Pacific Coast Clam Fisheries

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TECHNICAL REPORT

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The sea and its myriad inhabitants have intrigued and nourished humans for thousands of years. Among the many organisms utilized for various purposes are those collectively known as molluscs, represented by such diverse animals as snails, squid, octopi, and chitons. Also included in the phylum Mollusca are the bivalves ("two shells"), a group that includes oysters, scallops, mussels, and clams. These animals were sought not only for food, but their shells were used as money and fashioned into jewelry, buttons, and implements.

Because many of the bivalves, particularly oysters and clams, inhabit environments that are easily accessible, they were a major food item for Native Americans and pioneers who settled along the coasts. Large numbers of shells have been found by archeologists in Indian kitchen middens or "trash heaps." These shellfish were also important to the early settlers, and clam and oyster fisheries eventually became established along both the Atlantic and Pacific Coasts.

The clam fishery of the United States is a small but viable industry. Annual commercial clam landings from 1970 to 1980 averaged approximately 100 million pounds, with an ex vessel value (amount of money paid to the fishermen) of about $44 million. In addition, an unknown, but presumably significant, quantity of clams are harvested by individuals for personal use.

Even though the Pacific Coast clam industry is small—about one percent of the total U.S. catch--it is an important part of the heritage of many coastal communities and is a factor in the economies of some rural areas. (See Appendix A for production figures.) The West Coast industry played a vital role in the early development of a U.S. clam industry by pioneering the use of canning techniques for marketing clams. This development permitted widespread consumption of clams, which hadn't been possible earlier because clams are extremely perishable.

Clams are an increasingly popular food item on the West Coast. Growers, harvesters, and consumers have demonstrated an interest in insuring the survival of the industry, which is threatened by multiple use conflicts, increased governmental regulations, and environmental problems resulting from growing coastal populations.

Industry problems include industrial, agricultural, and municipal discharges, dredging and other navigation projects, freshwater diversion, and silt deposition from upland development. A molluscan fishery is particularly vulnerable to such activities because of the stringent water quality requirements necessary for successful reproduction and growth.

Washington State annually provides approximately 95 percent of the Pacific Coast production, with Alaska clams accounting for most of the rest. Washington's leadership in the Pacific Coast clam industry may be attributed to a number of factors, but perhaps most important is the abundance of suitable clam habitat. Oregon and California lack protected bays, estuaries, and coastal clam habitat necessary for significant clam production. In addition, recreational clam harvesting accounts for the bulk of the clam production in those states. Alaska has an extensive coastline and is rich in clam resources; however, harvest is restricted by paralytic shellfish poisoning and socio-economic factors.

In the following chapters, the Pacific Coast clam industry is reviewed by state: principal commercial species are listed, and history, current trends, and anticipated future developments are presented. Some recreational clam harvesting is reviewed, since it is often a major factor in total harvest and may have considerable impact on the commercial fishery.

Many factors influence the level of production and overall management of clam stocks on the West Coast. Water quality, certification of clam beds, management of available stocks, paralytic shellfish poisoning, commercial versus recreational harvest, marketing, transportation, encroachment of man, and other factors are directly or indirectly associated with the status of a given clam fishery. These factors are also addressed in the discussions that follow.

To resolve some of the issues involved in clam fisheries, federal, state, and local governments have enacted legislation addressing the fragile nature of coastal areas, their social and economic importance, and the conflicting demands for their use. Since the reproduction, propagation, and harvest of fishery resources—including shellfish—are clearly mandated as a legitimate use, individuals from a variety of backgrounds have entered the planning process required to implement these laws. This report is presented, in part, to provide pertinent information on the local clam industry for the general public, students, potential entrants into the industry, and those people who make decisions concerning the industry.

Species and Harvesting Methods

There are many different species of clams along the Pacific Coast, but only a few are of economic importance. The principal ones that are considered in this report are

the razor clam, *Siliqua patula*
the native littleneck clam, *Protothaca staminea*
the Manila clam, *Venerupis japonica*
the butter clam, *Saxidomus giganteus*
the basket cockle, *Clinocardium nuttalli*
two species of horse or gaper clams *Tresus nuttalli* and *T. capax*
the eastern softshell clam, *Mya arenaria*
the geoduck clam, *Panope generosa*

In addition, some minor or undeveloped species that will be discussed include

the surf clam, *Spisula polynema*
the Pismo clam, *Tivela stultorum*
cockles, *Chione* sp.
the jackknife clam, *Tagelus californianus*
the bean clam, *Donax gouldii*

(Descriptions of these species may be found in Fitch, 1953; Marriage, 1954; and Quayle, 1970.)

Clams occupy a variety of habitats: fresh-, brackish, and saltwater environments, and substrate types from the upper intertidal zone to the abyss. The depth to which clams burrow varies according to species and is determined by the length of their siphons. Table 1 gives a description of the major commercial species and where they are found. In addition, a summary of clam morphology and physiology is given in Appendix B.

Razor clams are found on surf-pounded ocean beaches, whereas the other species inhabit bays, inlets, and estuarine areas. Except for geoducks, all of the other species are collectively referred to as "bay clams," which are categorized further as "hardshell clams" and "softshell clams." The hardshell clams include native littlenecks, Manilas, butter clams, basket cockles, and horse clams. Methods used on the West Coast to harvest clams depend on the species sought, the type of substrate, and the tidal level at which the clams occur. Table 1 gives a description of the major species and where they are found.

Razor Clams

Razor clams are harvested primarily in the sports fishery. They are taken with a specialized clam shovel or a "tube gun." When a "show" is located, sand is removed with the shovel on the seaward side of the neck, which is grasped quickly before the clam can retract its siphon and dig deeper. The digger must be careful to avoid breaking the fragile shell and smashing the clam. If a tube gun is used, it is placed around the show, pushed into the sand, and cores of sand—usually two or three—are removed until the clam can be extracted.

Intertidal Bay Clams

Most intertidal hardshell and softshell clams are harvested by hand with an ordinary potato fork (called a clam rake or hack), a shovel, or a four-tined clam hack. The best method is to dig in rows, spreading the ground out evenly along the rows. Most of the clams are overturned as this is done, but a few more usually can be found as the substrate is carefully raked through once more. Hand harvesting is inefficient compared to mechanized hydraulic devices, but it may enhance clam populations by thinning adult clams without eliminating them. Competition for food and space is reduced, and they grow faster.

Hydraulic clam rakes are used by commercial diggers on some intertidal beaches along the West Coast. A gasoline-powered water pump in a skiff supplies enough water pressure to the rake to dig about one foot into the substrate. The clams float to the top of the resulting water-soil slurry and are picked by hand from the trench created by the rake. Hydraulic rakes are not only faster and more efficient than hand digging, but minimize clam breakage.

Harvested bay clams frequently are placed in clean salt water so that they can purge sand and mud from the gills and viscera before they are consumed. Buckets of sea water may suffice for a small recreational catch, but commercial quantities are often held in sink floats for purging before being shipped to market.

Subtidal Bay Clams

In Washington State and British Columbia, Canada, subtidal clams are harvested mainly with mechanical clam harvesters. These hydraulic gear types were originally developed on the East Coast for harvesting the vast clam beds there. The hydraulic escalator, or "Hanks," harvester was invented in the early 1950s by Fletcher Hanks of Maryland to dig softshell clams in Chesapeake Bay. Modified versions of the escalator harvester have been used in Puget Sound since about 1958.

The hydraulic dredge is attached to a boat which pushes the submerged portion of the dredge through the substrate. Powerful jets of water loosen the substrate and toss clams onto a chain-mesh conveyor belt, or escalator, which carries them to the boat. Small clams, gravel, and other debris fall through the mesh and are redeposited on the bottom. Although there are problems such as noise pollution, turbidity, and siltation associated with the escalator harvester, it is probably the most efficient method now available for harvesting subtidal clam stocks.

The "Long Island," or hydraulic jet cage harvester was also developed on the East Coast, primarily for harvesting the surf clam (*Spisula solidissima*), but has been used to a limited extent in Washington, British Columbia, and Alaska. This device can be operated in deeper water than the escalator harvester because it is limited only by the length of the water hose. There is no conveyor belt; rather, the dredge is towed behind the boat, and the clams—after being loosened by water jet—are collected in a steel-ring bag or collecting device. The dredge is hoisted out of the water periodically to empty the catch.

Another method of harvesting subtidal clams is the Venturi (suction) dredge. This vacuum device may be remotely operated from a boat or used by divers. Clams and other materials are picked up and either sorted out on deck or, if diver operated, ejected from the discharge end under water. In the latter method, another diver follows along behind the harvester and retrieves the clams after they fall on the bottom.

Geoducks

Few geoducks are harvested in the intertidal area because of the depth to which they burrow and the effort required to dig them. Some recreational diggers use a shovel and merely excavate the sand around the geoduck. However, others may use a "geoduck can," which is an open-ended metal tube similar to a stovepipe. The can is placed around the siphon and pushed as far as possible into the substrate, preventing the sides of the hole from caving in as sand is removed. When the siphon and shell are exposed, the clam can be extricated.

Subtidal harvesting of geoducks in Washington State occurs only on commercial tracts leased from the state. Clams are harvested individually by means of a hand-held, high-pressure water jet operated by a diver. The water jet loosens the substrate around the geoduck and allows the diver to remove the clam from its burrow relatively quickly. An experienced diver may harvest two clams per minute where clams are abundant.

Table 1. Description and Distribution of Primary Pacific Coast Commercial Clam Species.

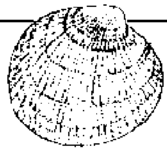
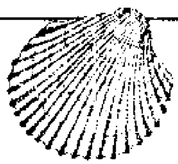
		Description
	RAZOR CLAM *Siliqua patula*	Thin elongate shell Greenish-brown with inner valve tinged purple
	NATIVE LITTLENECK *Protothaca staminea*	Oval to round shell; distinct radial and concentric ribs. White, gray, or brown
	MANILA CLAM *Venerupis japonica*	Looks like native littleneck but shell is oblong and compressed. Gray, brown, or variegated
	BUTTER CLAM *Saxidomus giganteus*	To 5 in. long; thick oval valves with close concentric rings. Grayish white.
	HORSE CLAM *Tresus nuttalli* and *T. Capax*	Large fragile shell, gapes at siphon. White with brown or black at valve. Long, unretractable siphon.
	BASKET COCKLE *Clinocardium nuttalli*	Heart-shaped heavy shell, 4 1/2 in. long. Brown with prominent ribs, scalloped edge.
	GEODUCK *Panope generosa*	Long rectangular shell, gapes at both ends, up to 9 in. long, 10 lbs. Gray-white with coarse growth rings.
	EASTERN SOFTSHELL CLAM *Mya arenaria*	Thin, easily broken shell, up to 6 in. long. Elliptical with concentric rings.

Table 1 continued

Habitat	Distribution	Comments
Sandy surf-swept beaches. Intertidal and subtidal to 30 feet.	Northern California to Aleutian Islands	Rapid burrower--may dig up to a foot in a minute. Position disclosed by slight depression in sand.
Mud-gravel substrate in protected bays. Upper 8 inches of intertidal to 1/3 tide level.	Baja California to Aleutian Islands	Observed at depths to 60 feet in Puget Sound. Burrows to about 8 inches.
Pea gravel, sand, or mud. Intertidal zone from -1.5 feet to just beyond half-tide.	Northern California to Alaska	Lives just below the substrate; easy to hand harvest.
Sand to gravel substrate in lower third of intertidal and subtidal to 60 feet.	Northern California to Aleutian Islands	Burrows to about 12 inches. Frequently harvested with native littlenecks.
Sand, mud, and gravel (*T. capax* prefers gravel). Intertidal and subtidal to 60 feet.	Baja California to Alaska	Burrows to 1 1/2 feet.
Mud and sand in bays, sloughs, and estuaries. Inhabits intertidal and subtidal zone to 80-ft. depth.	Southern California to Bering Sea	Because of short siphon, found near or on top of surface. Powerful foot enables it to travel rapidly.
Sand and mud in protected bays. Lower intertidal and subtidal to 200 feet.	Baja to Alaska	Because of extremely long siphon, may burrow to 4 feet. Largest burrowing bivalve on Pacific Coast.
Sand and mud in low salinity estuaries. Inhabits upper intertidal.	California to Alaska	Thought to have been introduced on West Coast with East Coast oyster seed. Now known to be indigenous.

Washington

Washington leads the West Coast in clam production for several reasons: Washington's ocean beaches contain large razor clam stocks, and the protected estuaries of Puget Sound, Grays Harbor, and Willapa Bay contain extensive intertidal and subtidal bay (hardshell) clam stocks (Figure 1). In addition to extensive clam habitat and resources, there is a tradition of private ownership of intertidal beaches and private leasing of state-owned subtidal bottom land that provides a favorable environment for commercial harvest.

Despite these factors, both the coastal razor clam fishery and the estuarine bay clam fishery have undergone radical fluctuations in production during the last four decades (Figure 2). The commercial razor clam industry has almost disappeared except for a small Indian fishery on the Quinault Indian Reservation; however, a large, active recreational razor clam fishery remains. Although bay clam landings appear relatively stable, there have been major harvest fluctuations within individual species. Historical production figures for Washington clam fisheries are given in Appendix A.

The bay clam harvest from Washington's publicly owned beaches, once the major source of commercial supply, declined gradually after 1940 for a number of reasons. Public beaches were heavily dug during the depression of the 1930s, and a subsequent lack of major setting reduced the standing stock. In addition, there were fewer people harvesting clams during and after World War II because of improved employment opportunities in other businesses. During the 1940s, purchase of tidelands by private citizens accelerated, effectively eliminating many tidelands as public clam harvesting areas. Finally, the value of butter clams declined, and fewer were harvested.

Other significant developments that have influenced bay clam production include the introduction in the late 1950s of mechanical harvesters, permitting the utilization of subtidal stocks, and the debut of the geoduck fishery. A small softshell clam fishery also developed in Skagit Bay in the 1960s. It was successful initially, but experienced legal problems in the late 1970s.

Figure 1. Clam harvesting areas in Washington State

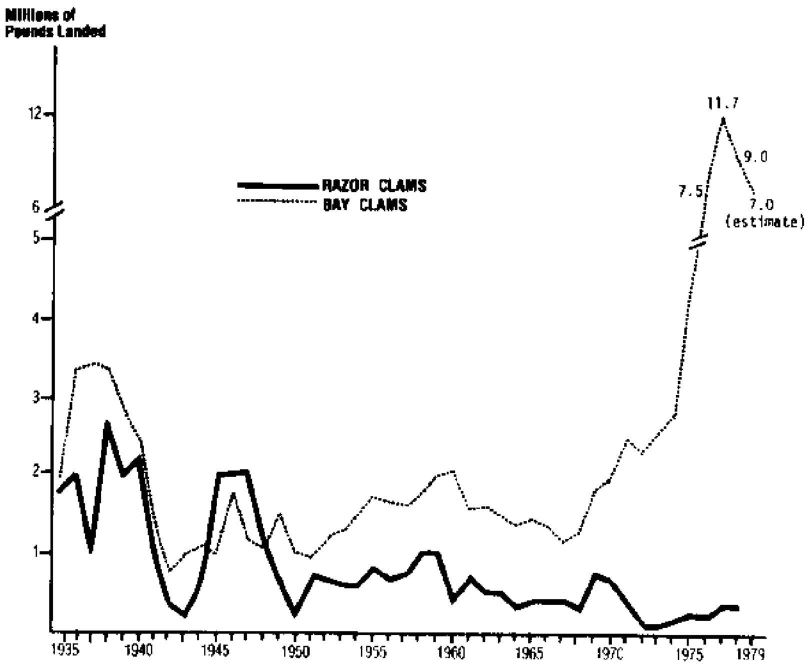


Figure 2. Washington State razor clam and bay clam (including geoducks) production, 1935–1978. (Production figures for 1979–1981 have been included in Appendix A.)

Commercial Razor Clam Fishery

The razor clam is found in surf-swept, sandy ocean beaches all along the Pacific Coast of North America, and is harvested commercially in a number of areas from Oregon to Alaska (Quayle, 1970). There are four main beaches in Washington where razor clams are relatively abundant: Long Beach, Twin Harbors, Copalis, and Mocrocks. Other beaches supporting significant razor clam fisheries are Taholah, on the Quinault Indian Reservation, and Kalaloch, north of the reservation (Schaefer, 1939).

In the late 1960s, diving and bottom grab samples indicated a razor clam population extending off the Washington coast to depths of at least 60 feet. At depths greater than 25 feet, however, razor clams of a different species (*Siliqua sloati*) appear, and the intertidal variety disappears. Although *S. sloati* is found in some abundance up to 60 feet (the deepest that grab sample observations have been made), it is thinner and has a maximum length of only 4 inches, which greatly diminishes its commercial potential. The offshore range of this species is not known, but local crab fishermen have found *S. sloati* shells in crab traps set in 16 fathoms.

The commercial razor clam fishery in Washington has been influenced by the recreational fishery to a great extent, so a history of the industry necessarily includes information about both segments of the fishery. Prior to 1900 there was a small clam fishery supplying local fresh markets, but large-scale utilization of the resource did not begin until canneries were introduced just after the turn of the century. In the peak year of 1915, over 3.2 million pounds of processed razor clams were canned, representing a catch of about 8 million pounds of unshucked clams (Schaefer, 1939).

As the commercial fishery expanded, concern about the razor clam stocks led to conservation efforts. In 1917 the Washington State Legislature passed a bill reducing the harvesting season from nine to three months (March through May) to eliminate harvesting during the summer spawning season. Further restrictions became necessary, however, and in 1929 a 3-1/2 inch commercial size limit was adopted.

In addition to the commercial fishery, a relatively large, unrestricted, personal-use recreational fishery had developed by the late 1920s. The widespread clam wastage and "bootlegging" (harvesting and/or selling clams illegally) associated with the recreational fishery finally led to the institution of sports-take regulations in 1929 (Schaefer, 1939). A summary of these regulations from 1929 to the present is given in Table 2.

The commercial razor clam industry changed significantly during and after the 1940s, partly because of circumstances that adversely affected the canneries. Because of declining clam stocks, a poundage quota, or allotment, system was imposed which, coupled with the limited commercial season, placed considerable economic strains on razor clam canners.

Expansion of Washington's Dungeness crab fishery contributed to the canners' problems. After World War II increased offshore crab harvesting placed additional demand on the limited supply of razor clams, which were a favorite bait of crab fishermen.

During the early 1950s inexpensive East Coast canned clams made a dramatic entrance into traditional razor clam markets and placed

Table 2. Washington State Razor Clam Fishery Personal Use Regulations, 1929-present.

