotgun"	Oval	Oval	"Double Barrel Shotgun"	Bifurcated	Two Circles
siphon shape (side view)						
tentacles	absent	present/distinct	present/fine	present/very fine	present/distinct	present/distinct
substrate depth	18 to 36 inches	8 to 15 inches	8 to 10 inches	8 to 15 inches	8 to 20 inches	at surface
substrate type	all (except clay)	grvl/cbble/sand	mostly mud/snd	all (except clay)	clay/rock/wood	snd/snd-mud
shell						
siphon color	brown to light brown w/ cream interior	grey/blue tentacles w/ brown exterior	dark brown w/ heavily wrinkled siphon	brown to light brown w/ red and cream circling siphon	mottled reddish and brown with cream white	creamy brown
other distinguishing features	large siphon, smooth/soft, obvious pseudofeces	horny plates on siphon, encrusted plates, hard tip when probed	leathery flaps, index finger shape to siphon	large, thin walled siphon, smooth/soft, different size siphon openings, cleft in shell, obvious pseudofeces	bifurcated siphon, slimy thin feel, toothed shell	"furry" look to siphon, very shallow, heavy round shell

Figure 10. Reference for subtidal clam identification (Bradbury et al. 2000).

Because geoducks are easily identifiable from the surface and have no ability to escape from predation, dredges and other disruptive methods are generally avoided in favor of high-pressure water wands (often known as "stingers"), which serve to liquefy the sand directly around the geoduck (Figure 11) (AAFC 2006). These stingers transform a geoduck's burrow into a kind of quicksand for a matter of minutes, during which time the harvester is able to easily retrieve the clam. Smaller recreational operations may use large steel cans, which are hammered into the sand around the geoduck. These "geoduck cans" hold the sand and water around the clam at bay during the manual digging and removal of the animal.

Figure 11. Geoduck harvester with stinger (Photo WDNR 2008).

Horse clams (*Tresus nuttali and Tresus capax*) are commonly found in commercial geoduck tracts (James 2008). As such, geoduck harvesters incidentally unearth horse clams. *Tresus spp.* exist in abundance in the Puget Sound and Inside Passage areas of Washington and British Columbia. In Washington, *Tresus spp.* is not targeted by any major directed commercial fishery due to its low value, although they were harvested with dredges from the mid-1960s until the mid-1980s (WDNR 2001a). The only horse clam harvest occurs when they are inadvertently unearthed during the commercial geoduck harvest, and this harvest is operated under commercial geoduck rules (surveyed beds, monitored harvest, on-the-water catch accounting, no harvest in sensitive nearshore habitat) (Bob Sizemore, pers. comm., August 25, 2008). When this happens, they must be reported as horse clams and accounted for in WDFW's databases (WDNR undated). Regulations in Washington prohibit wastage[1] (W.A.C. tit. 220, § 56.140) and allow for retention and utilization of horse clams when incidentally harvested in the commercial geoduck fishery (W.A.C tit. 220, § 52.019). If there is interest in a directed horse clam fishery, state and tribal managers provide for this under a horse clam harvest agreement (Bob Sizemore, pers. comm., December 27, 2007, W.A.C tit. 220, § 52.019). Because horse clams exist in abundance and thus are not a species of concern, and because they are utilized, accounted for and well-managed in the Washington commercial geoduck fishery, they are not considered to be bycatch according to the Seafood Watch bycatch criterion.

In British Columbia, there was a small commercial horse clam fishery until 1992 when DFO determined that there were insufficient data on horse clam stocks to be able to establish a TAC. As such, the fishery was closed and catch has been only allowed as incidental catch in the geoduck fishery (James 2008). As such, the harvest of horse clams is subject to the same gear restrictions, fishing seasons, and closures as the commercial geoduck fishery. Each management area has a limit on horse clam landings. In addition, DFO requires divers to provide comments on their harvest logs about horse clam populations (DFO 2006). Like the Washington fishery, horse clams are utilized, accounted for and well-managed in the British Columbia commercial geoduck fishery; therefore, they are not considered to be bycatch according to the Seafood Watch bycatch criterion.

Dungeness crabs are also commonly found in geoduck tracts. Cain and Bradbury (1996) conducted a study to determine if commercial geoduck fishing has a significant effect on

[1] Wastage is the deliberate discard of geoducks after they have been removed from the substrate. This includes high-grading (WDNR undated).

Dungeness crab catch-per-unit effort (CPUE). The study showed that there was no statistically significant change in Dungeness crab CPUE between pre- and post-fishing periods (Cain and Bradbury 1996).

