Biological Report 82(11.78)
August 1987

TR EL-82-4

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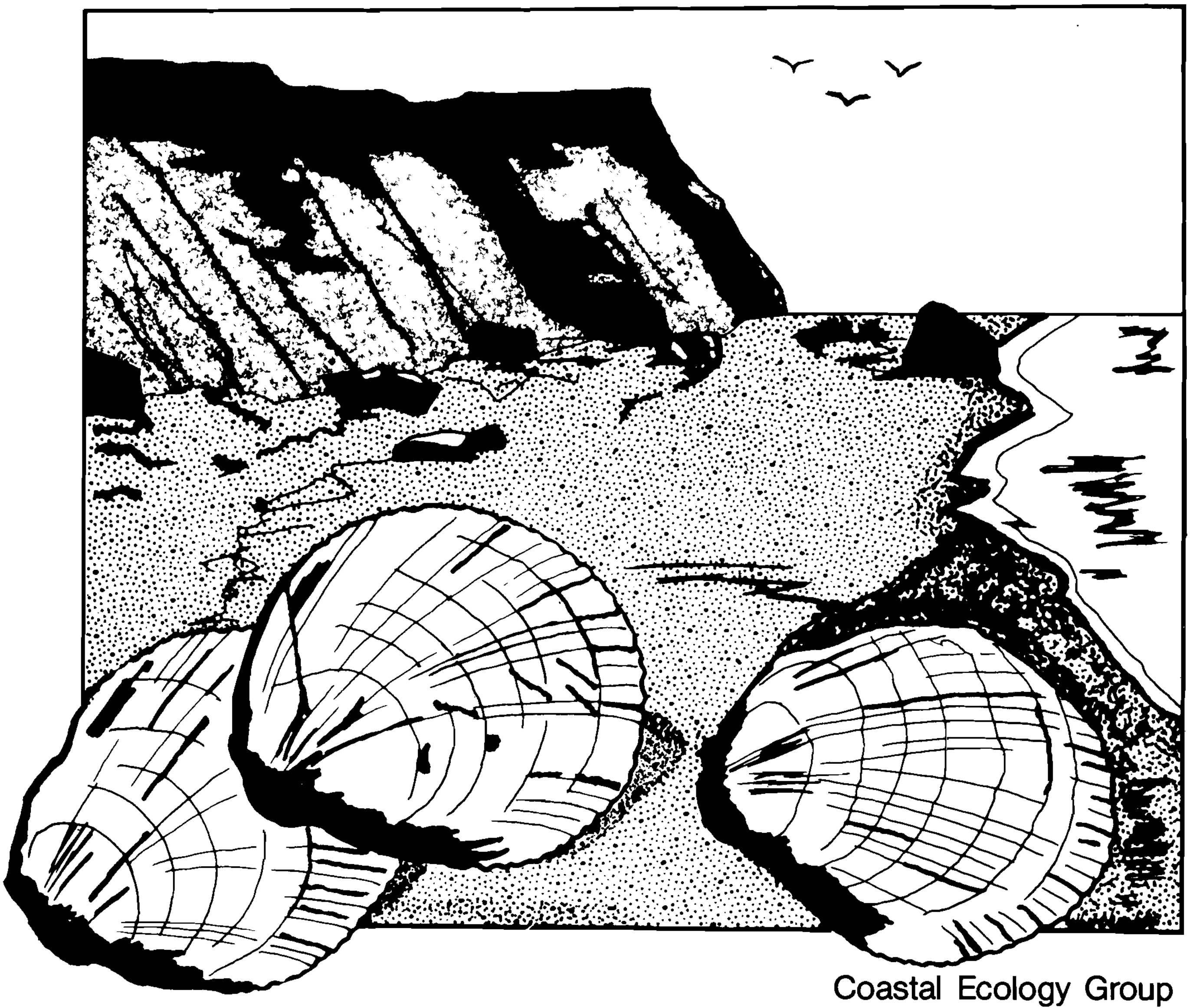
COMMON LITTLENECK CLAM



Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest)

COMMON LITTLENECK CLAM

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Vicksburg, MS 39180

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PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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or

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Attention: WESER-C
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Vicksburg, MS 39180

CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

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FIGURES

ACKNOWLEDGMENTS

Special appreciation is extended to Neil Bourne of the Pacific Biological Station in Nanaimo, B.C., Lynn Goodwin of the Washington State Department of Fisheries, William N. Shaw of the Humboldt State University in California, and Howard Feder and A.J. Paul of the University of Alaska for their reviews and helpful comments to this manuscript.