Year	Bag Limit	Legal Size	Season
to 1929	None	None	None
1929-42	36 clams/person	3-1/2 inches	None
1943-47	36 clams/person	None	March 1 - Sept. 30
1948-59	24 clams/person (except 18 in 1950)	None	March 1 - Sept. 30
1960-72	18 clams/person	None	March 1 - Sept. 30
1973-present	15 clams/person	None	July 1 - Sept. 30, complete closure; Afternoon closure, March 16 - June 30

canned West Coast razor clams at a distinct competitive disadvantage. As a result, the razor clam canning industry in Washington declined rapidly, and a greater share of the commercial catch that had been canned went to crab bait and fresh clam markets. By the late 1950s about 30 percent of Washington's commercial razor clam production was shipped to Oregon and California for crab bait. Attempts by the state to prohibit out-of-state exports were overturned in court.

The export of large quantities of razor clams for crab bait, along with the burgeoning recreational fishery, contributed to the demise of the commercial fishery. Because there was only a nominal $5.00 fee for a commercial license, many sports fishermen purchased the licenses in order to avoid recreational limits. By the 1960s, an estimated 30-40 percent of the commercial landings was actually harvested for personal use. Eventually, commercial digging was permitted only if there was a surplus of clams from the recreational fishery. In addition, several beaches were permanently closed to commercial fishing: Long Beach and Twin Harbors Beach in 1950, Copalis Beach in 1960, and Mocrocks Beach in 1968.

The sole remaining, non-Indian, commercial fishery in Washington exists—albeit sporadically—on the detached spits at the mouth of Willapa Bay. Because this area is not easily accessible and the stocks there are unstable, the fishery is difficult to manage and has no seasonal restrictions. It is a small fishery with reported catches of only 6,000 to 28,000 pounds annually. However, much more effort is expended and clams harvested than the reported catches indicate. Since the commercial license is still only $5.00 and there are no limits or restrictions on keeping clams for personal use, clams are harvested under a commercial license for personal use. In 1979 and 1980, over 1,500 commercial licenses were issued, but only 6.3 percent of the licensees reported commercial landings. To discourage improper use of the licenses and non-reporting of clam harvests, the Washington Legislature considered a bill in March 1981 that would raise the commercial razor clam fee substantially. The bill was not passed, but was to be reconsidered in the 1983 legislative session. An additional provision would require that all clams harvested commercially be sold, making it illegal to harvest razor clams for personal use with a commercial license.

Since 1960, most of Washington's commercial razor clam production has come from the Quinault Indian Reservation. Production statistics from 1950 through 1980 indicate that the catch averaged about 260,000 pounds per year. Data for the last decade provided by the Quinault Indian tribe are summarized in Table 3.

There was a record harvest of 890,161 pounds worth approximately $712,000 in 1977-78, mainly as a result of increased digger effort, a 13-month digging period, and light surf conditions in January and February 1978, which permitted more clam digging.

Prior to 1972, clam harvesting on the Indian reservation was loosely regulated. Since then the Quinault tribe has instituted more stringent rules. Clam harvesting by non-Indians is not allowed on reservation beaches, and Indian diggers are required to purchase a tribal license (about $5). Although clams may be dug year-round (as of early 1981), digging is allowed only on low, minus tides. The Indians harvest their clams with shovels and, because hand digging is a traditional part of tribal life as well as an important source of employment, there is little interest in using mechanical methods.

Buyers of reservation clams may be non-indian, but must purchase a tribal license. They buy clams from diggers on the beach at prices set by the tribe ($.90 per pound whole wet weight in 1981). Depending on the market, about half of the clams are sold for crab bait and the rest enter the fresh and frozen retail and restaurant markets. Razor clam processing on the reservation was attempted but could not be successfully implemented because of high processing costs and labor and quality control problems.

In addition to stricter regulation of the fishery, the Quinault tribe improved their management program. Since 1972, an annual standing crop assessment of reservation beaches has been made, and recommendations submitted periodically in order to maintain a high yield and maximize profits to tribal clam diggers.

Current Status

The razor clam resource is an important source of revenue to some members of the Quinault tribe and about 300 Indians were licensed in 1981 to dig clams. Market demand exceeds the supply of clams, so prices have remained relatively stable. However, the

Table 3. Quinault Indian Tribe Razor Clam Production, 1970-1980

Year	Pounds Landed*
1970	750,000
1971	678,838
1972	379,086
1973	179,818
1974	201,139
1975	135,033
1976	294,952
1977	373,142
1978	890,161
1979	645,389
1980	373,581

*One pound = approximately 4.2 clams

harvest record for the 1978-79 and 1979-80 seasons indicate that a decline occurred in both total clam abundance and average size. Reasons for the decline are unclear, but it probably resulted from a combination of factors, including a normal fluctuation in the clam population, over-harvest, and weather and market conditions.

To better monitor clam productivity and abundance, the fisheries division of the Quinault tribe has designed a detailed field sampling program; however, it lacks the personnel and funds to begin the new program. If razor clam harvests continue to decline, limits or reductions of total harvest, beach areas, or number of diggers may be considered.

Future

Because of its unique status, the Quinault razor clam fishery has the potential to become one of the most viable, commercial clam fisheries in Washington. For example, both the beach and uplands are exclusively held and managed by the tribe and are therefore less subject to encroachment by residential development than Puget Sound beaches. In addition, the Quinaults are exempt from most state and federal regulations, as well as many other political, social, and economic forces influencing Washington's non-Indian clam fisheries.

The future of the razor clam market is difficult to predict, since it depends to some extent on the demand for Dungeness crab bait, which is temporarily depressed. The fresh and frozen razor clam market for human consumption is improving, however. Rising prices for clams, aggressive marketing, and increasing public acceptance could insure a continued solid base and modest growth for this segment of the market. The limiting factor is supply, which will continue to be contingent on the vagaries of natural setting.

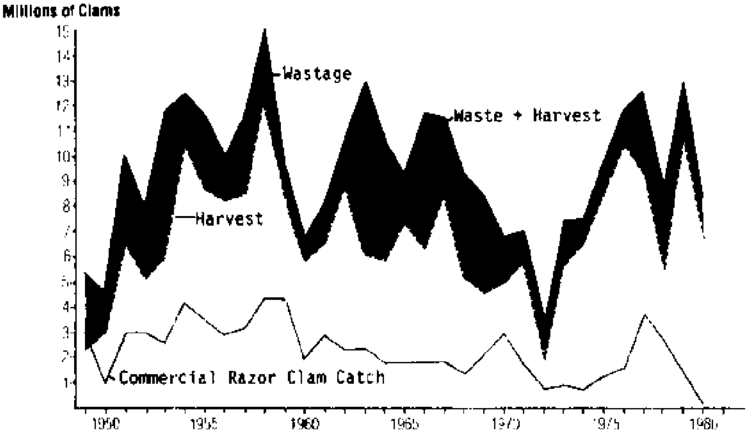
Recreational Razor Clam Fishery

As noted earlier, Washington's razor clam fishery has evolved from a commercial one to a predominantly recreational one. Figure 3 documents the latter stages of this transition, which ended in 1968 when the last major public beach was closed to commercial harvest. Recreational digger trips increased dramatically from 208,000 in 1946, when annual monitoring of the sports fishery began, to over 950,000 in 1977 (Figure 4). A 1980 decline in digger trips and number of clams harvested was attributed to a combination of extremely bad weather during many low tides, the depressed economy, rising gas prices, and the second 1980 eruption of Mt. St. Helens on May 26, which deposited volcanic ash on the highways to the beaches.

Current Status

Management of the recreational razor clam fishery by Washington Department of Fisheries consists of three basic aspects: management-enhancement, enforcement, and licensing. Management-enhancement includes a monitoring system to estimate number of diggers, average catch, size of clams taken, wastage, and total catch. Biological data such as assesement of clam abundance, reproduction, and recruitment are also compiled.

Recruitment and setting of razor clams have generally been declining, especially at Grayland and Long Beach, where populations are at very low levels. The two northern beaches, Copalis and



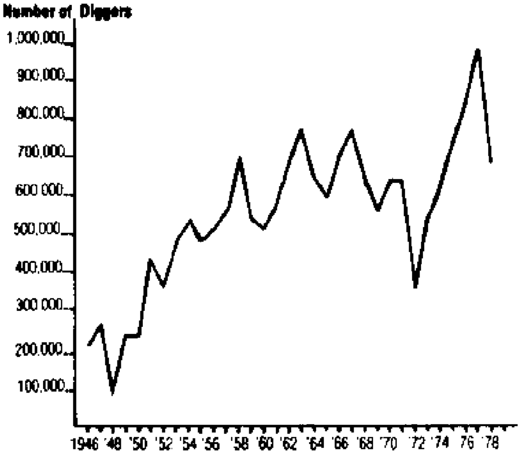


Figure 3. Summary of recreational and commercial razor clam harvest in Washington State, 1949–1981. Shaded area indicates estimated number of clams wasted.

Figure 4. Number of recreational clam harvesting trips (digger trips), 1946–1978.

Mocrocks, have had sporadic razor clam setting and inconsistent recruitment. Offshore clam populations are considered broodstock for intertidal populations, but how much they contribute is unknown and depends on ocean currents during early larval and juvenile stages of development.

A program has been initiated to enhance natural razor clam set on some beaches. Sexually mature razor clams were successfully spawned at the Nahcotta clam hatchery, resulting in the production of over one million juvenile razor clams. The clams were planted at selected sites in the spring of 1981. Transplanting of subtidal juvenile clams to underpopulated intertidal areas is also being studied and may prove to be an additional method of enhancing razor clam stocks.

Regulation enforcement is an integral part of the razor clam program. As a result of increased razor clam license funds (resident license fee is $2.50; nonresident license fee is $10 as of 1979), six additional officers were hired to patrol razor clam beaches. The number of citations issued increased during 1979 and 1980, and reports indicated that the officers contributed significantly to the enforcement of fisheries laws.

Present regulations require that all persons digging or possessing razor clams must have a recreational razor clamming license. The first 15 clams dug must be retained, regardless of size or condition. In addition, emergency beach closures are sometimes invoked to prevent wastage, especially when the standing stock of large clams on a beach is low and the abundance of undersized clams is large. This conservation method allows clams to grow large enough to satisfy sports diggers.

Despite stricter regulations and increased beach surveillance, illegal digging still occurs. Although catch statistics suggest that the fishery has not changed markedly, they do not reflect the extent of illegal digging, which some experts consider to be significant, perhaps equal to reported catches.

One program that may contribute to conservation efforts is education of the general public about razor clams and management procedures. The shellfish division of the Washington Department of Fisheries has such an education program planned for 1983, which it is hoped will result in a more responsible attitude toward the resource by recreational diggers.

Future

The future of the recreational razor clam fishery depends on many variables. Washington Department of Fisheries management personnel expect the fishery to remain stable and speculate that the general economy, the price of gasoline, lower clam populations, and to a minor extent the license fee itself, may prohibit increased participation. Major contributions from various enhancement projects may eventually improve the fishery, but not in the immediate future.

Commercial Bay Clam Fisheries in Puget Sound

Most of Washington's bay clam fisheries are found in various parts of Puget Sound. The species of clams found in Washington estuaries that have traditionally been important as commercial species are native littlenecks, Manila clams, butter clams, horse clams, softshell clams, and geoducks. Native littleneck and Manila clam harvests are closely associated with the oyster industry of southern Puget Sound. In central Puget Sound there is intertidal harvesting of native littleneck, Manila, and butter clams, as well as subtidal harvests of native littleneck, butter, and horse clams by mechanical harvesters. Butter and horse clams are generally harvested incidental to the highly valued native littleneck clams.

The extensive clam beaches of Puget Sound supported a small, but stable, commercial bay clam fishery in the early 1900s (Kincaid, 1919; Nightingale, 1927). Most of the productive clam beds were located in southern Puget Sound and Hood Canal. This industry was based primarily on native littleneck and butter clams. Since both species occur in similar habitats and can be dug together, and because they are highly palatable and relatively abundant, native littleneck and butter clams found a ready place in the fresh and canned clam markets in Washington's early days.

The early fresh market trade was limited by the shelf-life of the clams and the demand of the local market, whereas the Washington bay clam canning industry was forced to compete with canned East

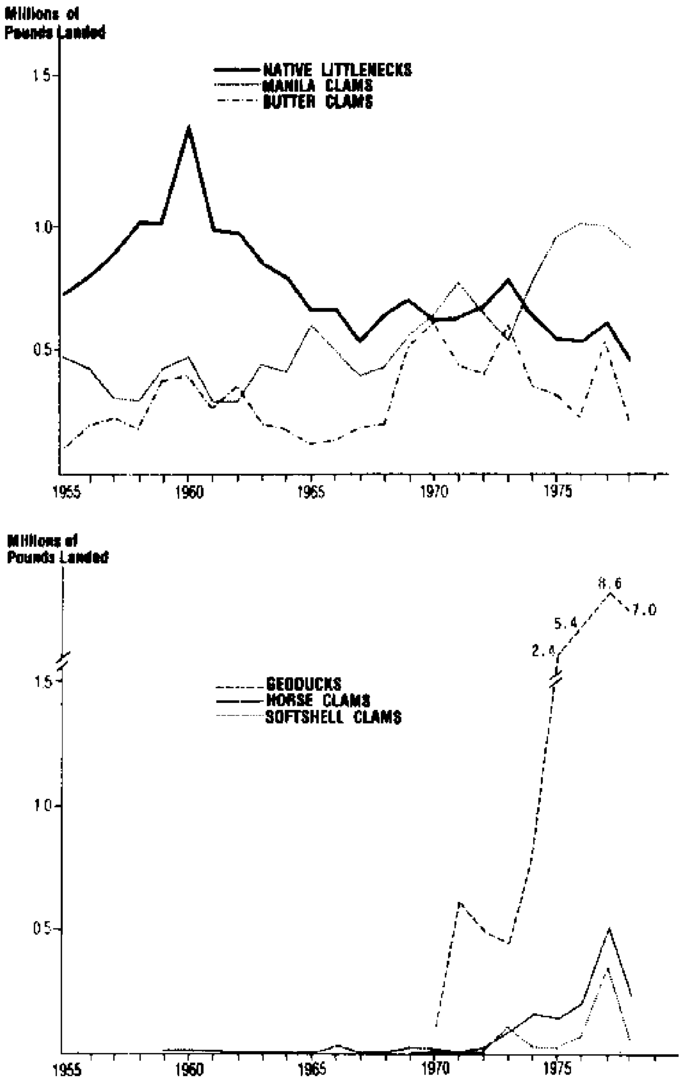


Figure 5. Washington State bay clam production, by species, 1955–1978. (Production figures for 1979–1981 have been included in Appendix A.)

Coast clams and razor clams. The butter clam's large size (up to 5 inches), high meat yield, and good flavor made it suitable for canning, but most native littlenecks were marketed fresh. Some butter clams were sold unshucked, but because they gape and lose fluids during storage, their shelf life is limited to a few days.

Data are not available to analyze historical trends in the early bay clam fishery, but the combined catch statistics for native littleneck and butter clams indicate that, except during World War I, production was relatively stable during the first quarter of the 20th century. Hardshell clam production remained relatively stable at one to two million pounds per year up to 1975, except for 1937

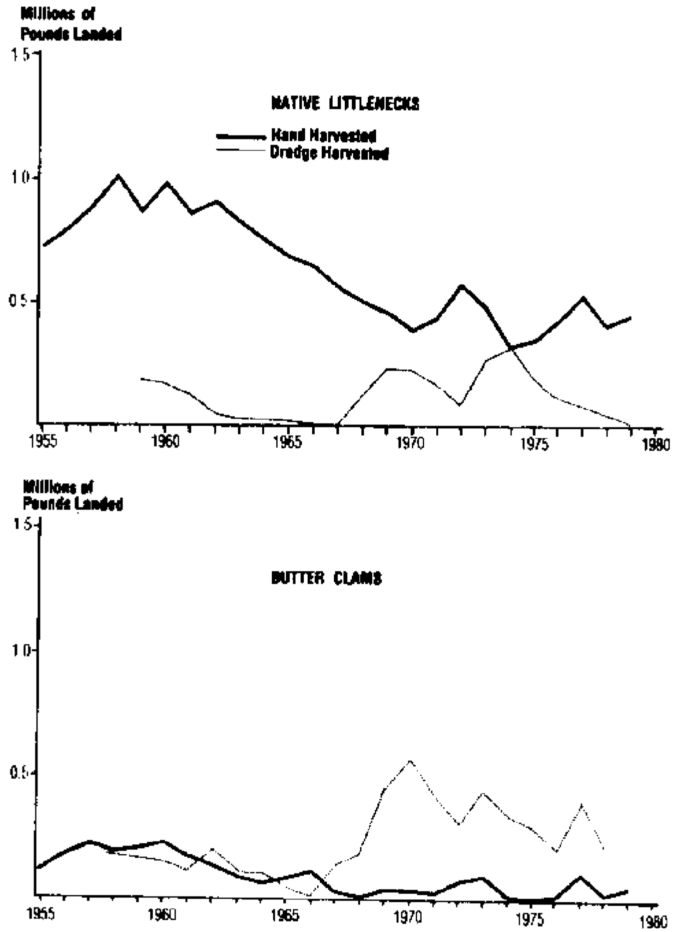


Figure 6. Native littleneck and butter clam production, by harvesting method, 1955-1979. (Production figures for 1980-81 have been included in Appendix A.)

when there was a record harvest of about 3.5 million pounds. Production figures for all Washington clam fisheries are given in Appendix A.

Although total bay clam production, excluding geoducks, has not changed noticeably, the proportional harvest of different species has changed. Native littleneck production, for example, declined during the last 20 years from approximately one million pounds per year in the late 1950s to only 500,000-600,000 pounds in the late 1970s (Figure 5).

The Manila clam, an exotic species accidentally introduced into the United States along the Pacific Coast, began making significant contributions to the southern Puget Sound fishery after World War II. Production rose from about 400,000 pounds per year in the early 1960s to over one million pounds in 1977. In recent years it has been the most valuable commercial clam resource in Washington, but since about 1975 it has been surpassed in terms of production and value by the geoduck.

Harvesting methods of bay clams significantly affected annual catch rates (Figure 6). The hand-harvested catch declined steadily after the early 1960s. A number of factors contributed to the decline: use of hydraulic-escalator harvesters for harvesting intertidal clam beds, relatively low prices paid for butter clams, general reduction in the number of clam beds in commercial production, and possibly overharvesting in the late 1950s and early 1960s without sufficient setting to maintain production.