In both Washington and British Columbia, geoducks themselves may also compose part of the fishery's bycatch due to an illegal process known as "high-grading." Geoduck harvesters have been known to discard low-quality geoducks in favor of larger or more lightly-colored geoducks (WDNR 2001a). These rejected clams are unable to rebury themselves and have a very poor chance of survival (WDFW 2008b). Every year, 2% of the Washington total allowable catch (TAC) is set aside to account for possible un-reported mortalities (WDNR 2001a). High-grading is a violation under Washington State law and the Canadian Fisheries Act and could compromise conservation efforts if it continues.

Numerous other infaunal and epifaunal species can be affected by geoduck fishing, although not caught; therefore, the impacts on these species are evaluated under Criterion 4: Effects of Fishing Practices on Habitats and Ecosystems.

Synthesis

High-grading of geoducks is known to occur in both the Washington and British Columbia commercial geoduck fisheries, but the extent and overall impacts are unknown. Horse clams (*Tresus spp.*) are commonly found in commercial geoduck tracts and removed during geoduck harvest. In Washington and British Columbia, horse clams that are harvested in the commercial geoduck fishery are utilized, accounted for and well-managed. Given this information, Seafood Watch deems bycatch in the Washington and British Columbia commercial geoduck fisheries to be a low conservation concern.

Table 3. Bycatch data for the Washington and British Columbia *Panopea abrupta* fisheries.

Fishery	Gear	Composition of Bycatch	Population Consequences of Bycatch	Bycatch/ Target Species ratio	Trend in Quality & Quantity of Bycatch	Ecosystem Effects	Sources
Washington	Stingers	Geoduck high-grading	Unknown	Unknown (likely low)	Unknown	Unknown	Bradbury et al. 2000; WDNR 2001a; W.A.C. tit. 220, § 56.140 (2008); W.A.C. tit. 220, § 52.019 (2008); WDFW 2008b
British Columbia	Stingers	Horse clams, occasionally other bivalves	Unknown	<1%-3%	Unknown	Unknown	DFO 2000; DFO 2006; UHA 2006; James 2008

Nature of Bycatch Rank:

Low	Moderate	High	Critical

Criterion 4: Effect of Fishing Practices on Habitats and Ecosystems

Habitat Effects

Wild geoduck harvesting generally involves the liquification of sub-tidal substrate with a high-pressure hand-held water jets ("stingers"). The stingers draw on the surrounding ocean water, pulling it through a long filter-capped hose and expelling it from the tip of a PVC wand. The suction is relatively mild and there have been no documented cases of organisms getting stuck in the stingers themselves (B. Dewey, Taylor Shellfish Farms, pers. comm., October 2006). According to the WDNR 2001 Final Supplemental Environmental Impact Statement (FSEIS) (WDNR 2001b), the harvesting of geoducks by hand-held water jets is the most environmentally benign method currently available.

The FSEIS also found that the commercial geoduck fishery does not have significant, long-term, adverse impacts to the benthic habitat and the marine environment (WDNR 2001b; WDNR 2006). Geoduck harvesting affects a relatively small area of total geoduck habitat and there is rapid recovery for the benthos at the sites disturbed by fishing. However, some short-term impacts are probable. Geoduck harvesting leaves shallow holes where the geoducks were removed. These holes refill within nine days to seven months. Geoduck harvesting does not change average substrate grain size, but may reduce fine material (less than 63 micron grain size) within the harvest holes, and increases turbidity (Ebasco Environmental 1992; WDNR 2001b).

Ecosystem Effects

Geoducks are important organisms in the benthic ecosystem of Puget Sound and the coastal areas of British Columbia. They dominate the infaunal population of their habitat. They are filter feeders and are believed to subsist entirely on phytoplankton, mainly diatoms and flagellates. Deeper clams (those below the photic zone) consume either live phytoplankton, which has been subsumed by wind-driven or tidal currents or "marine snow," a cascade of dead bacteria and plankton gradually sinking into deeper water (Strickland 1983).

Predation on geoducks takes place almost entirely during reproduction and the early stages of the larval cycle, when other organisms are able to access water-borne eggs and larvae. Once the geoduck has dug into the substrate and entrenched itself, it is very difficult to remove and is largely protected from predation; however, the starfishes *Pisaster brevispinus* and *Pycnopodia helianthoides* dig up and eat geoducks that are unable to bury themselves at the normal depth for adults (60 cm or more) (Goodwin and Pease 1989). In addition, several predators including crabs, moon snails, spiny dogfish (*Squalus acanthia*), cabezon (*Scorpaenichthys marmoratus*), and halibut (*Hippoglossus stenolepis*) graze on exposed geoduck siphons; though, this does not necessarily result in the death of the geoduck (Goodwin 1987; Goodwin and Pease 1989). To date, the impacts of geoduck removal on these predators and the food web have not been thoroughly studied.