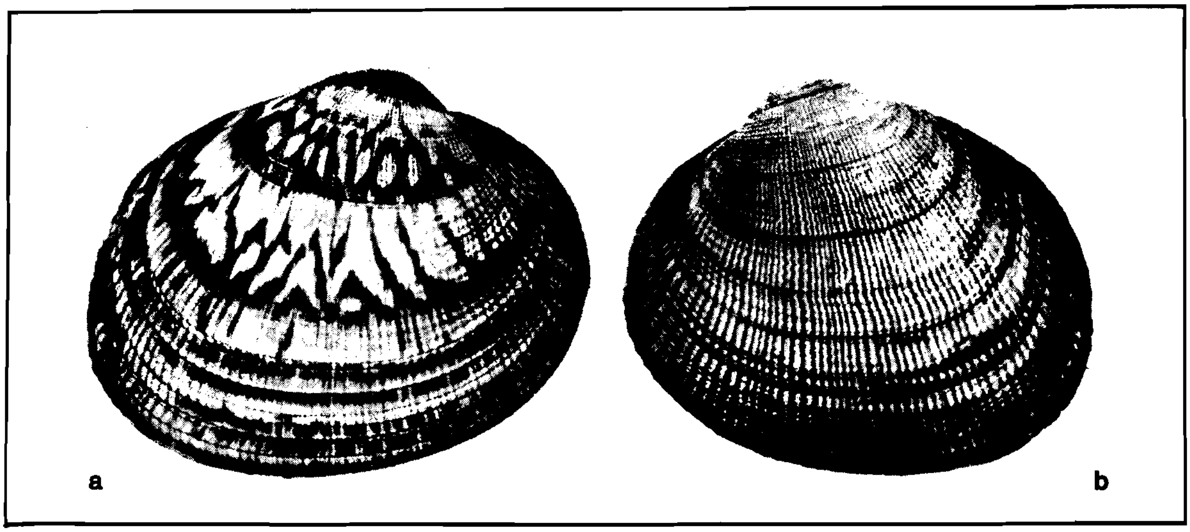

Figure 1. Common littleneck clam (a) with geometric color pattern, (b) without geometric color pattern (from Quayle and Bourne 1972).

COMMON LITTLENECK CLAM

NOMENCLATURE/TAXONOMY/RANGE

Scientific name ....*Protothaca staminea* (Conrad 1837)
Preferred common name ....Common littleneck clam (Figure 1)
Other common names...........Native littleneck clam, rock cockle, bay cockle, hardshell clam, Tomales Bay cockle, rock clam, ribbed carpet shell, steamer clam.
Class ....Pelecypoda
Order ....Veneroida
Family ....Veneridae

Geographic range: Aleutian Islands, Alaska, south to Cape San Lucas, Baja California, Mexico; commercially abundant only north of Oregon. In Washington, extensive intertidal and subtidal clam stocks are found in Puget Sound, Hood Canal, Grays Harbor, and Willapa Bay. The species is relatively scarce in Oregon; Tillamook, Yaquina, and Coos Bays are the most productive areas (Figure 2).

MORPHOLOGY/IDENTIFICATION AIDS

Conrad (1837) first described the common littleneck clam as follows: Shell suboval or suborbicular, convex, with numerous crowded radiating striae and finer concentric lines, more distinct on the anterior side and posterior extremity; ligament margin nearly parallel with the base; color variegated with yellow and brown, and with brown angular spots; cardinal teeth compressed; sinus of pallial impression profound; mean size (mm): length 50, height 42, diameter 30.