Introduction of the escalator harvester to Washington in 1959 not only supplemented native littleneck and butter clam production, its use also generated a small horse clam industry. Despite its abundance on some intertidal beaches, the horse clam had never gained much acceptance in Washington. It has a number of characteristics that tend to discourage commercial harvesting: hand harvesting is difficult because it burrows deep; it has a fragile shell that tends to break; and the valves gape, resulting in water loss and reduced shelf-life. The meat yield is low (only 25-30 percent of the total body weight is marketable), and the neck, which makes up about 60 percent of the shucked weight, has a tough, leathery, siphonal skin that requires considerable processing effort (Quayle and Bourne 1972). Many people consider the meat to be excellent for chowder stock or clam steaks, however.

Prior to 1973, horse clam production was erratic and not economical in Washington. The price paid to harvesters was about $1.00 per 55-pound bushel, which did not meet the $.015 per pound royalty. In 1973, however, horse clam production increased substantially as a result of a price increase to $.08 per pound, and in 1979 dredged horse clams delivered dockside fetched about $.12 per pound with a $.03 per pound royalty. Although horse clams have been more economical to harvest in recent years, the fishery has remained strictly incidental to subtidal native littleneck and butter clam harvests.

Commercial harvest of softshell clams with the Hank's harvester began in 1969 on privately owned and leased intertidal ground in Port Susan and Skagit Bays. A profitable specialty retail and institutional market for shucked and steamer clams developed in California and production expanded significantly in 1973, when approximately 104,000 pounds were landed (Figure 5). The softshell industry was virtually halted for the next several years by lawsuits prohibiting the use of mechanical dredges under Washington's Shorelines Management Act. However, a record 358,000 pounds of softshell clams were harvested in 1977, 341,500 pounds of which were hand harvested on tidal beds adjacent to the Skokomish Indian Reservation. Almost all of the clams were shipped to the East Coast where local clam supplies were severely limited because of disease and severe winters (Oceanographic Institute of Washington, 1981). Subsequent production figures show a marked decrease in softshell clam harvest.

Current Status—Intertidal Harvest

The intertidal hardshell clam fishery is a vital component of Washington State's commercial clam industry. Many small clam farms are located in the numerous bays of southern Puget Sound, and Sequim Bay, Discovery Bay, Port Townsend, Port Gamble, and in Hood Canal, Willapa Bay, and Grays Harbor. Most intertidal clams are harvested by hand on tidelands that are either owned by the harvester, or leased from other private owners or the state. Harvesters that lease tidal tracts are assessed a royalty or "stumpage fee" on the number of pounds harvested. The fee varies from $.03 to $.25 per pound, depending on the ownership of the land, and the species harvested.

The hardshell industry in south Puget Sound is closely aligned to the oyster industry and most clam growers are involved with both bivalves. Because of the abundance of Manila clams in south Puget Sound, clam harvesting is economically viable—perhaps the most lucrative of all intertidal bivalve endeavors in Washington. Manila clams are readily marketable at profitable prices, which—at least in recent years—have increased rapidly. In addition, processing costs are minimal and production costs are relatively low, consisting primarily of capital investment in clam ground, hand-harvest costs, and operating expenses.

Unlike the oyster industry, which depends on imported seed, south Puget Sound clam harvesting relies totally on cost-free natural reproduction. Although there is some variability in Manila clam setting, it occurs fairly regularly—particularly compared to native littleneck and butter clams—and there are enough good years to compensate for the poor ones. Also, because clams grow at different rates on different beds, the beds may be managed for fairly steady yields to match the demand of established markets.

The economics of the native littleneck industry are complicated because of the diversity of the industry and wide variations in cost and price. The figures in the paragraphs that follow are not intended to be representative or average, but are simply estimates based on several interviews. It is interesting to compare 1979 price estimates with those given by Goodwin and Westley (1969) in Table 4.

According to the Washington Department of Fisheries, the 1979 wholesale price for subtidal native littlenecks delivered dockside was $.40 per pound, and overhead costs averaged about 60 percent of the sale price. Harvesting subtidal clams apparently provides a very good return on investment; however, it is not clear whether this is true for intertidal native littlenecks. Variability in production costs for littlenecks may be related to taxes, value of tidelands, low productivity due to variation in recruitment, and the relatively slow growth rate of the clam.

Table 4. Intertidal Harvest, Cost per Unit of Output 1969 and 1979.

Expense Item	Cost per pound 1969*	Cost per pound 1979
Harvesting-- hand digging	$.10	$.25
Stumpage value to beach owner		
State lands	.03	.03-.05
Private lands	.06	.10-.25
Processing	.03	.05
Wholesale price of clams/pound	$.20-.30	$.70-.95

*Goodwin and Westley, 1969

Hardshell clams on intertidal beaches are harvested year round by contract diggers using forks or rakes. Most of these clams are sold fresh, unshucked, to wholesale fish houses in Seattle, Portland, and Newport. The price to the producer for hardshell clams (mostly native littlenecks and Manilas) was about $1.00 per pound in August 1980, but may have been higher in distant markets such as Los Angeles, which pay more for fresh clams. Most butter clams are dredge-harvested from subtidal stocks because the high cost of hand harvesting ($.09 per pound) relative to the market price limits intertidal harvest.

Except for 1977, intertidal harvest of softshell clams has remained relatively low and, because of existing restrictions on mechanical harvesters, is done totally by hand. Although the potential of these clams has long been recognized, it has never been realized. Washington Department of Fisheries surveys of commercially harvestable areas in Port Susan and Skagit Bays indicate a standing crop of about 19 million pounds covering 1,200 acres, with an estimated annual maximum sustained yield of about 1.9 million pounds (Goodwin and Jones, 1976). Allowances were made in the estimates for areas that could not be harvested because of sewage pollution and state regulations against harvest near drainage slough areas or areas with attached vegetation. Although early 1980s prices for softshell clams were relatively good (about $.91 per pound unshucked and $3.00 per pound shucked), the softshell clam harvest is not yet a significant factor in Washington's clam industry.

Current Status—Subtidal Harvest

Harvesting of subtidal hardshell clams in Washington is done with mechanical dredges on publicly owned beds leased from the state. The principal species harvested are native littleneck, butter, and horse clams. Leases are granted by the state on a first-come, first-served basis, with site selection determined in one of two ways. First, many sites are selected on the basis of pre-existing Washington Department of Fisheries (WDF) clam surveys. Alternatively, a prospective harvester, in the presence of a WDF observer, is allowed to explore potential clam ground (generally areas with fast currents and rock-gravel substrate).

Although native littlenecks are the most desired species, there are few clam beds containing only littlenecks; most clam beds have other species as well. A dredger looks for a tract that will produce a balanced mixture of native littlenecks, butter clams, and horse clams in profitable volumes. In assessing the worth of a tract, one dredger stated that he uses the following criteria: estimated daily harvest of 800 pounds of each species (a good clam bed can yield up to 200 pounds of native littlenecks per hour), protection from strong winds and rough water, acceptable water quality, and little likelihood of complaints from adjacent upland owners.

Once a desirable tract is found, the harvester finances a survey by Washington Department of Fisheries ($800-$1000) to estimate the standing crop, species composition, and total area. On the basis of the survey, the Department of Natural Resources assesses a minimum lease fee of $5.00 per acre per year. The harvester must also pay a royalty fee of $.05 per pound for native littlenecks, and $.03 per pound for butter and horse clams. Current estimates of prices paid to harvesters for hardshell clams from subtidal tracts are $.50 per pound for native littlenecks, and $.20 per pound for butter and horse clams.

Most native littleneck clams harvested subtidally are sold in the fresh markets, but butter clams are marketed fresh, frozen, and as canned chowder stock. The demand in recent years for canned butter clams has been small, primarily because of competition from less expensive East Coast imports, and severely depressed prices. Even though the market is improving, the price paid to harvesters remains relatively low. Other markets for butter clams include a small half-shell trade, clam strips, and fish and crab bait. The fresh food market brings $.95 per pound wholesale and $1.15 per pound retail.

Until recently the only market for horse clams was at a local cannery. Horse clams are mixed with butter clams in chowder stock and are used in the preparation of clam nectar. Because of the low meat yield, and labor involved in processing, horse clam harvesting is little more than a break-even endeavor. An additional crab bait market for horse clams has developed but it has not improved product price.

Future

In general, the future for the hardshell clam industry is promising. The market is constantly improving as demand continues to exceed supply, and there is some potential for increased harvesting in some areas. For example, production in southern Puget Sound might be increased through better clam bed management and the conversion of low profit oyster grounds into clam grounds. In addition, there are over 1,000 miles of public shoreline that could be utilized for commercial intertidal clam culture if techniques such as clam seed planting and/or beach enhancement were employed.

Planting beaches with hatchery-reared seed is being evaluated by the School of Fisheries at the University of Washington as one method of minimizing the problem of setting variation (Miller et al., 1978), particularly with respect to the native littleneck clam. The cost of hatchery seed has been prohibitive until recently, but one clam hatchery in Washington is selling Manila clam seed for approximately $4.00 per thousand for 10 mm clams. Although survival of hatchery seed to market size is low, this method may be a potential way to improve productivity of marginal lands.

Beaches can also be enhanced to provide a more suitable habitat for clams. One procedure involves the removal of mussels from clam beds to prevent accumulation of silt on the substrate. The substrate can be altered by working pea gravel into the sand or mud, providing a better medium for the clams and added protection for juvenile clams. To stabilize the substrate and reduce predation, the University of Washington's School of Fisheries is investigating the use of plastic netting on clam beds. A pilot study indicated that not only was the netting economical, it dramatically increased survival of both hatchery clam seeds and natural sets (Anderson and Chew, 1980).

The economic feasibility of Manila clam aquaculture has been demonstrated for certain areas in Puget Sound (Anderson et.al. 1982). However, only marginal profits can be expected in most instances, even with good management practices. The greatest sucess in Manila clam aquaculture will probably inure to clam and oyster growers who already have the capital, personnel, and intertidal land available for planting clam seed on a large scale.

The market for native littleneck clams is expected to remain favorable, but supply will depend on a number of factors, including reproductive success in clam producing areas that have a history of marked variation in setting, continued farming of productive intertidal beaches, and continued production from subtidal areas. Use of existing clam dredges is limited to a maximum water depth of 25 feet. Development of a subtidal dredge that can operate in deeper water could increase subtidal production substantially.

Continued utilization of subtidal clam stocks is also an important factor affecting the viability of the butter clam industry. The standing crop of butter clams in Puget Sound is estimated to be as high as 113 million pounds (Goodwin and Shaul 1978). Although clams cannot be harvested in all the subtidal areas surveyed because of water depth, substrate composition, or pollution, there is still a large resource of harvestable subtidal butter clams yet unexploited. The potential for expanding the butter clam market and improving product prices is promising. If prices rise sufficiently, intertidal hand harvest could be augmented by increased digging efficiency. Present prices do not provide enough incentive, however, for hand diggers to dig deep enough (10 feet or more) to effectively harvest butter clams.

The potential for the horse clam industry is similar to that for butter clams. Foreign buyers have inquired about the possibilities of marketing 20,000 to 30,000 pounds of horse clams per month. A Japanese company is interested in air-freighting whole, live horse clams to Japan. With increased interest, the fishery's prospects may improve, not only for subtidal harvesters, but perhaps for intertidal harvesters as well.

The future of the softshell clam industry is uncertain, because of restrictions barring the use of mechanical harvesters in that fishery. However, as 1977 production figures indicated, hand harvest can be profitable in a favorable market. Recent estimates of wholesale prices ($.91 per pound unshucked) indicate that the potential for profitably harvesting softshell clams is excellent.

Commercial Geoduck Fishery

Although the geoduck has never been abundant enough on Puget Sound's intertidal beaches to support a commercial fishery, there has been a small but very popular intertidal sports fishery. Commercial intertidal harvesting of geoducks was banned in the 1920s because the Washington Department of Fisheries feared overharvesting and wished to retain the recreational fishery. The ban remained in effect until 1969 when the Washington State Legislature amended the law and changed the status of the geoduck from a sport-only clam to a sport and commercial species. This change was a response to extensive surveys initiated by the fisheries department in 1967 and partially financed by the National Marine Fisheries Service to assess the distribution and abundance of Puget Sound's subtidal clams. Although the discovery of significant hardshell clam beds was expected, the large subtidal standing crop of geoducks found was an

Table 5. Estimates of Geoduck Standing Crop in Puget Sound, 1973.

Location	Acres	Estimated Number of Geoducks
San Juan Islands	160	307,000
Strait of Juan de Fuca	6,685	12,788,000
Central Puget Sound (including Hood Canal)	17,272	68,427,000
Southern Puget Sound	8,807	24,905,000
Total	32,924	106,427,000

Source: Goodwin, 1973.
Additional surveys have increased the estimates to 33,799 acres with 117,653,000 geoducks in various parts of Puget Sound and contiguous waters (Goodwin, 1978).

unforeseen benison. The initial surveys showed that subtidal geoduck stocks could support a commercial harvest (estimates of the standing crops in four regions of Puget Sound are given in Table 5.) Additional surveys have increased the estimates to 33,799 acres with 117,653,000 geoducks in various parts of Puget Sound and contiguous waters (Goodwin, 1978).

Harvest of subtidal geoducks commenced in 1970, but strict regulations were placed on the new commercial fishery. Harvest was restricted to areas no closer than a quarter mile from shore and in water no shallower than 10 feet below mean lower low water (MLLW). In addition, harvesting could be done only by divers using hand-held water jets or suction devices and only during daylight hours; however, no restrictions were imposed on seasons, sizes, or catch limits.

Because subtidal lands are state-owned and managed by the Department of Natural Resources, tracts were leased to harvesters by the state at public auction. The highest bidder (bonus bid) for a given tract had the exclusive right to harvest geoducks from the tract for a period of five years, after which time the lease reverted to the state and was renewed or cancelled. Harvesters paid a royalty fee of $.03 per pound (whole weight) on harvested geoducks and a one percent catch tax in addition to purchasing a Washington Department of Fisheries clam farm license and a geoduck harvest permit. Since the fishery began in 1970, approximately 2,500 acres of subtidal lands have been leased for commercial geoduck harvesting.

Although the potential annual harvest from the original leases was estimated to be about two million pounds per year, landings actually averaged only 400,000 pounds annually prior to 1974. The intent of industry pioneers was to harvest and sell whole, unprocessed clams. Unfortunately, only a very limited--although profitable--whole clam market developed. In order to expand its market, the industry was forced to develop a more salable product form and began processing the clams into steaks and chowder meat. According to an economic survey of the early industry (Erickson, 1972), approximately 90-95 percent of the harvested geoducks were sold in these forms. However, markets for these products proved insufficient, and the industry—plagued by lack of capital, limited markets, and high production costs—experienced economic difficulties. Only one processing firm survived this period.

During 1974 a large Japanese market was found for frozen geoduck steak siphons, and Washington's geoduck landings in 1975 soared to 2.4 million pounds. Subsequent production figures have exceeded the 1975 statistic (Figure 5).

Current Status

The demand for Washington geoducks in Japan has greatly expanded the market for these clams until 1982. Catch statistics reflect the rapid expansion and have been 5 million pounds or greater since 1975 (Figure 5), with a record catch of 8.6 million pounds in 1977. During 1982 a geoduck fishery began in Japan which eliminated the demand for Washington geoducks there. As of late 1982, approximately 160,000 pounds per month of the Japanese geoduck (*Panope japonica*) were being harvested. The development of the Japanese fishery was a major, but temporary, blow to the Washington geoduck industry, which had previously sold 50 percent of its harvest to Japan. However, the 1982 geoduck harvest in Washington met the maximum five million pound quota set by the Washington State Department of Fisheries, and new U.S. markets have partially compensated for the loss of the Japanese market.

The geoduck fishery is now the largest clam fishery on the West Coast, both in terms of value and number of pounds landed. The market price for geoducks is about $.35 to $.50 per pound and some estimates range as high as $.58 per pound. Divers receive between $.15 and $.25 per pound, depending upon the quality of the clams harvested.

A few changes have occurred in some of the geoduck harvesting regulations as well as the market. For example, the quarter-mile offshore, ten-foot depth restriction was altered for leases procured after June 30, 1979; harvesting is now permitted only 200 yards offshore (from mean high water), or at depths of 18 feet (below MLLW), whichever is more seaward. This new regulation doubled the area available for commercial geoduck harvest. Although there are indications that geoducks are more abundant in water up to 200 feet, harvest is limited to about 60 feet because diving time is severely limited in deeper water. In addition to the new offshore limit, the lease period has been reduced from five years to twenty months, and a maximum quota of 500,000 pounds has been set on tracts in many areas.

Some people close to the industry speculate that a monopoly exists in the Washington State geoduck industry, but they admit that this is difficult to verify because of the existence of surrogate or "dummy" companies. There is also a substantial amount of illegal harvesting (off-tract and/or night harvesting) as well as inaccurate reporting of landed quantities in order to reduce royalty payments to the state ($.08 per pound in 1981).

Factors such as the limited number of tracts, and financial constraints (bonus bids, bonding requirements, etc.) associated with the geoduck industry have reduced the number of participants in the fishery and prevented many new operators from entering it; however, there is little doubt that the industry is profitable for those already involved in it. There are 12 to 20 vessels currently harvesting geoducks from 11 tracts (approximately 18,500 acres) in Puget Sound.

Although much of the geoduck harvest is marketed in Japan, an increasing amount is being sold in Washington and other states as "king clam steaks," to avoid using the common name, "geoduck." This product and others are gaining acceptance in U.S. markets as a result of improved processing techniques and a general demand for clams.

Future

The geoduck fishery will probably maintain or exceed its present value and level of harvesting for some time to come, but changes in management and enforcement policies may be necessary to insure the stability of the resource. One solution implemented in 1982 was to confine all new leases to one area in south Puget Sound and lease tracts on a one-year basis. This not only allows easier enforcement of fishery regulations, but also prevents overharvesting of tracts. The dawn-to-dusk harvesting time limit may also require some alteration to assuage upland residents who complain about the noise from on-board air compressors and water pumps.

No techniques are employed at this time to enhance geoduck production on leased tracts. However, experimental re-seeding of geoduck beds with hatchery-reared seed has been conducted by the Washington Department of Fisheries and may provide a way to shorten rotation times for tracts and further increase production.

Recreational Clam Fisheries

The Washington Department of Fisheries began collecting information on the effort and catch of the Puget Sound recreational clam fishery in 1973. This was an ambitious undertaking, considering that the Sound has about 2,000 miles of shoreline, about 800 miles of which are publicly owned and contain over 300 major public user locations scattered throughout the state. In addition, creel sampling (sampling by examination of the sport catch to determine target species and amounts harvested) indicated that the fishery consists of 11 species: the native littleneck, Manila clam, butter clam, two species of horse clam, cockle, softshell clam, three species of *Macoma*, and geoduck.