Sea otters have also been seen excavating and eating adult geoducks (Goodwin and Pease 1989) but the extent of this is difficult to quantify because the impact of commercial geoduck removal on sea otter populations has not been thoroughly studied. As previously mentioned however, sea otters were re-introduced into British Columbia from 1969 to 1972 (Breen et al. 1982), and since have expanded their range, increasing in numbers to greater than 3,200 in 2005 (Harbo and Rogers 2006). In addition, sea otters cannot always prey upon geoducks because they can occupy hard substrates that are too difficult for sea otters to dig through, or live at depths that are too great for sea otters to dive and forage (Kvitek and Oliver 1992; Kvitek et al. 1993; Harbo and Rogers 2006). Studies on sea otter predation in soft-bottom prey communities also showed that otters do not often prey on geoduck, even at foraging sites where they make up a majority of available prey (Kvitek and Oliver 1992; Kvitek et al. 1993). All of this suggests that the commercial geoduck fishery is not negatively impacting sea otter populations, but this cannot be confirmed until more research has been completed.

Goodwin (1978) and Breen and Shields (1983) examined the impact of the commercial geoduck harvest on benthic organisms in Hood Canal and British Columbia, respectively. The relative abundance of the organisms was compared before and after geoduck harvesting on 11 commercial tracts (Bradbury 1999). The analysis represented the species most often associated with commercial geoduck tracts; not all species were observed during harvesting. These species included: Dungeness crab (*Cancer magister*), red rock crab (*Cancer productus*), graceful crab (*Cancer gracilis*), sunflower star (*Pycnopodia helianthoides*), pink short-spined star (*Pisaster brevispinus*), flatfish (Family Pleuronectidae), orange sea pen (*Ptilosarcus gurneyi*), sea whip (Family Virgulariidae), plumose anemone (*Metridium senile*), tube-dwelling anemone (*Pachycerianthus fimbriatus*), polychaete tube worms (*Spiochaetopterus spp.* and *Phyllochaetopterus spp*.), horse (gaper) clam (*Tresus spp.*), and laminarian kelp (*Laminaria spp.*). Only a few statistically significant changes in the relative abundance of the species were detected a year following geoduck harvesting; the majority (80%) of the changes detected were increases in species abundance. These increases may have resulted from geoduck harvesting (increased availability of food or space) or may have resulted from natural cycles of abundance or migration (Bradbury 1999).

The FSEIS (2001) found that geoduck harvesting does not have an effect on marine birds or mammals, and there are no long-term impacts to the marine environment except for a reduction in geoduck populations.

Synthesis
Stingers are thought to cause minimal damage to impacted areas, especially as harvestable geoducks inhabit sandy, dynamic areas of the benthos. The nature of the stinger apparatus allows harvesting to be precise and well-targeted. The WDNR FSEIS concluded that there are no long-term impacts from geoduck harvesting to the marine environment. Given this information, the habitat and ecosystem effects of geoduck harvesting are considered ‘benign’ according to Seafood Watch criteria.

Table 4. Ecosystem and habitat effects of the Washington and British Columbia *Panopea abrupta* fisheries.

Gear Type	Effect of Fishing Gear on Habitats	Habitat Resilience to Disturbance	Geographic Extent of Fishery Effects	Evidence of Food Web Disruption	Evidence of Ecosystem Changes	Sources
Stingers	Minimal Damage	High	Limited Area	Unknown	No evidence of substantial ecosystem impacts	Goodwin and Pease 1989; Ebasco Environmental 1992; Bradbury 1999; Bradbury et al. 2000; DFO 2000; WDNR 2001b; DFO 2006

Effect of Fishing Practices Rank:

Benign	Moderate	Severe	Critical

Criterion 5: Effectiveness of the Management Regime

Washington

The Washington commercial geoduck fishery began in 1970 and is the largest and most valuable clam fishery on the Pacific coast of North America (WDNR 2001b). Geoduck landings over the past decade averaged 3.3 million pounds and $17 million (Figure 12). This fishery encompasses the entirety of Puget Sound, the Strait of Juan de Fuca, and the San Juan Islands. Although much of the area included under this delineation is not feasible geoduck harvesting territory due to contamination, depth or substrate quality, it falls under the management regime nonetheless.

Washington provides the great majority of the US geoduck harvest. State landings descended from high numbers in the mid- to late-1970s to a low in 1995 before returning to previous levels (Figure 12). This increase in landings reflects the revised, more conservative annual harvest rate of 2.7% implemented in 1997 (WDNR 2001a).