The following description was extracted from Fitch (1953). The shell is oval and has inflated valves ornamented by well-defined, radiating ribs and less prominent concentric ridges. The lunule (a heart-shaped impression anterior to the umbo) is often only faintly defined. The ventral margin is slightly crenulated. The pallial sinus (a U-shaped indentation) extends slightly more than

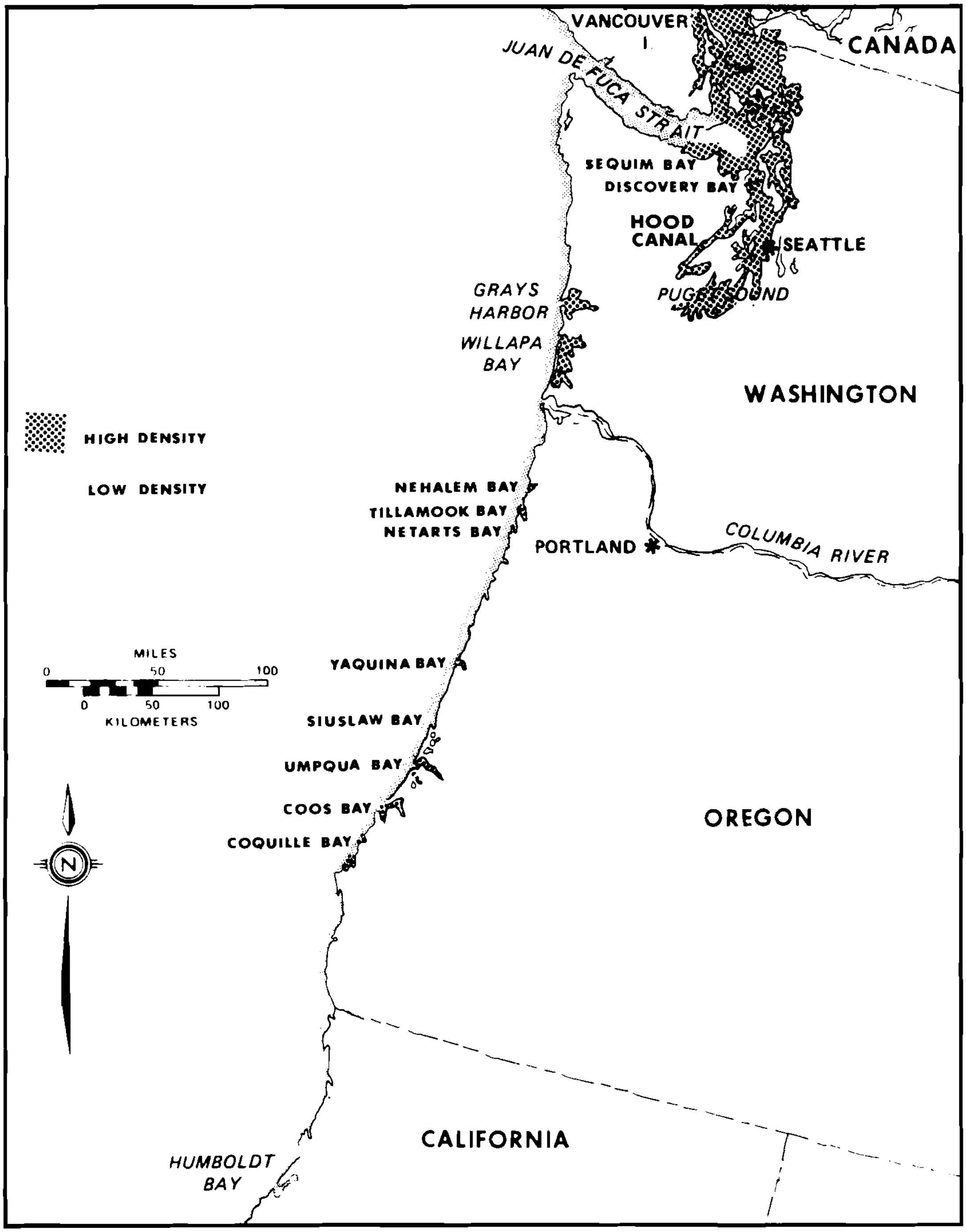

Figure 2. Distribution of the common littleneck clam along the Pacific Northwest coastal region.

halfway to the anterior adductor muscle. Color is highly variable, yellowish gray or gray if in sloughs and bays; specimens collected along the open coast are often whitish with geometric patterns of wavy brown lines or blotches on sides. The common littleneck clam attains a maximum length of 6.4 cm. It differs from chione clams (Chione spp.) and Japanese littleneck clams (Tapes japonica) in having a pallial sinus that extends more than halfway to the anterior adductor muscle, and from the rough-sided clam (Protothaca laciniata) and thin-shelled littleneck clam (P. tenerrima) in having radiating ribs that are more prominent than concentric ridges.