Digging effort has been estimated by a complicated sampling scheme using aerial observations covering about 60 percent of the shoreline and 80 percent of the user locations. Catch is estimated by creel census of users on the beach. An average estimate of 774,000 user trips and an average catch of 2.3 million pounds of clams per year for the period 1972 through 1978 represents a considerable fishery (Table 6).

As a result of the magnitude of the recreational clam fishery, the Department of Fisheries instituted a sports fishery program in its shellfish unit. A major goal of the program has been to inventory public beaches, elucidating locations, boundaries, and--where necessary--ownership, since a variety of federal, state, and local governmental agencies own tidelands. Another goal is to increase recreational clamming areas by permitting harvesting on public beaches that presently lack access by acquiring more public beaches through clarification of ownership.

Table 6. Puget Sound Recreational Clam Effort and Harvest, 1972-78.

Year	User Trips	Harvest (lbs.)
1972	823,000	2,734,000
1973	695,000	2,447,000
1974	890,000	3,254,000
1975	744,000	2,142,000
1976	709,000	1,376,000
1977	798,000	2,104,000
1978	760,000	1,885,000

In addition to expanding the number of beaches available to the sport clam fishery, biological studies to evaluate ways to increase the productivity of the Washington public beaches have been initiated. Methods being studied include habitat improvement (e.g., altering the substrate to increase clam production), and seeding of beaches with hatchery-reared juvenile clams. Even if procedures are initially successful, there is no guarantee of long-term production since good clam production depends on many variables. There are a few good beaches, such as one at Fort Flagler State Park (which yields an estimated 11 tons of clams per acre per year). Such areas are rare, however, because clams are usually overharvested on productive beaches, and the beaches may not be capable of sustaining high yields.

Some difficulties encountered in developing a management program for the sports clam fishery in Washington have been lack of recognition of the recreational fishery as a legitimate land use and lack of coordination among government agencies. Resolution of some of these problems was necessary before research and enhancement projects could be initiated.

Another problem is recreational clam diggers' apparent ignorance of regulations, especially those concerning bag limits (40 clams per person in Puget Sound). This lack of information could probably be alleviated by a public education program.

Industry Problems and Constraints

Environmental Quality

Water quality is a primary consideration for clam growth and harvesting. Domestic pollution in Washington waters has reduced by about 25 percent the potential areas for subtidal hardshell clam harvesting because clams from the affected areas do not meet certification standards of the Washington Department of Social and Health Services (WDSHS). In addition, a number of potentially harvestable intertidal clam areas are not certified, including Dyes Inlet and parts of Totten Inlet and Oakland Bay in south Puget Sound (Hayes, personal communication). Only one sewage treatment plant in Puget Sound presently has secondary treatment capabilities, and most of the domestic pollution that enters the Sound from treatment plants has undergone only primary treatment.

Paralytic shellfish poisoning (PSP) is a recurring problem in Washington waters, as it is all along the Pacific Coast. The causative agent of PSP is the marine dinoflagellate *Gonyaulax* sp., which becomes concentrated in filter feeders, such as bivalve molluscs, during certain times of the year, especially summer and fall months. The WDSHS monitors certain clam producing areas for PSP from May through October. Areas in Washington that are regularly affected by PSP are Sequim Bay and Discovery Bay along the Strait of Juan de Fuca. A large bloom in the fall of 1978 distributed *Gonyaulax* cysts into south-central Puget Sound as well. Consequently, PSP was detected as far south as Fauntleroy and Des Moines during the summer of 1979 and south of the Tacoma Narrows Bridge by the summer of 1980. Some recreational shellfish harvesting in intertidal areas around Vashon Island were closed during the 1979 outbreak because of PSP contamination. Subtidal shellfish were not seriously affected, however.

In order to provide accurate information to the public regarding PSP, WDSHS has established a "PSP Hotline." This is a toll-free telephone number (1-800-562-5632) with an up-to-date status report on areas closed to shellfish harvest because of PSP.

Another problem affecting clam beds, particularly in the intertidal area, is siltation. In addition to silt deposition from natural runoff, storms, and floods, erosion from increased upland development and construction of marinas contributes to siltation of clam beaches. Subtidal clam beds have also been destroyed by dredging and dredge spoil disposal. In addition, there is some concern that the use of mechanical harvesters on subtidal and intertidal clam beds may adversely affect clams by suspending and depositing fine sediments, causing clams to be smothered.

Biological factors that govern the availability of clam resources include predation and variation in recruitment, or setting, which presents some difficulty in adjusting digging frequency to achieve maximum sustained production, particularly in marginal harvesting areas. The moon snail (*Polinices lewisi*) is a major predator of littleneck, butter, and to a lesser extent Manila clams, particularly in southern Puget Sound. The snail drills a hole in the clam and consumes the meat through the drill site. The only effective control is to hand harvest the snails. Additional predators include ducks and other birds, which consume considerable numbers of seed clams, and fish, crabs, and starfish.

Climatic conditions also influence clam fisheries, either by affecting clam beds directly, or by preventing harvesting. Strong wave action on exposed clam beaches can dislodge newly set and juvenile clams, subjecting them to predation. Survival of late summer razor clam sets can be adversely affected by winter storms, particularly if fall growth is slow (Tegelberg and Magoon, 1969).

Subtidal hardshell clam tracts located in areas subject to excessive wave action are not harvestable by dredge, particularly during the stormy winter season. Similarly, geoduck tracts located in areas exposed to winter storms are dangerous to harvest in bad weather. There is a problem within the industry of securing a balance between those tracts that can be harvested only in summer and those in sheltered waters that can be harvested during winter months.

In addition, there is an occasional "winter kill" of clams in southern Puget Sound, which sometimes results in heavy mortalities. Although the possibility of disease has not been totally rejected, this phenomenon is probably related to a combination of low salinity and freezing winter temperatures.

Marketing and Harvesting

Biological and environmental impediments notwithstanding, many of the crucial issues influencing the commercial clam industry are those involving labor, management, marketing, and government regulations. The first consideration is that of harvesting the resource. Hand digging is expensive in Washington, where labor costs generally are high. This limits hand harvest to land with relatively dense populations of clams. Mechanical harvesters used in Puget Sound are limited to water no deeper than 25 feet, and on relatively smooth bottom terrain. Large areas of subtidal clam land are located in deeper waters or over rocky terrain. Much of the intertidal clam area is simply too small and too rough for mechanical harvesting, necessitating hand harvest.

A number of people in the hardshell clam industry have expressed concern about the potential adverse effect of mechanical harvesters on clam ground productivity. Whereas hand digging is claimed by some to improve clam beach quality, there is a tendency for mechanical harvesters to cause substrate compaction.

Obtaining reliable labor is a continuing problem. The labor source for intertidal harvesting is primarily high school students and some older people. However, diggers earn a fairly good return on time worked. One clam grower indicated that an average digger can harvest about 200 pounds of clams per tide (about four hours) for which he/she receives $.15-.20 per pound.

Harvest labor is also a problem in the geoduck industry. Divers are paid well for work that is extremely hard and risky, but turnover is high, and there is some difficulty in getting divers to work consistently every day. Some people in the industry have complained about the inefficiency and high cost of using divers to harvest geoducks. Others, however, contend that the method is a good conservation practice that is in the best interest of the resource.

Illegal harvesting of geoducks in off-tract areas and falsification of landing reports are additional problems for Department of Natural Resources and Department of Fisheries enforcement agents. Proper management of the fishery is impaired by such activities, since royalty payments and estimates of resource utilization are based on the quantities of geoducks harvested.

Most hardshell clams are sold in the shell without any further processing involved. Although all clam fisheries have common problems, there are a few related to marketing, processing, quality control, and other commercial aspects that are peculiar to the geoduck and razor clam industries. These will be discussed separately for each of those species.

Geoduck Fishery Management and Technological Problems

Obtaining a sufficient supply of reasonably priced geoducks to insure the volume of production necessary for the industry to operate profitably is an increasingly serious problem. The issue is complex and involves management of the geoduck fishery as well as other aspects of the industry.

The guiding philosophy behind the management of the geoduck resource has evolved as biological information has accumulated and as the industry itself has changed. Geoduck tracts were originally leased to operators for five years. Initially, permitting the geoduck industry to evolve on a farming basis was considered (i.e., leases would be renewable and harvesters would be encouraged to develop their own long-term sustained yield management programs). That idea was abandoned when it was discovered that (1) setting was inconsistent in harvested areas, and data indicated that geoduck larvae, for unknown reasons, prefer to set in areas containing high densities of adults, and (2) growth rate information indicated that geoducks take 8 to 10 years to attain a weight of 2-1/2 pounds. These findings suggest that a long rotation time (i.e., 8 to 10 years) is necessary before a given tract can be reharvested. These factors, coupled with evidence that poaching (illegal harvesting) had reached significant proportions, compelled the state to assume virtually total management of the geoduck resource.

Smaller tracts, shorter leases, and an industry quota of 5 million pounds per year were instituted by the regulatory agencies to cope with management and enforcement problems. The geoduck industry expanded rapidly, however, and by 1981, total harvests met or exceeded the estimated maximum sustained yield. In addition, short-term leases made it difficult to guarantee a consistent supply of geoducks over a long period of time. As a result, bonus bids on geoduck tracts were increased to levels that according to the industry, made the profitability of future operations uncertain. In the 1979-80 auction, bonus bids ranged from $4,200 to $78,000 per tract, a marked increase over previous bids. Price fluctuations depend on the quality of the tract (geoduck density and substrate type) and the quality of the clams harvested (i.e., size, condition, and color). A limited number of available tracts and high bonus bids forced many operators out of the fishery, excluded newcomers to the fishery, and contributed to an emerging monopoly of the geoduck industry by one company.

There was also competition from the geoduck industry in Canada, which supplied a consistently higher quality product. Although higher quality clams were available in Puget Sound, they were not always abundant on the leased tracts.

The problems faced by the geoduck industry are basically related to management and policy. The industry wants to be assured of long-term supplies at a reasonable cost. The state, however, is constrained by a limited resource base and political considerations in securing the supply of geoducks demanded by the industry.

There are also some processing and quality control problems. Geoducks must be processed within 24 hours of harvesting or their valves begin to gape, they lose water and body fluid, die, and the meat dries out. Transporting harvested clams from scattered geoduck tracts in Puget Sound to a processing plant can take several hours, and the wide distribution of tracts almost precludes the establishment of an optimally located plant.

Perishability and quality control in processing present problems in maintaining acceptable bacterial levels in processing geoduck steaks. Workers must adhere to high standards of personal hygiene and cleanliness when preparing the steaks. The processing and packaging of geoduck steaks requires considerable care to insure a high-quality product. Although the requisite technology is available, disciplined application is essential.

Razor Clam Fishery Management and Technological Problems

Since the most significant commercial razor clam fishery is located within the Quinault Indian Reservation, most of the problems discussed in this section pertain to that fishery. However, some may be extrapolated to the small, non-Indian fishery around Willapa Bay.

The sharp decline in Quinault razor clam harvests for the 1978-1979 and 1979-1980 seasons, combined with increased digging effort, has caused concern within the tribe regarding continued availability of the resource. Fluctuations in razor clam production are difficult to determine, however, because of many variables other than clam abundance that affect the size of the harvest—weather conditions, markets, and number of diggers, for example. Interpretation of harvest records is complicated further by inconsistent reporting methods and incomplete reports.

Examination and assessment of clam management practices of state management agencies and those practiced by the Quinault Fisheries Division may provide the biological data necessary for better management of the reservation razor clam beaches. Funding for these endeavors, however, is not available. Instead, circumstances may necessitate limiting or reducing total harvest, time of harvest, and the number of harvesters (300 in 1981).

As with geoducks, there are some processing and quality control problems. Razor clams are extremely perishable and must be processed within 24 hours. In addition, razor clams cannot be marketed whole, except as crab bait, and those used for the restaurant and retail markets are processed by hand.

Preparing the "dressed" or "steaked" razor clams requires removing the shell, gills, and viscera, and cutting open the body and siphon. It is difficult to produce a good quality product on a consistent basis, however, because of fluctuations in the biological activity of the clams. For example, clam weight drops markedly during the summer spawning season, and the condition of the clams may vary throughout the year, depending on availability of food and other environmental factors.

Producing good quality, dressed razor clams requires considerable skill and tolerance for tedious work. Most workers in the industry prefer digging because it pays better than processing. The Quinaults have also had difficulty finding a sufficient retail market for dressed razor clams. Limiting factors are the high price of dressed razor clams (about $5.00 per pound in 1982), a 50-60 percent weight loss during processing, and the high cost of hand labor for processing. Thus, the razor clam "steak" market is limited to the small specialty retail and restaurant trades, particularly along the Washington and Oregon coasts, where there is more product familiarity than elsewhere.

Despite processing and marketing problems, demand for fresh razor clams appears to be increasing, and it is likely that the fishery will be limited more by supply than demand. Part of the razor clam harvest (sometimes as much as 50 percent) has traditionally been sold for Dungeness crab bait, but in recent years the fresh clam market has taken over most of the Quinault harvest. Periodically, Alaskan razor clams enter the West Coast crab bait market, but disruption of Washington's market is likely to be lessened as Washington razor clams are increasingly used for food rather than bait. In addition, the Dungeness crab fishery is temporarily in a depressed economic state and crab bait sales are at an all-time low.

Regulations and Jurisdictional Conflicts

Increasing demand for clams necessitates expanding clam growing and harvesting areas and introducing more aquaculture techniques and equipment, which creates socio-legal and regulatory problems. (A detailed study and analysis of many of these problems may be found in a report by the Oceanographic Commission of Washington, to the Washington State Legislature.) One of the prime constraints to commercial clam production and culture in Washington is the paucity of subtidal and intertidal clam growing areas. Most of the tidelands within Puget Sound are privately owned or leased for oyster culture. Consequently, only a small amount of public tideland exists, much of which has been designated for recreational use.

Although intertidal clam harvesting areas are not as closely regulated as subtidal areas, some people in the industry consider the fee and/or taxation structure for intertidal lands unfair compared to that for subtidal leases. The taxes levied on owners are equivalent to those for upland farmers and are based on the potential value of the area for other uses. Furthermore, a state lease for clam cultivation requires the lessee to pay the state the value of the pre-existing resource in addition to costs of resource appraisal by the state. One proposed solution for beach owners is to zone aquaculture areas in Puget Sound and tax them as clam beaches for other potential uses.

Conflicts between clam harvesters and other beach users' groups are increasing, and many waterfront landowners have organized to contest the use of mechanical harvesters and other equipment associated with clam harvesting. Two major actions have occurred in recent years with regard to this issue. In *English Bay Enterprises Ltd.* vs. *Island County* (1977), the court decreed that mechanical harvesting constituted "dredging" and required a substantial development permit. Another case, still pending in Superior Court, involves harvest of subtidal clam beds in Agate Pass, Kitsap County. The situation is aggravated by newcomers to the business who have little technical expertise and in some cases do not understand the necessity of maintaining good relationships with upland owners.

Subtidal clam harvesters are also experiencing regulatory pressures that discourage change and innovation, particularly with respect to physical structures required in clam farming and other aquaculture practices. There are two major problems associated with this complex aspect of the industry: the regulatory environment is in a continual state of change; and procedures for entering the subtidal fishery (i.e. using mechanical harvesters or diving gear) are complicated, lengthy, and the outcome is uncertain. An example of the maze of government regulations and procedures facing applicants attempting to obtain subtidal harvesting permits follows:

1. Obtain approval for a tract lease from the Department of

Natural Resources and submit an application. The application must comply with the provisions of the Washington State Environmental Policy Act (SEPA).

2. Send application and environmental impact statement to Washington Department of Fisheries (WDF).

3. Comply with provisions of the State Shorelines Management Act (SMA), including application for a substantial development permit from the local government agency.

4. If the above permits are obtained, which may take 12-18 months, the harvester is eligible for a clam farm license ($15 per annum) and a mechanical harvester's license ($300 per annum). However, the latter has no bearing on the decision of local jurisdictions regarding the substantial development permit. Commercial geoduck harvesters must also obtain a geoduck tract license ($100 per annum), and each diver must have a personal commercial fishing license ($50 per annum).

5. Obtain required permits (Section 404 and Section 10 permits) from the Army Corps of Engineers (ACOE). This procedure is essentially a duplication of all the foregoing steps.

6. Obtain a certificate of approval from the Washington Department of Social and Health Services.

A national permit program has been proposed which may eliminate the necessity for the section 404/10 permits for mechanical clam harvesting from the Army Corps of Engineers. The program would provide for general permits to be granted for a wide variety of fishery-related activities throughout the nation, including clam harvesting. However, further clarification of the proposal is needed before the Seattle District ACOE will place mechanical harvesting under this permit system. There is also some speculation that this program would eventually place intertidal beach rehabilitation and hand harvest of clams under the Corps' regulatory control.

The complexity, cost, and uncertainty of obtaining permits necessary for conducting the activities associated with clam farming and harvesting are discouraging capital investment and the kind of technological advancement needed to increase productivity. Local, state, and federal agencies will have to modify and/or streamline their policies and procedures if the commercial clam industry is to continue at its present level in Washington State.

Alaska

The clam resources of Alaska are considered to be quite large: approximately 160 different species have been found, 28 of which have commercial potential (Baxter, 1965). Although the exact abundance and location of most clam stocks is unknown, estimates of potential annual yields are as high as 50 million pounds per year (Paul and Feder, 1976).

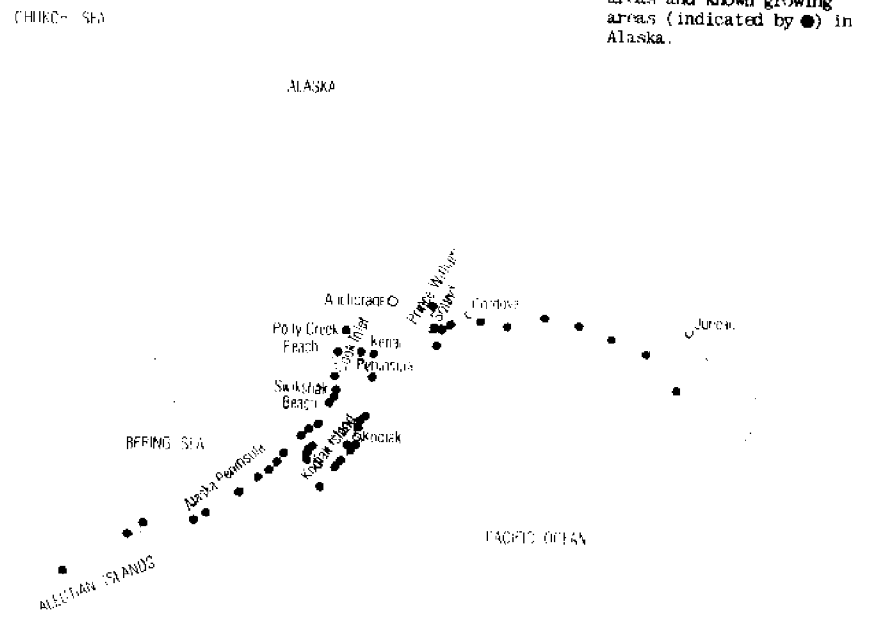
The three main types of clams that have been harvested in Alaska are the razor clam, butter clam, and cockle. Of these, the razor clam has been the most important, comprising about 95 percent of the commercial catch since the 1950s (Paul and Feder, 1976). Recent assessments of surf clam (*Spisula polynema*) populations in the southeast Bering Sea (Hughes et al., 1977, 1979) are encouraging and may lead to the development of a new clam fishery. If fully utilized, Alaska's clam resources could make an important contribution to the economy of the state. In addition to the potential for a multimillion-dollar-a-year industry, the resources could be exploited year round, providing a source of continuous employment. The latter consideration is particularly important in Alaska, where much employment is seasonal.