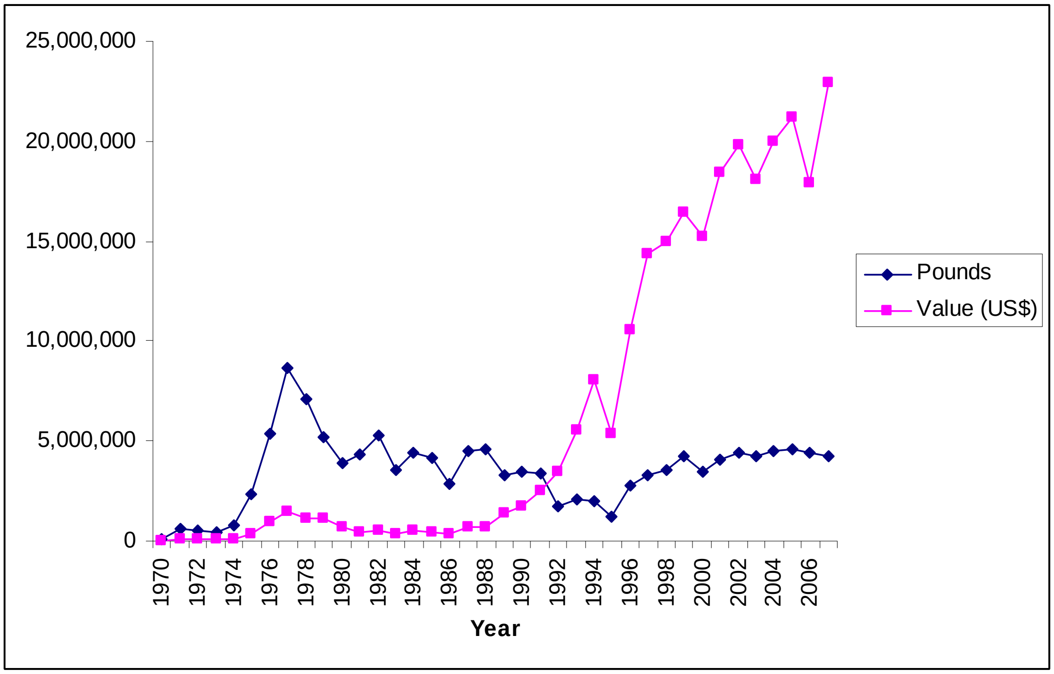


Figure 12. Historic landings and value (US$) of commercial geoduck in Washington (WDFW 2008a).

The Washington commercial geoduck fishery is jointly managed by two state agencies – the Washington Department of Fish and Wildlife (WDFW) and the Washington Department of Natural Resources (WDNR) – as well as the Puget Sound Treaty Indian Tribes that have a right to 50% of the harvestable surplus of geoducks. The state agencies and the tribes are responsible for determining geoduck population size and sustainable yield, and for keeping adverse effects to the environment at a minimum (WDNR 2001b, Bradbury et al. 2000). WDFW began conducting dive surveys of geoduck populations in harvested areas in 1967, which have continued on an annual basis. Individual tribal dive survey programs were established in 1996 (Bradbury et al. 2000).

The geoduck fishery is divided into six distinct management regions, each with a respective TAC (Figure 13). Each region is composed of a varying number of geoduck beds, the total biomass of which is estimated based upon summarizing biomass of individual tracts within a region, generally based on a 900 square ft transect (Bradbury et al. 2000). In some regions, hundreds of tracts can be rotated into harvest over time (B. Sizemore, pers. comm., August 25, 2008). Many tracts are left unfished in a given year. For assessment purposes, tracts that have been fished down 65% or more are not harvested and left to recover. State and tribal managers conduct post-harvest surveys on fished tracts to verify changes in geoduck density following harvesting, monitor compliance with harvest management agreements, and establish a baseline density level for estimating recovery of the tract. Once the mean pre-fishing density is reached, the bed will again be eligible for harvest (WDNR 2001a).

Once the TAC is calculated for each of the six management regions (Figure 14), an age-based equilibrium yield model is used to reach an annual harvest rate. The objective of this model is to predict the outcome of various levels of harvesting pressure on state geoduck stocks, and to recommend one of these levels based on a desired fishing strategy (Bradbury et al. 2000).