Commercial clam harvest in Alaska presently is constrained by several factors. Although Alaska's marine waters are virtually free of industrial and domestic sewage pollution, paralytic shellfish poisoning (PSP) contamination is ubiquitous in some areas. Strict regulations have been enacted through Alaska's Shellfish Sanitation Program to prevent the harvest of contaminated clams for human consumption. Butter clams concentrate up to 80 percent of the toxin in the gills and siphons. Razor clams, however, do not accumulate PSP as rapidly, dissipate it quickly, and concentrate it in the digestive gland, which is removed when the clam is prepared for eating. At the present time, most razor clams harvested for human consumption come from south central Alaska beaches.

Commercial Razor Clam Fishery

Razor clams extend from Southeastern Alaska westward to the Bering Sea and the Aleutian Islands. In a review of razor clam populations in Alaska, Nickerson (1975) stated that there are 49

Figure 7. Clam harvesting areas and known growing areas (indicated by ●) in Alaska.



known growing areas (Figure 7), about half of which could probably support a commercial fishery. There is little information on the extent and abundance of subtidal stocks, but they may be considerable.

A commercial razor clam fishery in Alaska began in 1916 with the harvest of razor clams beds near Cordova (Figure 8). It developed primarily to satisfy on increased demand for razor clams in Washington and Oregon.

During the early years of the fishery, most razor clams were canned in Cordova. As the clam beds at Cordova were depleted in the early 1920s, additional razor clam stocks were exploited at Polly Creek Beach in Cook Inlet and Swikshak Beach on the Alaska Peninsula. By 1922 the U.S. Government, fearing the loss of an important industry, established regulatory controls on the Alaska clam fishery.

Production during the 1920s was erratic (Figure 8) because the Cordova beds were overharvested and market conditions were poor (Orth et al., 1975). Although production began to increase in 1930, it declined again in 1932, apparently because of stock depletion, cold temperatures, and severe winter storms. In 1935 harvest quotas were placed on the Alaska razor clam fishery and the 4-1/2 inch size limit established in 1924 continued (Nickerson, 1975).

From the mid-1930s to the 1950s, razor clam production was relatively stable, from one to two million pounds per year. By the mid-1950s, however, several factors coalesced to cause a sharp decline. Canned razor clams from Alaska, produced with relatively high harvest and processing costs, could not compete with the cheaper, dredge-harvested clams from the Atlantic Coast. In addition, the U.S. Food and Drug Administration (FDA) withdrew its

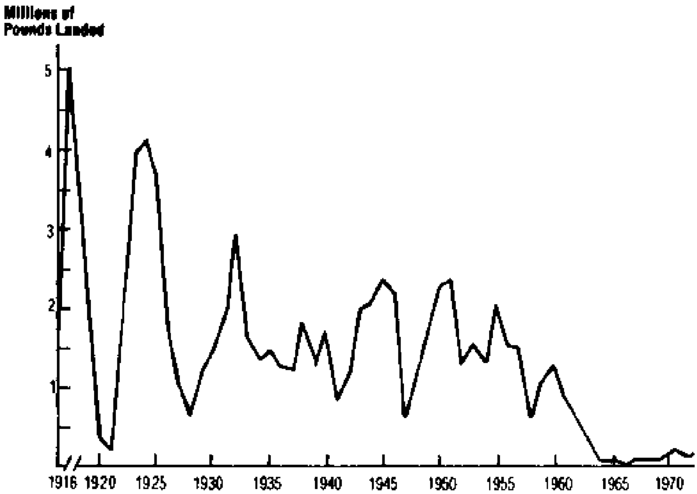


Figure 8. Commercial razor clam production in Alaska, 1916-1970 (from Orth et al., 1975).

endorsement of Alaska's membership in the National Shellfish Sanitation Program (NSSP) in 1954 because of PSP problems with hardshell clam stocks and the inability of the territory to comply with provisions of the program. As razor clams were increasingly diverted for use as Dungeness crab bait, canneries could not match the prices paid by the crab bait buyers and almost all the razor clams went to the bait market. In addition to meeting its internal demand, Alaska exported significant quantities of bait clams to Washington, Oregon, and British Columbia.

The clam beds of south central Alaska incurred extensive damage during the Alaska Good Friday earthquake in 1964, especially in Prince William Sound. Entire clam populations were lost to the six-foot land rise that accompanied the earthquake. Clam harvests in Prince William Sound have steadily declined since that time (Figure 9). In the Kodiak area digging continued on a fairly regular basis until increasing state and federal regulations, poor market conditions, and the 1964 earthquake caused a decline in production in the 1960s (Kathy Rowell, personal communication). In the last five years, production has been drastically reduced.

Interest in expanding Alaska's razor clam fishery for human consumption has persisted, and in 1971 efforts were initiated by the state to re-establish membership in the NSSP. This not only was required to ship fresh and fresh-frozen razor clams to other states, but was considered essential to obtain approval for hardshell clams for out-of-state markets as well.

Alaska regained its NSSP status in 1975, and commercial harvesting of razor clams for human consumption resumed. Only three beaches (Swikshak, Cordova, and Polly Creek) were approved for this purpose because more background data was available for those particular areas. Regulations were modified to allow harvesting of bait clams from unapproved areas provided the clams were treated with a yellow dye to prevent them from entering the food market.

Research in the use of hydraulic razor clam dredges has

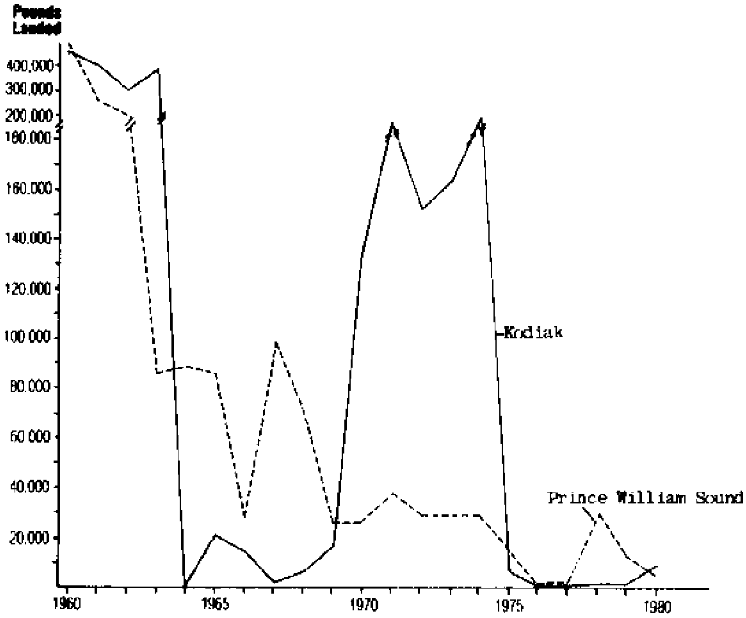


Figure 9. Razor clam harvest in Prince William Sound and Kodiak, 1960-1980

continued in order to better utilize razor clam resources at competitive prices.

Current Status

Most of the razor clam harvest is still utilized for crab bait; however, there is a limited market for fresh, frozen, and canned razor clams for human consumption, primarily in the harvest areas. There is also a potential market for Alaskan razor clams in the Pacific Northwest and California because of product familiarity. At the present time, at least one processor is licensed to ship razor clams interstate; however, few clams have been exported (Torgerson, personal communication). The seasonality and high variability of clam supplies make it difficult for processors to become established.

Razor clam landings for Prince William Sound and Kodiak (Figure 9) show that production has declined over the last two decades. Part of the reason for the decrease is that clamming in Alaska is now only a source of seasonal or part-time employment. Social and economic changes, combined with the relatively low productivity of hand harvest, have resulted in a paucity of commercial clam diggers.

Some of the difficulties encountered in the razor clam industry (e.g., high production costs, variable supply, and lack of experienced diggers) can be minimized with the introduction of suitable, efficient mechanical dredges. Efforts begun in 1963 to adapt an East Coast mechanical clam harvester to the Alaska razor clam industry are continuing. Since 1975, one harvester in Cordova has patented a hydraulic dredge for harvesting subtidal stocks, and another has purchased a dredge from the East Coast: these are the only two harvesters presently equipped to mechanically harvest razor clams (Nickerson, personal communication).

Mechanical or hydraulic clam harvesters presently are allowed in all approved areas with prior permission from the Commissioner of Fish and Game and appropriate permits. Other required licenses for commercial fishermen are as follows:

1. Commercial fishing license resident, $10; nonresident, $30

2. Vessel license, $20

3. Entry or interim-use permit, ranges from $10 to $100 (Alaska Department of Fish and Game, 1981)

There is no closed season on razor clams at this time, and the only size restriction is the 4-1/2 inch minimum in Prince William Sound (Alaska Department of Fish and Game, 1981).

Future

Because of the importance of the bait market to the Alaska razor clam industry, the future of the fishery is heavily dependent on the viability of the Dungeness crab fishery, the price of bait substitutes, and the continued preferences of crab fishermen for razor clams. Introducing mechanical harvesters into the fishery will be an important factor in determining labor costs, landings, and, therefore, bait prices.

Assuming that mechanical harvesters are utilized more in the coming years, a smaller labor force would be required, productivity would increase, and production costs would stabilize, if not decrease. This would favor the expansion of the food clam market. However, as pointed out for the Washington razor clam industry, some problems which are unique to razor clam processing would have to be solved or minimized. For example, hand processing requires considerable skill and is labor intensive, contributing to high product prices. In addition, a reliable, consistent source of quality clams is necessary to establish and maintain a viable market for razor clam products. Transferring of bait-clam harvesting to uncertified beach areas would permit greater utilization of certified beaches for food-clam harvest effort and would alleviate supply problems to some extent.

Overcoming supply and competition barriers in order to expand the razor clam food market will require a considerable marketing effort, but conditions are more favorable now than in past years. The development of Alaska's shellfish sanitation program increases the possibility for intrastate marketing of fresh or quick-frozen razor clams (whole, unshucked), through large chain stores and other outlets in NSSP member states. The clams would probably be packaged and sold, as some clams now are, in paper or plastic trays sealed with a transparent wrapping (Nickerson, 1975).

Bay Clam Fisheries

The two remaining species, in addition to the razor clam, which have been harvested commercially in Alaska, are the butter clam and the cockle. Other abundant but unexploited intertidal species include littlenecks, horse clams, softshell clams, and surf clams (Paul and Feder, 1976). Butter clams are abundant throughout southeast alaska and on isolated beaches farther north. There are no population estimates, but the resource is considered to be quite large. Butter clams grow slowly in Alaskan waters and require 8 to 10 years to reach a commercial size of 2-1/2 inches (Paul and Feder, 1976).

According to Orth et al. (1975), butter clams were canned incidental to salmon and razor clams in the early 1900s. The first significant harvest didn't occur until 1930, however, when 25,000 pounds were landed. The catch remained at approximately the same level until 1942 when production increased substantially because of the wartime demand for shellfish and other alternative sources of protein. In 1946, however, the discovery of PSP in canned butter clams interrupted the growth of the butter clam industry (Figure 10). A survey of major beaches showed that PSP was ubiquitous and that it would be difficult and costly to define safe harvest areas. The PSP problem, followed by increased federal regulations and compounded by competition from Atlantic canned clams, eventually led to the collapse of the butter clam fishery, and it never recovered.

From 1960 to 1976, less than 2,000 pounds of butter clams were processed in Alaska (Nosho, 1972). Although a small, family operated butter clam fishery in Kasitsna Bay on Cook Inlet survived, the industry in Alaska essentially ceased in 1955.

Basket cockles are found throughout Alaska, but no assessment of the commercial potential of this species is available. Cockles grow relatively slowly in Alaska and take from 5 to 15 years to attain a shell length of 2 to 4 inches. The history of the basket cockle is similar to that of the butter clam. Because the two species often occur together, they can be harvested simultaneously. In addition, the cockle, as noted previously, lives just below the substrate surface, which facilitates harvest. Thus cockles were harvested with butter clams and canned.

At one time Alaska was the major commercial source in the United States for cockle meat (Nosho, 1972). Exact catch statistics are

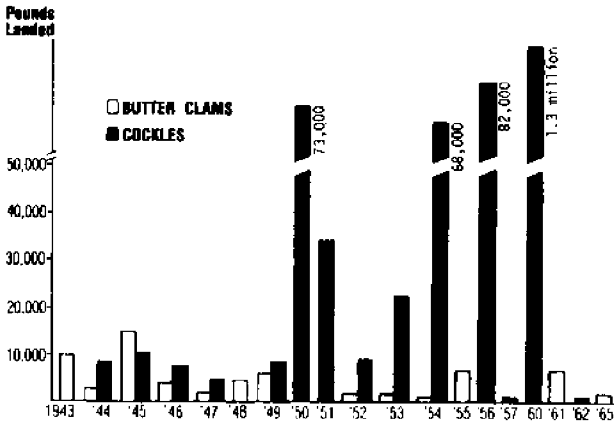


Figure 10. Bay clam production in Alaska, 1943-1962

difficult to obtain because razor clam and cockle production was recorded together in certain years. However, data indicate that cockle landings fluctuated substantially from 1943 to 1962 and peaked in 1960 (Figure 10) with a catch of approximately 1.3 million pounds (Nosho, 1972). High labor costs, relatively low meat recovery, and restrictions related to PSP finally caused the decline of the fishery, and production decreased in 1962. No landings have been recorded since that time.

Current Status

Commercial butter clam and cockle fisheries are virtually nonexistent in Alaska, although the butter clam industry around Prince William Sound may revive as PSP sampling improves. Market ex-vessel price problems are the major inhibiting factor for the fishery (Kimker, personal communication).

A small salmon processing plant in Kasitsna Bay harvests and cans approximately 200 cases of butter clams per year. Butter clam harvesting is allowed there because sufficient background data, toxicity tests, and survey results exist for state authorities to approve the beaches.

Other areas where butter clam harvest is permitted are "westward" Alaska (from Cape Fairfield on the Alaska Peninsula, westward), Cook Inlet, and Prince William Sound (October 1 through April 30) with permission from the Commissioner of Fisheries. Hardshell clams maybe taken by hydraulic or mechanical clam diggers in all of these areas. The only minimum size restrictions presently in effect are those on littleneck clams (1-1/2 inch minimum) and butter clams (2-1/2 inch minimum) in Prince William Sound (Alaska Department of Fish and Game, 1981).

Future

The outlook for the utilization of hardshell clams in Alaska improved after 1975, when the state re-entered the National Shellfish Sanitation Program. Regulations allowing the harvest of hardshell clams from some areas may contribute to increased production in coming years.

Perhaps the most promising development in Alaskan clam fisheries has been the discovery of vast surf or pink clam (*Spisula polynema*) resources in the southeast Bering Sea. A cooperative study, jointly funded by industry and federal and state agencies, was initiated in 1977 to determine the resource potential, obtain biological data, and examine the short-term effects of such a fishery on the environment (Hughes et al., 1977). Results of surveys near the Alaska Peninsula estimated the resource to be between 248,000 and 324,000 metric tons of harvestable surf clams, which could sustain a yield of 19 to 25 million pounds of meat per year. In addition, tests for PSP suggested that surf clams may not concentrate the toxin to any appreciable extent, making them safe for human consumption (Hughes, et al., 1979).

An East Coast-style hydraulic harvester was used in the surf clam survey and the financial feasibility study indicated that with the type of equipment utilized clam harvesters could expect to make a reasonable profit. The overall catch rate with a six-foot wide harvester was 1,683 pounds of surf clams per hour, and the environmental impact was generally minimal or immeasurable (Hughes et al., 1979).

Results of the surf clam survey were very encouraging and indicated that the resource would support a viable fishery. Alaskan surf clams may be able to supplement Atlantic surf clam landings, which decreased in the late 1970s (Ritchie, 1977). The Alaska surf clam rivals its East Coast counterpart in flavor, making it a suitable alternative for the U.S. chowder and clam strip industries. If problems of high production costs, PSP restrictions, and market competition can be overcome, the Alaskan surf clam resource may become the largest, most productive commercial clam fishery in Alaska or on the Pacific Coast.

Recreational Clam Fishery

The major recreational clam fisheries in Alaska utilize the razor clam stocks on the east side of the Kenai Peninsula and some areas of Prince William Sound (Paul and Feder, 1976; Kimker, personal communication). The Sport Fish Division of the Alaska Department of Fish and Game has monitored the eastside fishery since 1969 and reported no decrease in the average size of clams in heavily dug areas (Alaska Department of Fish and Game, 1973). Recreational harvest figures are given in Table 7.

Industry Problems and Constraints

Although Alaska's clam resources are sizeable, only a small part of their productive potential have been utilized. The exploitation of these resources continues to be restricted by a variety of problems. In order to expand, Alaska's clam industry must compete with other clam suppliers, both domestic and foreign. This is not likely to happen because of the high cost of hand harvesting and processing in Alaska. If markets outside Alaska are developed, the cost of transportation presents another obstacle to supplying those markets. Development of an efficient, environmentally safe

Table 7. Estimates of Total Effort and Razor Clam Harvest for the Recreational Clam Fishery

Year	Total Estimated Effort (Man-days)	Estimated Harvest (Number of Clams)
1969	12,200	375,800
1970	11,100	306,450
1971	6,800	187,760
1972	15,400	437,530
1973	23,770	682,600
1974	27,410	872,450
1975	24,260	896,080
1969-1974 mean	16,110	477,100

Source: Commercial Fisheries Statistics, Statistical Leaflet No. 25, Alaska Catch and Production mechanical dredge would reduce the cost of clam production and provide a more consistent and reliable supply of clams for processors. A food clam industry has been established for razor clams, however, and fresh market demand increased steadily after the three major growing areas were approved for commercial harvest.