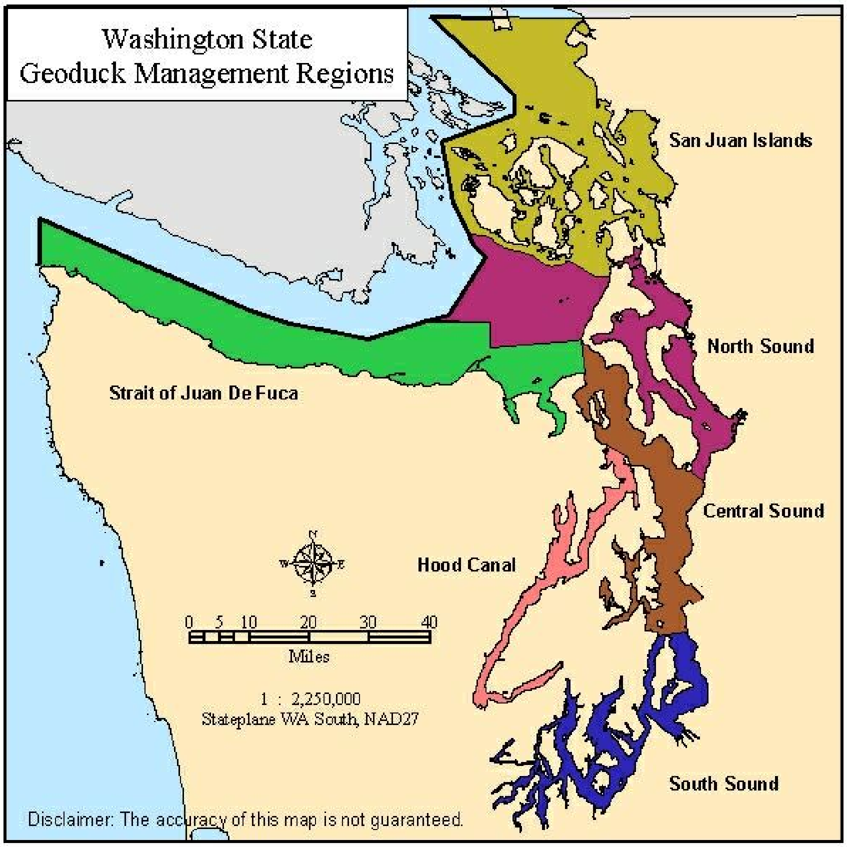


Figure 13. Map of Washington geoduck fishery, divided into six management regions (WDFW 2006).