Full utilization of razor and hardshell clam stocks for human consumption depends on several factors. The present Shellfish Sanitation Program restricts commercial harvesting for food razor clams to three areas: Cordova (Copper River Flats and Orca Inlet), Swikshak, and Polly Creek Beach. These three areas were chosen because they were utilized in the early razor clam fishery, have been highly productive, and have few incidences of PSP.

Expansion of source beaches is critical to harvesting sufficient quantities of clams to make processing feasible. The state, however, is reluctant to fund additional programs of beach certification and monitoring unless the clam fishery is well financed, intends to process in Alaska, and makes a significant contribution toward increasing Alaska's employment opportunities (Torgerson, personal communication). If more money is allocated for monitoring and beach certification, harvest of other clam species may also increase. Some Alaska Department of Fish and Game biologists regard hardshell clam resources as having greater potential than razor clams (Orth et al., 1975).

Present commercial fishing regulations allow hand harvesting of hardshell clams in Prince William Sound, Cook Inlet, and along the Alaska Peninsula; harvesting with hydraulic clam diggers is allowed by permit only in portions of those areas (Alaska Department of Fish and Game, 1981). Future hardshell clam harvesting will be influenced directly by the economic factors previously mentioned, increased beach certification, and compliance with provisions of the state Shellfish Sanitation Program, especially with regard to PSP. Another factor influencing utilization of Alaska's clam resources is shortage of risk capital; however, there is adequate capital in Alaska's other shellfish industries, some of which could be transferred to development of a clam industry if these other fisheries should decline (Torgerson and Lowman, personal communication).

Despite restrictions and problems affecting expansion of the clam industry, interest in Alaska's clam stocks is increasing. The prospects of a new surf clam fishery in the southeast Bering Sea are encouraging, and the implementation of Alaska's Shellfish Sanitation Program will probably result in certification of more harvest areas. In addition, demand for clams and clam products in the United States, especially on the Pacific Coast, augurs well for the expansion of Alaska's clam fisheries if the major difficulties can be resolved.

Oregon

The Oregon coastline contains little suitable clam habitat. Some productive razor clam habitats are found along Oregon's 300-mile coastline, but the protected bays and estuaries (preferred habitat of hardshell clams) are relatively small. However, clam stocks in Oregon historically have supported a small commercial fishery and a recreational fishery, both of which continue to this day.

The commercial clam fishery usually is divided into two parts, the bay clam and coastal razor clam fisheries. Species of clams that are harvested are the razor clam, native littleneck, butter clam, cockle, horse clams and the softshell clam.

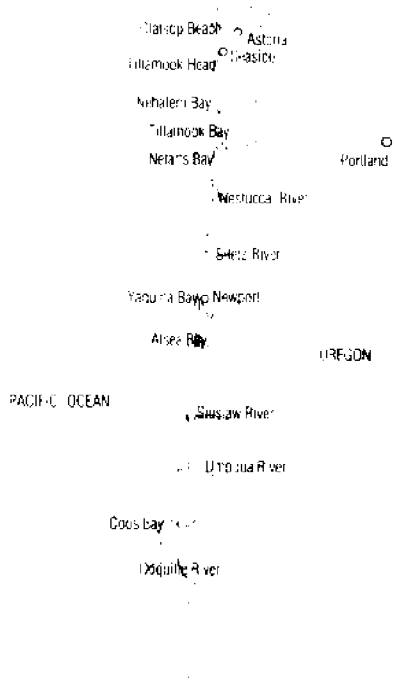
According to Cleaver (1951), the following Oregon bays have a history of commercial clam harvest (Figure 11): (north to south) Nehalem, Tillamook, Netarts, Nestucca, Yaquina, Alsea, Suislaw, Umpqua, Coos, and Coquille Bays. Tillamook, Yaquina, and Coos Bays account for most of Oregon's commercial bay clam catch, and the ocean beaches support a small razor clam fishery. Although Oregon has scattered razor clam populations along its entire coastline, the most productive area is the 18-mile stretch of beaches extending from the Columbia River to Tillamook Head, south of the city of Seaside.

Commercial Razor Clam Fishery

There is little statistical information on the razor clam fishery in Oregon prior to 1941. Subsequent data suggest an adverse impact on total catch because of World War II restrictions on beach use and a shortage of diggers. After World War II, the commercial fishery increased steadily from a low of 13,353 pounds in 1942 to a high of about 337,000 pounds in 1950 (Figure 12). An intensive sport fishery developed during the postwar period, with harvests probably equal to the commercial catch (Cleaver, 1951).

There was a marked decline in commercial razor clam harvest by the mid-1950s, and in the early 1960s production decreased to an average of 34,000 pounds per year. Catches increased again in the late 1960s, peaking at 120,542 pounds in 1967; however, another decline followed and, except for 1976 (114,297 pounds), landings have remained relatively low.

Figure 11. Historical commercial clam harvest areas of Oregon



Current Status

The razor clam fishery is managed primarily by a season closure extending from mid-July through August, and by a 3-3/4 inch size limit. Commercial diggers must possess a $40 commercial license and a state health certificate. In addition, a record indicating the quantity of clams and market destination must be in the digger's possession to prevent use of a commercial license to dig unlimited numbers of clams for personal use.

In Oregon, most commercially dug razor clams are sold to two Oregon processors. Diggers are paid $.85 to $.95 per pound for unshucked clams, and $2.20 for cleaned razor clams. Most clams are processed into fresh or frozen steaks; however, the high cost of raw clams and labor requires a high retail price ($4.75 to $6.50 per pound), which limits the sale of razor clams to the speciality retail and restaurant trade.

Razor clams are marketed primarily in Portland and along the Oregon coast, with lesser amounts sold in Seattle and along the Washington coast. Attempts to develop markets outside these localities have been unsuccessful because of high prices and product unfamiliarity (Smith, Bellbouy Crab Co., personal communication).

Future

Expansion of the commercial razor clam fishery in Oregon is unlikely at this time for reasons mentioned above (i.e., high

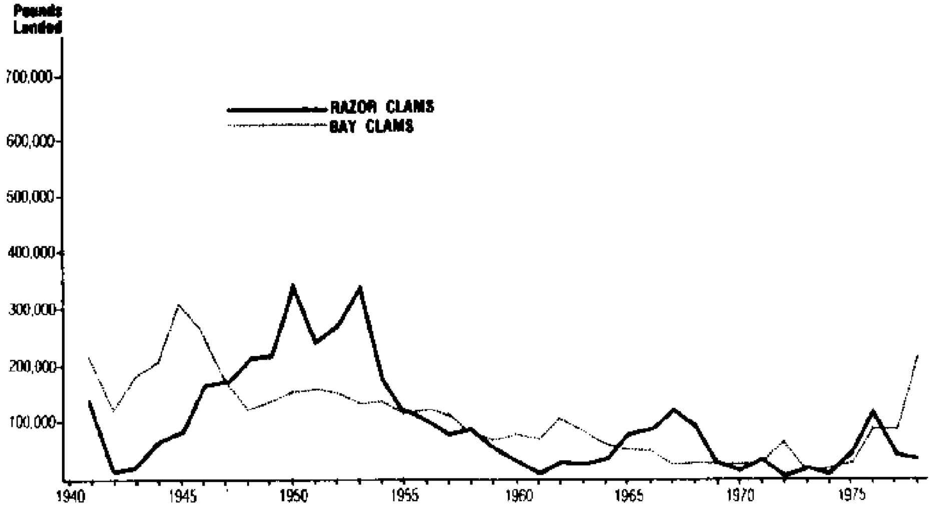


Figure 12. Oregon commercial razor and bay clam production, 1940-1978

production costs and limited markets). Most of the factors constraining the commercial razor clam fishery in Washington are also applicable to the industry in Oregon. The reader is referred to the section on the Washington razor clam industry for a more detailed discussion of those problems.

Commercial Bay Clam Fisheries

The history of Oregon's commercial bay clam fishery is sketchy. Records of total clam catch were collected from 1928 to 1950. In the 1940s, the state estimated bay clam and razor clam catches, but it was not until 1950 that harvesters were required to report their catch by species (Marriage, 1954). According to these statistics (Figure 13), Oregon's commercial clam harvest was never large. Peak production occurred in the 1930s, spurred by the demands of an economic depression (Cleaver, 1951). The highest production recorded was 664,297 pounds in 1938.

Restrictions on night digging and ocean beach closures caused a sharp decline in clam production during World War II. Clam catches increased after the war, but production levels were below those of preceding decades. Cleaver (1951) attributed the decrease to reduced digging activity, resulting from an improved post-war economy, and an increase in oyster farming in Tillamook, Yaquina, and Coos Bays, causing the loss of some traditional clam producing areas. Since the mid-1950s, bay clam production has declined steadily, and in recent years has been negligible. A summary of bay clam landings by species (Figure 13) shows trends in the fishery during the last decade and also the increased utilization of horse clams, especially within the last five years.

In 1955 an enterprising commercial harvester in Coos Bay began harvesting intertidal horse clams by hand-held water jet. Although the state immediately outlawed the use of all mechanical clam harvesters (including hydraulic devices) in the intertidal zone, a

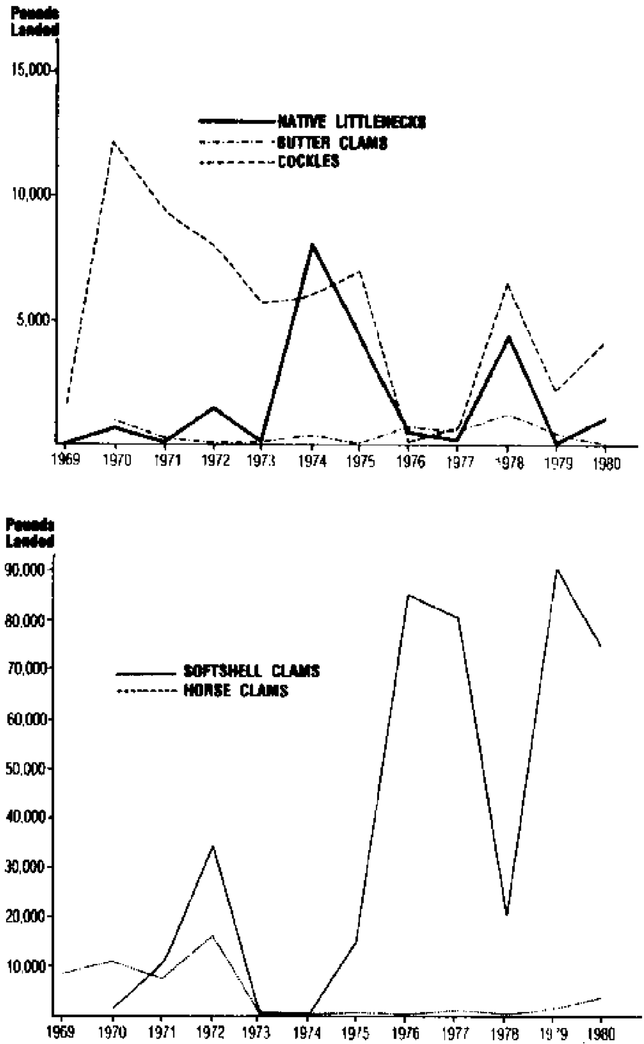


Figure 13. Oregon commercial bay clam production by species, 1969-1980

1959 regulation change permitted their use subtidally, with special permission from the Department of Fish and Wildlife (Snow, personal communication).

There has been little harvesting of subtidal clams becuse of the lack of information on the location and extent of subtidal clam stocks. As a result, the Oregon Department of Fish and Wildlife began an inventory of subtidal clam stocks in ten Oregon estuaries in 1973. Subtidal clam populations having commercial potential were found in Tillamook, Yaquina, and Coos Bays (Gaumer and Lukas, 1975; Gaumer, 1976).

Current Status

Oregon is reluctant to allow full-scale commercial harvest of its subtidal clam stocks until a number of important management questions are answered:

1. The effect of harvest on existing stocks
2. The effect of harvest on the substrate
3. The relationship between intertidal and subtidal clam populations (e.g., the importance of subtidal populations as spawning stock).

To gather data on these questions, several areas in Yaquina Bay were opened in 1976 for horse clam harvest on an experimental basis. The results of the study are still being evaluated.

Future

The future of Oregon's commercial bay clam fishery appears to depend on the utilization of subtidal stocks. The resource is relatively small, however, and estimates of maximum sustained yield are not yet available. Other potential clam fisheries do not appear promising. A variety of commercial clam species occur in Oregon's offshore coastal zone, and although little is known about the abundance of these species, it is assumed to be low. In addition, there appears to be little potential for private clam farming operations in intertidal areas because tideland for such purposes is scarce in Oregon estuaries (Snow, personal communication).

Besides the management problems associated with the exploitation of Oregon's subtidal clam stocks, there are several other constraints to a subtidal horse clam fishery. For example, the Oregon State Department of Health has closed a number of potentially harvestable areas because of possible health hazards.

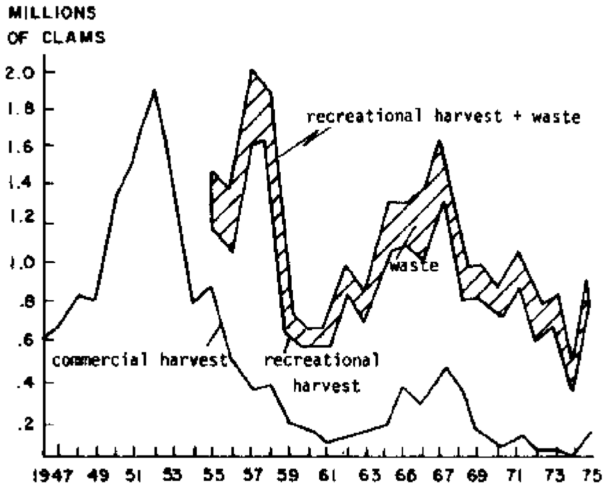
Marketing horse clams poses another problem. At present, there are no local processors willing to handle horse clams, and the unpredictability of future supply does not justify the effort or cost to potential processors. In addition, there are processing problems. Removing the tough, leathery skin from the siphon of horse clams requires considerable hand labor and the meat recovery is poor (22-24 percent average). Both factors make processed horse clams an expensive product ($2.25-$2.50 per pound retail). A high retail price and the fact that horse clams are not well known except in very localized areas of southern Oregon and northern California limits their market potential (Gaumer and Mills, personal communication).

Recreational Clam Fishery

Surveys of the bay clam recreational fishery through the years reveal an intensive fishery, particularly on cockles and horse clams. In 1971, Oregon reported a recreational catch of over two million clams. Spot surveys conducted in 1975 and 1976 indicated that digging effort was increasing markedly, placing considerable pressure on clam stocks. Therefore, catch limits as well as other clam harvest regulations were imposed in 1977, and a routine sampling program of the bay clam sport fishery was initiated to monitor more closely the impact of harvesting.

The annual sport catch of razor clams has been estimated since 1955. The recreational harvest has ranged between 0.5 and 1.5 million pounds per year (Figure 14), with an exceptional catch in 1976 of about 1.5 million clams, or about 250,000 pounds. Wastage has presented a problem in some years and has approached 25 percent of the catch at times, although it appears to have abated somewhat during the last few years.

Figure 14. Oregon recreational razor clam catch, 1947-1975



California

California's long coastline is notably lacking in protected bays (Figure 15). Thus it is not surprising that California's clam stocks have never been extensive (Bonnot, 1949); however, these stocks did support a small commercial clam fishery prior to World War II. The species that have appeared in commercial catches include razor clams, native littlenecks, butter clams, cockles, horse clams softshell clams, Pismo clams, jackknife clams, and bean clams.

Commercial and Recreational Fisheries

The history of the clam industry in California is essentially one of a small commercial fishery that eventually was supplanted by a recreational one. Commercial catch statistics, compiled since 1916, reflect both the magnitude and trend of California's clam fishery (Figure 16). The two most important species in the early fishery were the Pismo clam and softshell clam. The Pismo clam, which ranges from south of San Francisco to Baja, California, was once abundant at Pismo Beach. Catch statistics clearly show the dominant position of the Pismo clam fishery in California's past. A marked decline in catch during World War II resulted from a military closure of Pismo Beach. In 1947, commercial harvest of the species was prohibited because of reduced resource abundance and increased digging pressure from the recreational fishery (Aplin, 1949).

A small softshell clam fishery centered in San Francisco and Tomales Bays supplied local markets. Catches of 200,000 to 300,000 pounds were recorded through the 1930s and the clam beds were finally abandoned just after World War II because of sewage pollution (Bonnot, 1949).

In early catch statistics, two types of bivalves constituted the catch classification "cockle": the native littleneck clam, found scattered throughout the northern bays of the state, and three species of *Chione* found from Point Conception, south. None of the species was ever found in great abundance and the commercial fishery on cockles was never very large. Production persisted at low levels through the late 1920s; however, increased digging pressure during the economic depression of the 1930s resulted in a marked, but

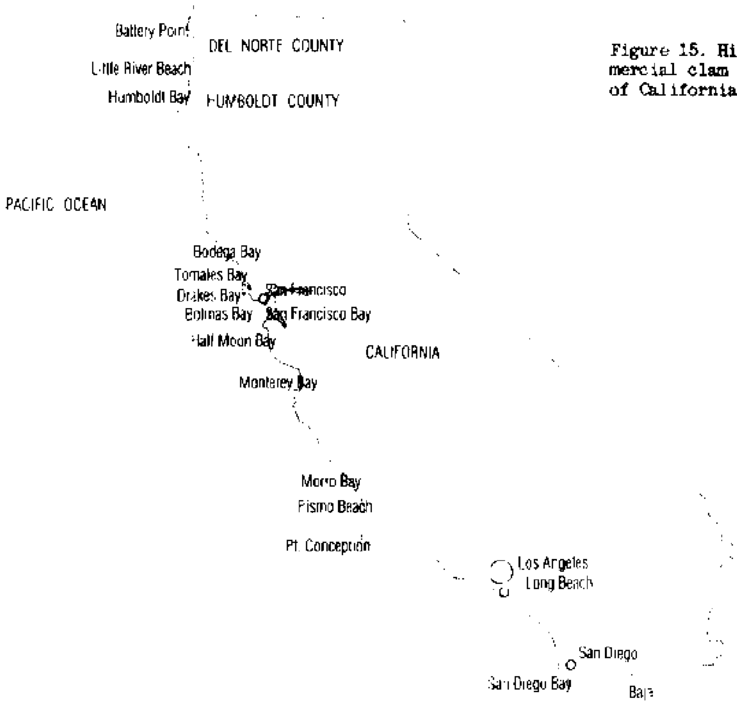


Figure 15. Historical commercial clam harvest areas of California

temporary increase in catch. The result was overexploitation (Bonnot, 1949), and with the start of World War II the fishery rapidly declined to insignificance.