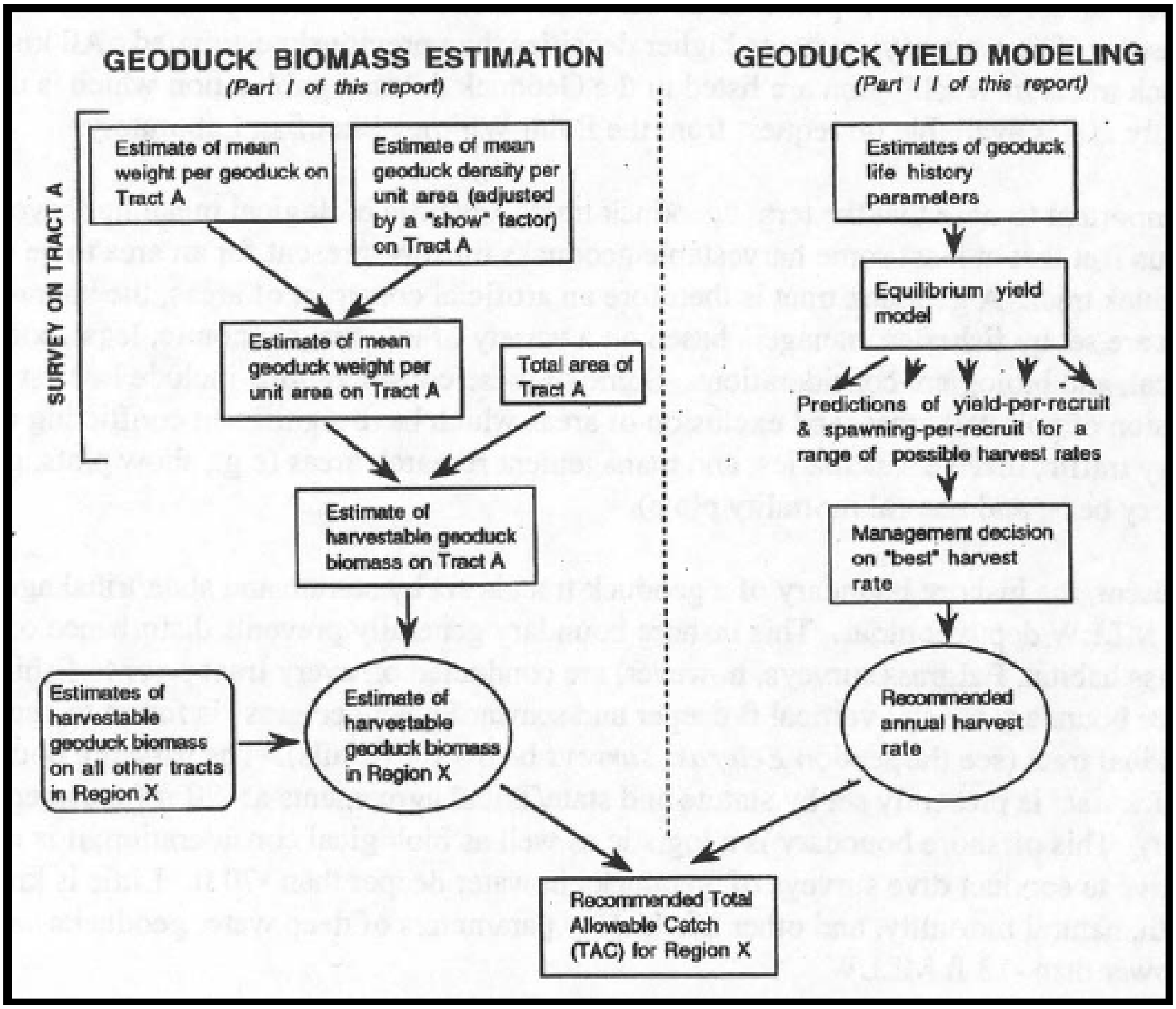


Figure 14. Model for the determination of geoduck TAC by region (WDFW 2006).

Stock assessments are an on-going activity, and the results are summarized every year to form the basis for setting annual quotas; however, the stock assessment information is only shared amongst state and tribal fishery managers and is generally not distributed to the public at large (B. Sizemore, pers. comm., December 27, 2007).

As previously mentioned, the incidental harvest of horse clams in the commercial geoduck fishery is operated under commercial geoduck rules (surveyed beds, monitored harvest, on-the-water catch accounting, no harvest in sensitive nearshore habitat) (Bob Sizemore, pers. comm., August 25, 2008). They must be reported as horse clams and accounted for in WDFW's databases (WDNR undated). Regulations in Washington prohibit discarding (W.A.C. tit. 220, § 56.140) and allow for retention and utilization of horse clams when incidentally harvested in the commercial geoduck fishery (W.A.C tit. 220, § 52.019). If there is interest in a directed horse clam fishery, state and tribal managers provide for this under a WDNR horse clam harvest agreement (B. Sizemore, pers. comm., December 27, 2007, W.A.C tit. 220, § 52.019).

Poaching and high-grading occur but to an unknown extent. WDFW uses investigative dives and enforcement crews to reduce the risk of such problems occurring. Every year, 2% of the state TAC is set aside to account for possible un-reported mortalities (WDNR 2001a).

The effect of the commercial geoduck fishery on habitats and ecosystems is a low conservation concern. As such, no mitigative measures for habitat impacts are necessary at this time.

WDFW oversees gear regulations, licenses, and landing logs. During all commercial geoduck harvesting, a WDNR enforcement vessel is required to be on the tract or within visual distance of the tract except for emergency and operational requirements to ensure that regulations are followed. Violations of any provision, including WDFW regulations, may result in civil fines and possible suspension or termination of the harvest agreement (WDNR 2001a). WDNR also inspects both the harvest areas and vessels on a routine basis in order to deter and reduce wastage. WDNR divers conduct dives to check for wastage and other harvest violations, and enforcement crews inspect vessels and perform on-water weigh-outs in order to reduce the opportunity for wastage. If any wastage or violations occur, WDNR and WDFW can impose criminal and civil penalties against the responsible harvest company and harvester (WDNR 2001a).

British Columbia

The British Columbia commercial geoduck fishery was initially unregulated, but in 1981, license limitation restricted the fleet size to 55 boats. In 1989, British Columbia introduced a system of individual vessel quotas (IVQs) followed by a three-year rotational closure plan. This allows geoduck harvesting on only one-third of the coast during any given year, but the target area is harvested at three times the annual rate.

Individual geoduck beds are grouped together into geoduck management areas (GMAs). Each of the three geographic regions (North Coast, West Coast of Vancouver Island, and Inside Waters) is divided into three sub-units with approximately equal geoduck harvest areas (Figure 15). With the exception of Area 24 (Clayoquot Sound), which is fished annually, each of the sub-units is on the three-year rotational closure plan. This concentrates effort, making it easier to monitor quotas and validate landings (DFO 2004). British Columbia has increased the number of GMAs recently to diffuse fishing pressure and to reduce the chances of over-harvesting. There were large over-harvests in the last five years, due primarily to over-estimation of standing stock and GMA macro-management. Currently, with more GMAs and more frequent bed harvest reviews, fishery managers believe quotas to be at more appropriate levels (Hand, pers. comm., October 5, 2006). Management uses conservative assumptions are used to estimate unsurveyed populations, and as of 2000, approximately 10% of total coast-wide geoduck bed is closed due to suspected overharvesting (DFO 2000).

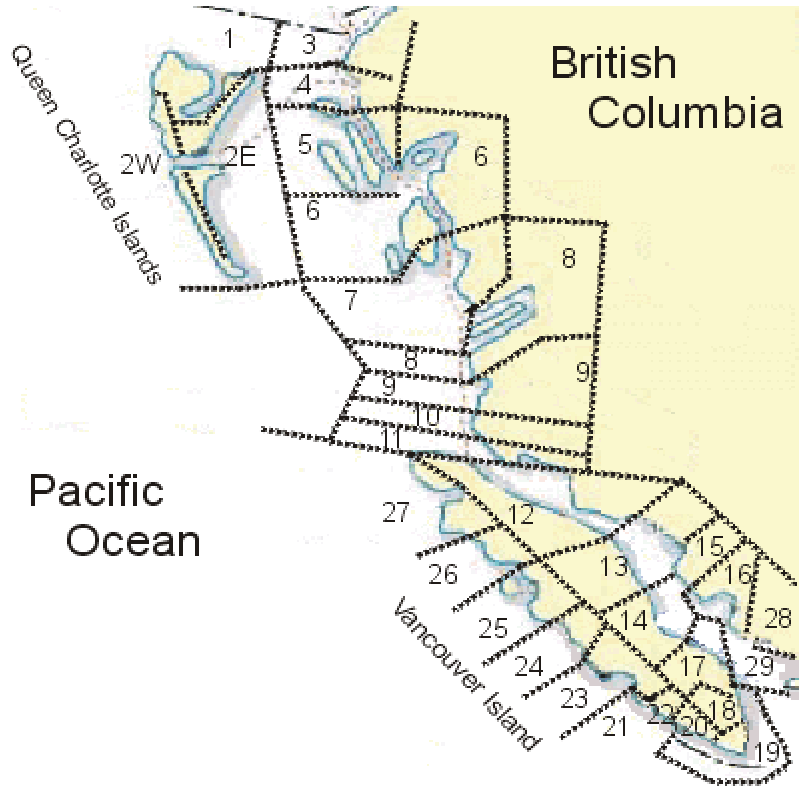


Figure 15. Geoduck management areas (DFO 2004).

Geoduck divers do not harvest at depths greater than 20 meters. This serves to allow for a reservoir of broodstock in deeper waters. Geoduck harvesting is also prohibited in marine protected areas, and there are unharvestable beds (due to rocky substrate, contamination, or other factors) which serve to protect a certain amount of breeding clams.

The geoduck fishery was poorly managed in the early, unregulated years resulting in over-harvesting and economic difficulties (Khan 2006). This changed beginning in 1989 with the establishment of the IVQ system, new closures, and regulations based on improved scientific data. The historical goal of British Columbia management and the Underwater Harvesters' Association (UHA) was to harvest 1% of estimated *virgin* biomass per year (DFO 2000; UHA 2006). The fishery is now managed primarily under a conservative system of rotational openings/closures that aim to harvest between 1.2% and 1.8% of the *current* biomass (DFO 2008b). In closed areas, all harvesting is prohibited for two years, and then open for one year at three times the normal harvest rate. In the event where the biomass of an individual geoduck bed has declined to 40% of its virgin biomass, the bed is closed to all harvesting (DFO 2008b).

The current fishery management plan is largely a product of a management arrangement between UHA and DFO. At present, the vast majority of collected data is provided by members of the UHA, a group comprised of the 55 British Columbia geoduck license holders as well as crew members and industry wholesalers. UHA and DFO have officially co-managed the geoduck fishery since 1989, the same year that the IVQ system was introduced (Khan 2006).

The most recent stock assessment of the British Columbia geoduck fishery was conducted in 2005. A large percentage of the assessment and management in the fishery is funded by UHA. They fund full-time biologists as well as other DFO positions and numerous fishery-related projects, such as geoduck disease studies and genetic research.

Since the UHA began to co-manage the fishery, excess fishing has been more effectively controlled, the economic value of the fishery has increased, and general compliance with regulations has escalated (Kahn 2006). Management advice for the geoduck fishery is presented through the Geoduck Sectoral Committee, a multi-stakeholder table. These meetings are open to public observers, and the public has a 30 day period to comment on the annual management plan to ensure transparency. All assessments and quota determinations are prepared by government scientists. The scientific process, called the Pacific Scientific Advice Review Committee (PSARC), is an open and transparent forum (DFO 2008b).