During the 1930s, a minor commercial butter clam fishery was centered in Humboldt Bay. Production ranged from 10,000 to 40,000 pounds per year. After World War II, the fishery persisted, although at an extremely low level, until the early 1960s when it virtually disappeared.

Other species of clams also were harvested commercially, but not in large quantities. A small horse clam fishery existed in Humboldt and Monterey Bays, but ceased in the 1950s. The razor clams found on Little River Beach (Humboldt County) and Battery Point (Del Norte County) were harvested until 1949, but the commercial fishery was never a significant one (Warner, personal communication). In addition, populations of jackknife clams, found primarily in the protected bays and estuaries of southern California, supported a minor bait fishery following World War II.

In summary, California had a small commercial clam fishery through the 1950s, which declined rapidly after World War II and is now negligible. Pollution, overharvesting, economics, and increasing pressures from recreational diggers for more beach areas combined to cause its collapse.

Current Status

Theoretically, commercial clam harvest is still possible in Humboldt Bay by "market order" (i.e., a commercial fisherman with a bona fide order from a wholesale fish dealer may harvest the number of clams specified in the order). In lieu of a market order, a

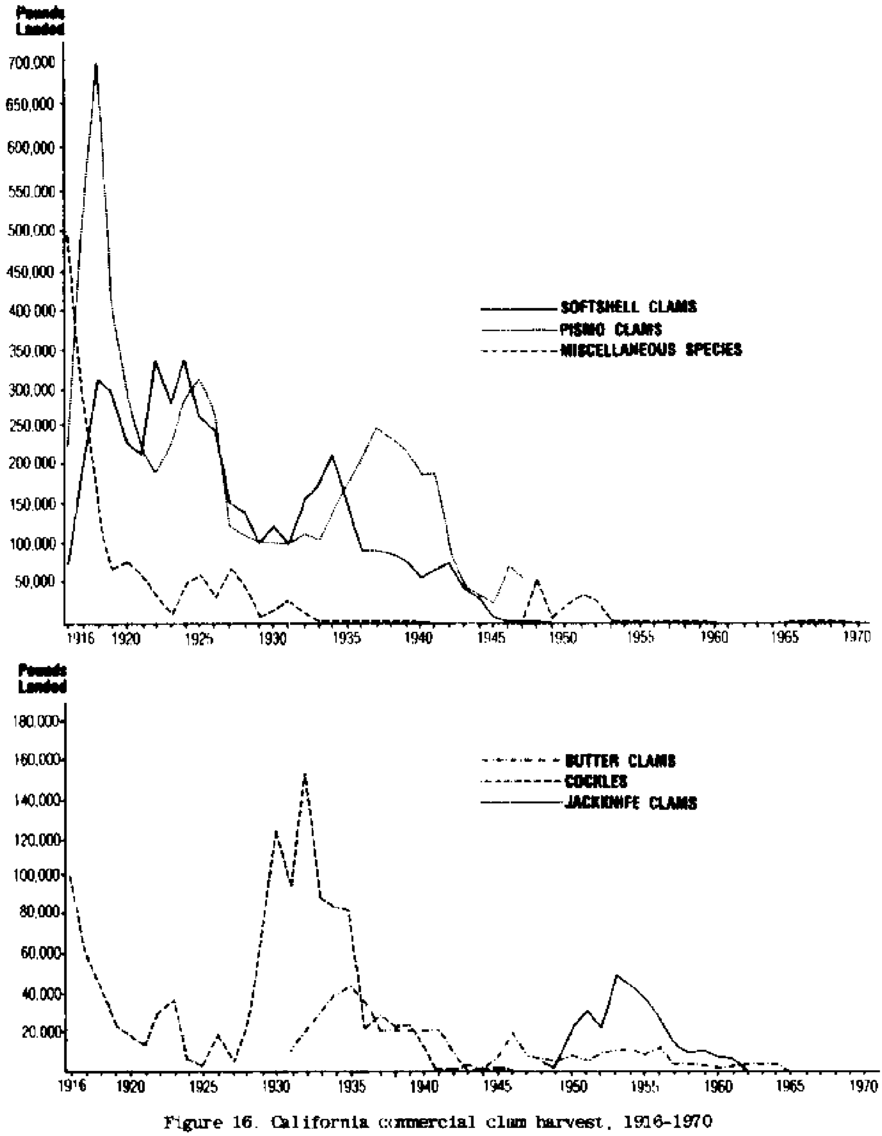


Figure 16. California commercial clam harvest, 1916-1970

commercial license holder may harvest clams in intertidal areas, but must adhere to sport limits and size restrictions. If a mariculture lease is obtained from the state, size and catch limits do not apply to lease area harvests.

San Francisco Bay is probably the only area in California with enough clams to permit a commercial fishery (Dahlstrom, personal communication). There are considerable lower intertidal populations of Manila and softshell clams, as well as some subtidal stocks, which are inaccessible to sport diggers and could be utilized in a commercial venture. Legislation was enacted in the 1970s permitting a commercial fishery on these stocks. A private corporation, which owns part of San Francisco Bay's subtidal lands, and an aquaculture firm are both interested in pursuing a commercial fishery. Because the bay is polluted, depuration is required before these clams can be sold for human consumption. This is a costly process and the companies involved have not yet begun commercial operations.

Since World War II California's clam resources have been insufficient to support both commercial and recreational fisheries. As a result, the California Legislature has reserved the state's clam resources almost exclusively for recreational clam diggers (Dahlstrom, personal communication). Management of clam stocks for recreational fisheries is difficult, however; California's clam resources are relatively small, distributed over a wide geographical area, and comprised of many species.

Although some data has been collected, there is still a paucity of information on clam populations and abundance in most areas. Limited information is available on horse clam populations in Tomales and Humboldt Bays, and clam distribution in several other bays (e.g., Bolinas Bay, Morro Bay, and Elkhorn Slough) has been surveyed (Dahlstrom, personal communication; Crane, et al., 1975).

The first comprehensive survey of the recreational Pismo clam fishery in Pismo Beach and Monterey Bay initiated in the late 1970s was designed to estimate effort, catch, and clam wastage. The study has been completed and a summary report is in progress (Burge, personal communication). The recreational clam fishery in Humboldt Bay is monitored for effort, but not catch per unit of effort (Warner, personal communication). A study of the horse clam populations of Humboldt Bay from 1969 through 1973 (Wendell et al., 1976), which included standing crop estimates for three major clam beds, indicated a general decline in population.

The razor clam stocks of Humboldt and Del Norte counties are in well-defined areas, and there is a sampling program established in those counties to monitor clam stocks, catch, and effort on a regular basis. The razor clam fishery, although small, is relatively stable (Warner, personal communication).

A number of methods are used to manage California's recreational clam fisheries. Catch limits are placed on all important sports species, and size limits are set for littleneck clams, softshell clams, cockles, and Pismo clams. Closed seasons are employed in managing Pismo clam stocks, and beach closures are used in both the Pismo and razor clam fisheries.

The condition of the Pismo clam stocks determine management procedures. Abundance depends heavily on a good set, which occurs approximately once every ten years. When sampling data indicate that a good set has taken place on a particular beach, it is closed for five years, until the clams reach harvestable size (Burge, personal communication). The two major razor clam beaches (Pismo Beach and Morro Bay) are managed slightly differently; they are divided into north and south sections, which are closed in alternate years.

Since a good portion of clam stocks occur in the lower intertidal zone, the tide plays an important conservation role. The limited number of low-tide days contributes to the stability of California's clam stocks, even in intensely dug areas (Dahlstom, personal communication).

Future

Although there is little future potential for commercial clam harvesting in California, there is potential for clam mariculture operations. The following are important considerations for such operations:

1. Most of the tidelands in California are state-owned and the state retains fishing rights.

2. Intertidal and subtidal lands can be leased from the state.

3. There are procedures for entering into a lease for land-based mariculture similar to those required to obtain oyster land leases.

4. Clam farming would be permitted only where native clams do not exist. Presumably, culture under these restrictions would involve beach rehabilitation and/or the planting of artificially reared clam seed.

5. In many areas residents would object to the use of public land for private benefit or profit.

Because of stringent state regulations and economic factors, the potential for clam mariculture in California appears extremely limited (Feldman, 1978; Dahlstrom and Smith, personal communications).

Clam Fishery Problems

The major problem facing the recreational clam fishery in California is the discharge of sewage and animal wastes into marine waters (Dahlstrom, personal communication). Although there are considerable impacts from urban development in clamming areas, these are being minimized. Harbor dredging, once a problem in clam producing areas, has been curtailed to some extent, and marina development is closely controlled (Schwartzell, personal communication).

The California State Department of Health evaluates oyster-growing areas for the certification required under the National Shellfish Sanitation Program, but usually does not declare areas safe or unsafe for recreational clam harvest. Where an area is grossly polluted, such as San Francisco Bay, county health departments establish a permanent quarantine; in other cases, notices are posted on unsafe beaches by county health departments (Young, personal communication).

There are some localized areas closed to shellfish harvest because of industrial pollution. Eastern quahogs (*Mercenaria mercenaria*), introduced 10 to 15 years ago, have established a reproducing population in Colorado Lagoon near the city of Long Beach (Crane et al., 1975). The clam bed has recreational harvest potential, but is restricted because of lead pollution (Dahlstrom, personal communication).

Appendix A Pacific Coast Clam Production

TABLE A.1 Pacific Coast Razor Clam Pack, 1913 to 1937, in Cases of 48 One-pound Cans

Year	Oregon	Washington	British Columbia	Alaska	Total Pacific Coast
1913	5,419	51,064	-	-	56,483
1914	11,205	52,720	-	-	63,925
1915	7,829	67,463	-	-	75,292
1916	2,253	31,911	-	6,398	40,562
1917	-	20,862	-	47,353	68,215
1918	-	20,875	-	42,356	63,231
1919	-	39,355	-	26,083	65,438
1920	-	35,414	-	4,291	39,705
1921	-	52,526	-	1,600	54,126
1922	-	64,928	-	17,494	82,422
1923	1,692	30,011	248	41,175	73,126
1924	855	26,748	5,125	43,192	75,920
1925	2,580	26,074	6,571	56,169	91,394
1926	2,400	37,559	5,653	22,611	68,223
1927	3,337	66,280	4,802	15,323	89,742
1928	2,946	55,261	8,742	7,415	74,364
1929	773	31,544	6,525	14,126	52,968
1930	-	27,367	6,312	17,004	50,683
1931	405	25,925	4,284	21,730	52,344
1932	700	22,272	4,229	34,570	61,771
1933	59	19,315	-	19,106	38,480
1934	30	12,616	-	15,827	28,463
1935	212	26,310	-	16,943	43,465
1936	279	24,068	-	14,949	39,296
1937	552	9,670	-	14,522	24,744

Table A.2 Early Puget Sound Clam Statistics, from Nightingale (1927).

Year	Whole Clams Pounds Landed	Cans--48-lb. Cases Clams	Cans--48-lb. Cases Nectar	No. of Canneries	Lbs. Bait	No. Licenses Clam	No. Licenses Bait
1905	--	3,500	--	--	--	--	--
1906	--	8,850	--	--	--	--	--
1907	--	8,850	--	--	--	--	--
1908	--	8,200	--	--	--	--	--
1909	--	5,000	--	--	--	--	--
1910	--	8,200	--	--	--	--	--
1911	--	6,200	--	--	--	--	--
1912	--	6,000	--	--	--	--	--
1913	--	8,200	--	--	--	--	--
1914	--	5,000	--	--	--	--	--
1915[1]	--	875	--	--	--	183	--
1916	--	3,529	15	--	--	--	--
1917	1,179,375	19,956	603	3	--	236	--
1918	772,568	7,944	177	4	--	177	4
1919	925,531	3,788	619	4	--	232	--
1920	486,955	3,524	154	4	--	145	--
1921	385,856	4,810	--	4	--	115	2
1922	441,184	5,538	60	4	17,680	121	15
1923	572,305	8,400	515	6	15,500	119	9
1924	554,631	9,366	2,400	4	12,700	132	10
1925	--	--	--	--	--	--	--

[1]Eight months

Table A.3 Summary of Washington Commercial Razor and Bay Clam Production, 1935-1979 Pounds Landed

Year	Razor Clams[1]	Bay Clams[3]	Total Production
1935	1,809,311	1,975,015	3,784,326
1936	2,048,201	3,454,782	5,502,983
1937	1,009,897	3,583,110	4,593,007
1938	2,679,664	3,372,617	6,052,281
1939	2,061,813	2,827,772	4,889,585
1940	2,199,614	2,461,426	4,661,040
1941	1,094,745	1,414,807	2,509,552
1942	367,035	787,060	1,154,095
1943	213,418	1,005,090	1,218,508
1944	622,582	1,102,062	1,724,644
1945	2,057,210	977,487	3,034,697
1946	2,048,065	1,772,784	3,820,849
1947	2,014,100	1,223,848	3,237,948
1948	1,256,693	1,124,557	2,381,250
1949	720,601	1,516,333	2,236,934
1950	249,840	1,003,523	1,253,363
1951	700,117	986,086	1,686,203
1952	691,325	1,196,227	1,887,552
1953	608,301	1,347,856	1,956,157
1954	597,301	1,566,019	2,163,320
1955	828,763	1,746,561	2,575,324
1956	696,859	1,661,321	2,358,180
1957	757,213	1,647,629	2,404,842
1958	1,029,547	1,766,158	2,795,705
1959	1,004,965	2,036,372	3,041,337
1960	443,748	2,096,255	2,540,003
1961	669,360	1,604,985	2,274,345
1962	552,061	1,633,120	2,185,181
1963	531,527	1,540,845	2,072,372
1964	397,700	1,403,401	1,801,101
1965	422,265	1,473,426	1,895,691
1966	403,755	1,391,179	1,794,934
1967	410,562	1,190,444	1,601,006
1968	318,059	1,295,134	1,613,193
1969	750,000	1,823,686	2,573,686
1970	680,090	2,032,642	2,712,732
1971	405,831	2,468,462	1,874,293
1972	179,818	2,300,960	2,480,778
1973	201,139	2,584,179	2,785,318
1974	170,763	2,799,025	2,969,788
1975	294,952	4,389,967	4,684,919
1976	373,142	7,542,433	7,915,575
1977	890,161	11,752,572	12,642,733
1978	645,389	9,951,541	10,596,960
1979	373,581	7,222,792	7,590,373
1980	19,290[2]	6,373,614	6,392,904
1981	2,290[2]	6,774,057	6,776,999

[1] Razor clam catches include Quinault Indian Reservation figures.

[2] Subject to revision

[3] Includes geoduck landings

Source: Washington Department of Fisheries. 1981 Fisheries Statistics.

Table A.4 Washington Commercial Bay Clam Production, by Species, 1955-1979, Pounds Landed

Year	Native Littlenecks	Manila Clams	Butter Clams	Horse Clams	Softshell Clams	Geoducks
1955	725,942	472,611	107,515	--	--	--
1956	789,757	433,579	199,112	--	--	--
1957	880,759	303,160	226,129	--	--	--
1958	1,066,845	294,035	186,422	--	--	--
1959	1,058,801	423,184	374,250	9,450	--	--
1960	1,411,106	469,731	389,299	13,992	--	--
1961	911,644	291,647	288,934	50	--	--
1962	958,573	299,837	350,059	--	--	--
1963	857,549	420,023	204,348	--	--	--
1964	786,761	414,301	180,866	--	--	--
1965	675,408	606,884	136,591	6,690	--	--
1966	654,027	498,648	139,245	42,000	--	--
1967	534,004	395,458	191,453	14,100	--	--
1968	649,234	434,654	208,966	2,280	--	--
1969	708,874	542,303	525,860	36,490	6,998	--
1970	625,350	540,069	609,315	30,668	44,826	82,236
1971	626,896	762,226	465,920	2,150	1,020	610,250
1972	678,026	649,531	413,293	29,545	37,425	493,140
1973	780,312	539,820	598,698	97,411	103,944	463,994
1974	646,685	778,730	359,720	161,969	36,832	803,358
1975	545,188	963,745	323,364	149,544	32,885	2,369,515
1976	547,247	1,110,807	232,431	214,596	71,454	5,365,898
1977	617,068	1,078,433	527,440	523,274	358,062	8,646,746
1978	474,030	1,840,493	237,262	244,258	65,758	7,089,656
1979	348,482	1,475,497	107,182	48,234	15,182	5,228,215
1980	521,855	1,466,111	406,060	60,902	8,493	3,910,193
1981	625,396	1,508,088	250,161	100,285	--	4,290,127

Source: Washington Department of Fisheries

Table A.5 Washington Hand and Dredge Harvest of Native Littleneck and Butter Clams, 1955-1979 Pounds Landed

Year	Native Littlenecks		Butter Clams	
	Hand Harvest	Dredge Harvest	Hand Harvest	Dredge Harvest
1955	725,942	--	107,525	--
1956	789,757	--	199,112	--
1957	880,759	--	226,129	--
1958	1,066,345	--	186,422	--
1959	874,336	184,465	201,440	172,810
1960	977,626	163,480	232,710	156,589
1961	859,810	131,834	168,737	120,197
1962	904,130	54,443	143,796	206,263
1963	820,375	37,174	93,175	111,173
1964	753,730	33,031	75,933	104,933
1965	647,165	28,243	88,981	47,610
1966	643,977	10,050	122,179	17,069
1967	543,004	--	38,738	152,715
1968	505,800	120,120	15,729	193,237
1969	463,273	230,318	46,527	479,333
1970	387,634	228,843	39,484	569,290
1971	435,946	174,567	33,697	432,223
1972	575,680	83,784	81,312	331,981
1973	483,494	270,705	102,306	454,002
1974	321,084	325,185	11,761	347,960
1975	348,374	196,789	16,314	307,050
1976	434,478	112,769	22,492	209,939
1977	526,621	90,447	131,612	395,828
1978	418,122	55,908	43,075	194,187
1979	323,159	25,323	42,441	64,741
1980	455,247	66,608	72,089	333,971
1981	610,006	15,390	41,528	208,633

Source: Washington Department of Fisheries

Table A.6 Central Alaska Butter Clam and Cockle Production in Pounds and Value to Fishermen, 1942-1969 Pounds Landed

Year	Butter Clams		Cockles	
	Pounds	Value	Pounds	Value
1942	--	$ --	--	$ --
1943	9,780	256	--	--
1944	2,625	171	8,580	270
1945	14,749	959	10,918	420
1946	3,672	275	7,368	442
1947	1,456	109	4,696	282
1948	4,026	121	--	--
1949	5,652	339	8,316	499
1950	--	--	73,200	4,392
1951	--	--	32,073	2,566
1952	1,428	93	8,830	662
1953	1,222	98	20,200	1,616
1954	963	82	67,778	5,422
1955	6,161	555	--	--
1956	--	--	81,678	6,534
1957	--	--	640	45
1958	--	--	--	--
1959	--	--	--	--
1960	--	--	1,270,290	165,138
1961	--	--	5,800	860
1962	--	--	500	260
1963	--	--	--	--
1964	--	--	--	--
1965	1,500	1,000	--	--
1966	--	--	--	--
1967	--	--	--	--
1968	--	--	--	--
1969	--	--	--	--