High-grading and poaching is a violation under the Canadian Fisheries Act, but no specific actions have yet been taken by DFO to control these issues (DFO 2008b). As previously mentioned, the incidental harvest of horse clams in the British Columbia commercial geoduck fishery is subject to the same gear restrictions, fishing seasons, and closures as the commercial geoduck fishery. Each management area has a limit on horse clam landings. In addition, DFO requires divers to provide comments on their harvest logs about horse clam populations (DFO 2006).

The effect of the fishery on habitats and ecosystems is a low conservation concern. As such, no mitigative measures for habitat impacts are necessary at this time.

The British Columbia commercial geoduck fishery is monitored and enforced through DFO's Catch Validation Program, a program designed to monitor, record, and verify catches. Each vessel must carry and fill out a Validation and Harvest Logbook with details of their fishing activity. In addition, geoduck harvesters must validate landings of geoduck at the first point of landing through a contracted third party, which are designated observers by DFO. Validated landings are used to ensure that IVQs and bed quotas have not been exceeded. The observers have many duties, some of which include monitoring effort within geoduck beds and management areas on a daily basis, managing fishing activity to avoid excessive harvesting, and reporting any excessive harvesting to resource managers (DFO 2008b).

Table 5. Commercial harvest management measures for the Washington and British Columbia *Panopea abrupta* fisheries.

Fishery	Management Jurisdictions & Agencies	Total Allowable Landings	Size Limit	Gear Restrictions	Trip Limit	Area Closures	Sources
WA	WDFW, WDNR, Puget Sound Treaty Indian Tribes	2.7% of current surveyed biomass	None	Only a manually operated water jet not exceeding 5/8 inch inside diameter is allowed	Varies according to region	Waters < -18ft and > -70 ft; polluted areas; paralytic shellfish poisoning areas; unsurveyed areas	Sizemore 1999; Bradbury et al. 2000; WDNR 2001b; WDFW 2006
BC	DFO, UHA	1.2-1.8% of estimated current biomass by bed	None	Only a manually operated water jet not exceeding 5/8 inch inside diameter is allowed	Varies	Three-year rotation closures; other closures exist due to over-harvesting, interest conflict, health concerns, or habitat protection	DFO 2000; UHA 2006; DFO 2008b

Synthesis

In Washington, the commercial geoduck fishery is regularly assessed, using both fishery-dependent and independent data. Population abundance declined from the mid- to late-1970s through the early 1990s but has since recovered due to the revised, more conservative TAC of 2.7% of estimated commercial biomass. The fishery is effectively monitored and enforced by WDFW. Seafood Watch deems these management measures are to be highly effective.

British Columbia maintains up-to-date stock assessments and fishery management plans for the commercial geoduck fishery. The fishery has a history of over-exploitation but has reduced quotas and implemented a number of management measures in an effort to repair past damage. The current 1.2%-1.8% take of estimated virgin biomass is considered sustainable based on a recent stock assessment (Zhang and Hand 2007). DFO and UHA strictly monitor and enforce the fishery. Based on this information, Seafood Watch considers management in the British Columbia geoduck fishery to be highly effective.

Effectiveness of Management Rank:

Washington and British Columbia

Highly Effective ■ Moderately Effective ■ Ineffective ■ Critical ■

Overall Evaluation and Seafood Recommendation for Wild-caught Geoduck

Demand for Pacific geoduck (also known as *mirguai*), a large, burrowing clam native to the Pacific Northwest of the US and coastal British Columbia, has increased with the expansion of the American sushi industry. The geoduck's high fecundity and young age at sexual maturity are tempered by its low intrinsic rate of increase, long life span and ease of capture, making them moderately resilient to fishing pressure. The two primary wild-caught geoduck fisheries available in the U.S. market occur in Washington and British Columbia. Neither of these fisheries is overfished nor undergoing overfishing. Bycatch in both fisheries is deemed to be a low conservation concern. Geoducks are generally harvested with hand-held water jets (stingers), which cause minimal damage to impacted areas, especially since geoducks inhabit sandy, dynamic areas of the benthos in shallow areas less than 20m. Both Washington and British Columbia have robust stock assessments, management measures to rebound stocks from previously overfished conditions, and strict monitoring and enforcement; therefore, management is deemed to be highly effective in both fisheries. The combination of individual criteria results in an overall recommendation of "Best Choice" for both wild-caught Washington and British Columbia geoduck.

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Inherent Vulnerability		√		
Status of Stocks	√ **Washington**	√ **British Columbia**		
Nature of Bycatch	√			
Habitat & Ecosystem Effects	√			
Management Effectiveness	√			

Overall Seafood Recommendation for Wild-caught Geoduck:

Washington and British Columbia:

Best Choice ☐ Good Alternative ☐ Avoid ☐

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Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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