Source: Nosho, 1972

Table A.7 Oregon Commercial Clam Production (whole wet weight), 1928-1980 Pounds Landed

Year	Total	Bay Clams	Razor Clams
1928	110,471	--	--
1929	56,600	--	--
1930	163,370	--	--
1931	143,159	--	--
1932	131,530	--	--
1933	127,635	--	--
1934	224,270	--	--
1935	469,445	--	--
1936	447,509	--	--
1937	471,615	--	--
1938	664,297	--	--
1939	607,985	--	--
1940	658,564	--	--
1941	338,371	214,000	124,371
1942	134,550	121,000	13,550
1943	196,505	178,000	18,505
1944	268,121	204,000	64,121
1945	384,134	306,000	78,134
1946	416,858	265,000	160,858
1947	343,555	178,000	165,556
1948	331,667	122,000	209,667
1949	349,696	135,000	214,696
1950	586,569	149,000	337,569
1951	395,362	155,000	240,362
1952	416,180	149,000	267,180
1953	471,527	135,000	336,527
1954	312,016	135,504	176,512
1955	282,159	115,643	166,516
1956	227,381	122,677	104,704
1957	189,348	110,766	78,582
1958	168,058	79,594	88,464
1959	117,486	66,108	51,378
1960	106,578	77,023	29,555
1961	87,434	69,589	17,845
1962	132,950	106,487	26,463
1963	108,873	84,773	24,100
1964	97,658	62,862	34,796
1965	122,649	49,567	73,082
1966	131,238	47,258	83,980
1967	148,057	27,605	120,452
1968	120,328	27,866	92,462
1969	47,125	22,001	25,124
1970	40,690	25,884	14,806
1971	58,753	28,746	30,007
1972	74,718	62,168	12,550
1973	34,452	18,200	16,252
1974	25,315	16,315	9,000
1975	68,278	26,866	41,412
1976	202,351	88,054	114,297

Table A.7 Oregon Commercial Clam Production continued

Year	Total	Bay Clams	Razor Clams
1977	130,211	85,733	44,478
1978	255,136	216,926	38,210
1979	29,880[1]	94,912	32,000[2]
1980	19,256[1]	80,464	

[1] Based on 16.6% recovery rate

[2] Estimate

Source: Marriage, 1954; Biennial Report of the Fish Commission of the State of Oregon; Darrell Demory, personal communication

Table A.8 Oregon Commercial Clam Production by Species and Primary Commercial Harvesting Areas, 1969-1978 Pounds Landed

Year	Native Littlenecks	Butter Clams	Cockles	Horse Clams	Softshell Clams	Total
COOS BAY						
1969	--	--	--	--	--	5,109
1970	141	505	2,658	1,218	65	4,522
1971	--	84	466	10,278	12,019	10,893
1972	--	--	1,872	30,751	508	44,642
1973	--	--	2,280	65	--	2,853
1974	106	402	2,724	0	--	3,232
1975	293	--	6,398	15,024	--	21,715
1976	--	816	--	85,713	--	86,529
1977	50	--	5	12,011	--	12,066
1978	--	--	6,064	35,740	--	41,804
YAQUINA BAY						
1969	--	--	1,581	--	--	1,581
1970	--	--	444	--	--	444
1971	--	--	1,819	--	--	1,819
1972	--	--	57	--	--	57
1973	--	--	--	--	--	--
1974	--	--	--	--	398	398
1975	--	--	--	--	--	--
1976	--	--	--	--	--	--
1977	182	547	85	69,331	505	71,013
1978	--	149	--	171,898	--	172,047
TILLAMOOK BAY						
1969	--	--	--	--	--	4,770
1970	646	380	6,945	--	30	7,819
1971	50	133	5,538	67	160	5,948
1972	1,406	52	4,980	3,055	144	9,637
1973	9,442	95	2,285	120	55	11,997
1974	7,999	10	1,300	--	--	9,309
1975	4,029	--	608	--	--	4,637
1976	445	--	215	--	150	820
1977	--	60	531	433	326	1,350
1978	1,045	1,303	518	3	36	2,905

Table A.8 continued

Year	Native Littlenecks	Butter Clams	Cockles	Horse Clams	Softshell Clams	Total
UMPQUA BAY						
1969	--	--	--	--	9,384	9,384
1970	--	--	--	--	10,631	10,631
1971	--	--	--	--	7,459	7,459
1972	--	--	360	200	5,545	6,105
1973	--	--	--	--	786	786
1974	--	--	--	--	445	445
1975	--	--	--	--	463	463
1976	--	--	--	--	--	--
1977	--	--	--	--	35	35
1978	--	--	--	--	--	--
NETARTS BAY						
1969	--	--	--	--	--	--
1970	--	--	2,110	--	--	2,110
1971	--	--	1,568	--	--	1,568
1972	--	--	914	--	--	914
1973	--	--	1,191	--	--	1,191
1974	--	--	2,049	--	--	2,049
1975	--	--	--	--	--	--
1976	--	--	--	--	--	--
1977	--	--	--	--	--	--
1978	--	--	--	--	--	--

Source: Darrell Demory, personal communication

Table A.9 California Clam Landings, 1916-1976 Pounds Landed

Year	Cockles[1]	Washington Clams[2]	Softshell Clams	Pismo Clams	Jackknife Clams	Misc. Species
1916	90,945	--	75,674	220,566	--	534,291
1917	61,005	--	187,864	502,069	--	308,497
1918	44,933	--	312,143	665,684	--	129,084
1919	24,817	--	302,576	417,515	--	66,744
1920	18,054	--	233,124	299,015	--	79,875
1921	14,504	--	216,600	219,507	--	59,832
1922	31,564	--	343,262	193,491	--	35,291
1923	36,117	--	283,095	237,948	--	25,845
1924	6,341	--	243,324	293,149	--	49,379
1925	2,991	--	264,056	323,245	--	61,839
1926	17,976	--	245,962	274,317	--	35,202
1927	5,914	--	151,383	133,000	--	64,663
1928	22,651	--	148,542	125,832	--	44,662
1929	65,466	--	101,460	109,744	--	13,498
1930	125,213	--	116,571	108,860	--	17,266
1931	92,250	10,442	101,738	104,672	--	30,793
1932	153,433	22,908	165,041	110,277	--	8,183
1933	87,688	29,929	173,039	106,215	--	1,258
1934	82,607	39,620	222,011	140,737	--	4,918
1935	81,093	42,042	153,405	181,855	--	4,454
1936	22,802	35,272	90,971	209,805	--	4,496
1937	28,552	21,629	92,915	223,955	--	3,396
1938	23,831	23,086	87,219	214,571	--	4,545
1939	23,070	21,135	75,721	192,694	--	4,149
1940	14,476	22,983	63,235	167,478	--	3,188
1941	600	20,764	65,988	168,797	--	1,624
1942	257	9,848	73,144	93,613	--	760
1943	--	728	46,557	45,870	--	120
1944	407	1,423	31,316	34,534	--	--
1945	1,069	6,565	13,425	26,079	--	--
1946	43	20,341	22,239	69,177	--	132
1947	282	8,009	22,584	60,557	--	2,656
1948	843	6,602	1,373	--	5,247	55,774
1949	137	4,925	--	--	--	10,144
1950	--	7,022	--	--	20,908	29,774
1951	--	5,295	--	--	29,453	41,535
1952	--	9,256	--	--	22,155	29,128
1953	--	10,216	--	--	47,777	2,160
1954	10	10,279	--	--	43,747	1,128
1955	98	7,491	--	--	36,837	2,100
1956	--	10,629	--	--	26,683	688
1957	94	3,661	--	--	12,358	394
1958	--	3,961	--	--	8,788	680
1959	--	2,876	--	--	9,336	726
1960	--	1,655	--	--	6,988	488
1961	--	1,976	--	--	5,823	200
1962	--	3,185	--	--	4,458	480
1963	--	3,879	--	--	--	869
1964	--	4,133	--	--	--	467

Table A.9 continued

Year	Cockles[1]	Washington[2] Clams	Softshell Clams	Pismo Clams	Jackknife Clams	Misc. Species
1965	--	--	--	--	--	1,681
1966	--	--	--	--	--	2,154
1967	--	--	--	--	--	2,532
1968	--	--	--	--	--	1,842
1969	--	--	--	--	--	156
1970	--	--	--	--	--	475
1971	--	--	--	--	--	165
1972	--	--	--	--	--	684
1973	--	--	--	--	--	212
1974	--	--	--	--	--	1,252
1975	--	169	--	--	15,869[3]	18,377[3]
1976		144	--	--	10,648[3]	18,451[3]

[1]In early catch statistics, cockles were classified as native littlenecks and three species of *Chione*.

[2]In California, the butter clam is known as the Washington clam.

[3]Bait

Appendix B Biology

Many of the problems encountered by clam populations and the clam industry are related, directly or indirectly, to the biology of the animal. The following information may provide a better understanding of those problems.

The phylum Mollusca has six main categories, or classes, and clam belong to the class Bivalvia, which is also known as Pelecypoda and Lamellibranchia. Clams, like other bivalves, possess a soft body, which is laterally compressed and enclosed between two hinged shells or valves. Another prominent feature is the foot, which is also laterally compressed, hence the name Pelecypoda—"hatchet foot." The gills are relatively large and function in food collecting as well as respiration.

Shell

A typical clam shell has a bulge along the outside edge called the umbo (Figure B.1), which is the oldest part of the shell. As the clam grows, new material is deposited, forming concentric growth rings. The two shell valves are attached by an elastic hinge ligament that forces the valves apart when the adductor muscles relax. A system of articulating hinge teeth and ridges prevent the valves from slipping sideways.

The clam closes its shell by contracting its two large adductor muscles. Prominent muscle scars form where the muscles attach to the inner surface of the valves. Another impression, termed the pallial line, is formed where the mantle, the outer tissue layer that envelops the soft viscera, is attached immediately beneath the valves. Part of the pallial line indents posteriorly where the siphon retractor muscles attach. This area is referred to as the pallial sinus. The size, shape, form, and position of these muscle scars are often used for identification.

Mantle

The mantle performs some respiratory and sensory functions, but its primary function is to secrete shell material. A bivalve shell is composed mostly of calcium carbonate and may be divided into three principal layers: an outer, brownish colored periostracum, the middle or prismatic layer, and the inner, nacreous layer. Shell growth usually is rapid in young bivalves and decreases with age. Deposition of shell material is influenced by water temperature, and occurs more rapidly in warmer waters or during warmer months. Growth increments along the shell are narrowest along the hinge line by the umbo, and become wider at the front and back. In clams that have approximately circular shells, increments are greatest in the mid-ventral area where shell gape is widest. Although the precise color patterns, size, and sculpturing of the shell may vary from one group of bivalves to another, these characteristics are remarkably constant for very closely related groups.

Foot

In most clams, the blade-like foot is laterally compressed and

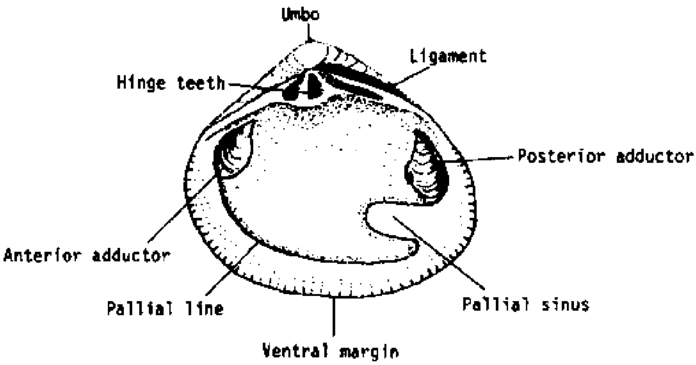


Figure B.1 Morphology of the internal surface of a clam shell.

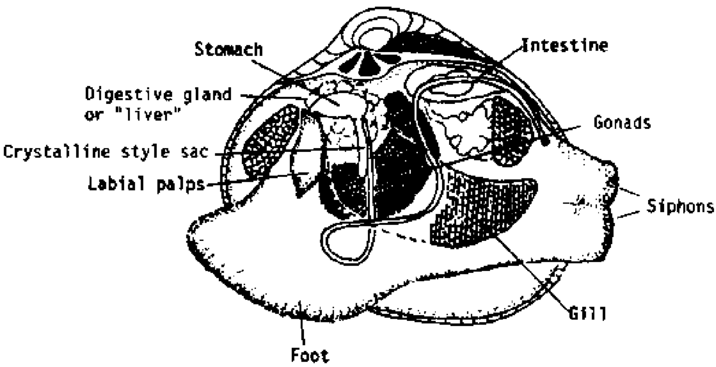


Figure B.2 Internal anatomy of a clam showing main body parts (with left valve removed).

extends anteriorly as an adaptation for burrowing (Figure B.2). The clam digs by combining muscular action and hydrostatic pressure. As a pair of muscles extends the foot downward, it is filled with blood from the visceral mass, causing it to dilate and anchor in the substrate. Other muscles associated with the foot then contract, pulling the shell downward until the foot retracts.

Siphons

Siphons are tubular extensions of the mantle edge allowing clams to burrow and live completely embedded in the substratum. The length of the siphon, or "neck," varies by species, but is typically longer in deeper burrowing clams. For example, a geoduck neck may be three feet long when extended through the substrate up to the surface. The siphons circulate water through the clam. Water enters through the ventral, inhalent siphon and exits via the dorsal, exhalent siphon. Although the two siphons are separate in some bivalves, they are fused in most of the common species of clams.

Gills

The gills, or ctenidia, comprise one of the characteristic features of the Lamellibranchs ("sheet gills"). Four of these highly specialized structures are present, two on each side of the visceral mass. In clams and similar bivalves, the gills are used for filter feeding as well as respiration. Thousands of hairlike cilia on the gill surfaces produce water currents which draw water in through the inhalent siphon and circulate it over and through the gills, where oxygenation of the blood takes place. Simultaneously, food particles, mostly phytoplankton and detritus, are entangled in mucous along the gills, sorted by size, and shunted by cilia along food grooves to the labial palps and mouth. Suitable-sized particles are ingested, and rejected material is expelled, usually through the inhalent aperture, when periodic valve closure forces water out.

Digestion

After ingestion, food enters the digestive system, which is composed of a short esophagus, stomach, crystalline style, digestive diverticulum ("liver") and intestine. In the stomach, particles are further sorted by cilia. Some of the larger, coarse particles may go directly through the intestine and be voided without being digested, while other particles are processed by the crystalline style or pushed through small ducts into the digestive diverticula. The crystalline style is a transparent mass of gelatinous material, sometimes mistaken for a worm, which secretes digestive enzymes. Cilia cause the crystalline style to rotate in the stomach against a gastric shield, grinding food particles and facilitating digestion. This rotary action also pulls food-laden mucous strands into the stomach from the esophagus. Fine particles are directed into the digestive glands, where they are absorbed and digested. Wastes are subsequently conducted to the intestine and excreted.

Reproduction

Most bivalves are dioecious (separate sexes) and possess paired gonads that are closely associated with the visceral mass. Prior to spawning (release of eggs and sperm) the gonads appear as conspicuous, milky white masses within the mantle tissue.

Spawning often occurs simultaneously within a population, a phenomenon which enhances the probability of successful repopulation. However, the time and duration of spawning depends on the species in question and environmental factors, such as water temperature, salinity, availability of nutrients, and tidal stage. Most clams release gametes through the exhalent siphon; fertilization occurs in the water. The ensuing development, or life history, varies somewhat according to species, but the general pattern is as follows.

Life History

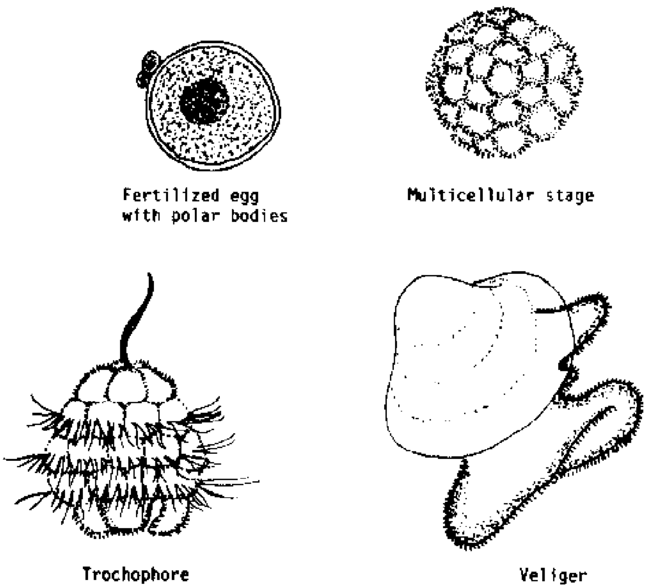
The embryo quickly passes through several developmental stages (Figure B.3) and becomes a free-swimming trochophore larva (approximately 10-12 hours). Within a relatively short period of time (about 24 hours after fertilization) it develops into a veliger larva with a microscopic foot, a digestive system, and a velum, which is a specialized organ for swimming and feeding. Also during this time, the larval shell, or "prodissoconch," is growing, and the larva may be classified as a "straight" or "D" hinge, or an umbo stage, depending on the appearance of the shell.

The pelagic bivalve larva is well adapted for distribution and perpetuation of the species, tasks requiring a delicate balance between locomotive efficiency and shell growth. This balance is accomplished by development of the velum. As with other planktonic forms, bivalve larvae are dispersed by the currents and are also vulnerable to predation and sudden, detrimental changes in environmental conditions. In general, survival to setting is very low, and may be less than five percent of the original number of larvae.

As the larval shell becomes progressively thicker and heavier, the swimming capabilities of the veliger diminish and the fully developed larva sinks more often and more rapidly to the bottom. The larva creeps along the bottom on its foot until it finds a suitable surface for attachment, adhering to it by means of a byssus or byssal threads. The tough, organic threads are secreted by a gland in the foot and harden upon exposure to sea water. Metamorphosis, or transition to a sedentary mode of life, is also marked by a sudden disappearance of the velum.

Larval life ceases when the clam attaches itself to a substratum. This event is synonymously termed setting, settlement, spatting, or spatfall, and the larvae are called spat. For a clam spat, the attachment is only temporary and it eventually breaks free and burrows permanently into the substrate.

Figure B.3 Larval development of a clam



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