The hinge ligament is external. The interior surface is smooth and white and has a crenulated internal ventral margin (Quayle and Bourne 1972). Shape differs widely in different localities: some clams are long and narrow and others are short and broad; the shells are thin and flat in some, and thick and strongly convex in others (Fraser and Smith 1928). The length and height relationship for common littleneck clams at Galena Bay, Alaska, is shown in Figure 3.

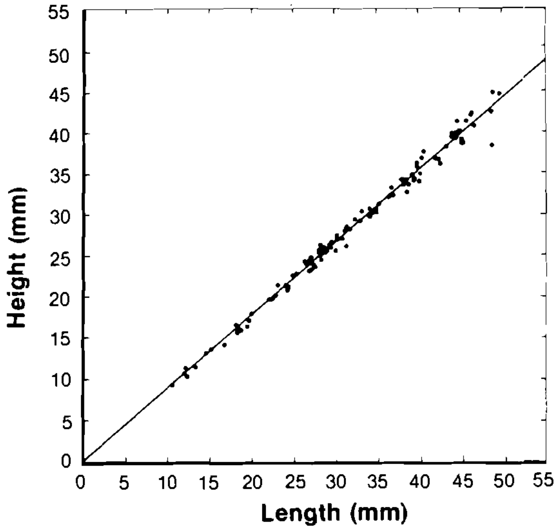

Figure 3. Length and height relationship of common littleneck clams collected in Galena Bay, Alaska (Feder and Paul 1973).

REASON FOR INCLUSION IN SERIES

The common littleneck clam is one of the most widely distributed hardshell clams along the entire coast of the Northwest region, occurring especially in well-sheltered areas and estuaries such as Puget Sound, Grays Harbor, and Willapa Bay. Because the common littleneck clam is fairly numerous and its habitat is easily accessible, it is important as both a commercial and a recreational species.

Like other natural resources, common littleneck clams are subject to man-made problems, such as overfishing, water pollution, and loss of habitat due to intensive development of coastal areas. Some of these interferences are critical to the existence of the clams. Statistics already show that the quantity landed in the U.S. Pacific Northwest (which does not include Alaska) is decreasing each year and the effort needed to harvest the clams is increasing.

LIFE HISTORY

Spawning

Although sexes are separate in the common littleneck clam (Quayle 1943), it is not uncommon to find hermaphroditic individuals (Fraser and Smith 1928). Time of spawning varies throughout its range, depending largely on water temperature. A shortened spawning period is characteristic of clams at the northern and southern limits of their range, and appears to be primarily a temperature-related phenomenon (Feder et al. 1979).

Early studies in British Columbia reported that these clams are plump and firm during the late spring and summer months, but thin and watery during the early months of the year. Also, spawning occurs in February and March and no sign of spawning is found during summer (Fraser and Smith 1928). However, later studies conducted in Ladysmith Harbor, British Columbia, noticed that the tubules of the ovary were filled with follicular cells in December and January (Quayle 1943). In British Columbia, most clams spawn in late spring but some spawn sporadically throughout the summer (Quayle and Bourne 1972).

In Southcentral Alaska, spawning starts in late May when the water temperature is about 8 °C. In Prince William Sound, Alaska, histological examination of females throughout the reproductive cycle indicates a single annual spawning period that may last for 4 months. Males appear ripe throughout most of the year (Feder et al. 1979). Spawning begins in late May to mid-June and continues into September (Nickerson 1977). In summer, when water temperature fluctuations are usually extensive, two periods of high temperature and two corresponding spawning peaks can be expected.

During spawning, eggs and sperm are discharged through the inhalant siphon (Quayle and Bourne 1972) and mass fertilization takes place in the open water.

Eggs and Larvae

After fertilization, the eggs divide rapidly and embryos develop to trochophore larvae (60 to 80 μm) about 12 hours later (Quayle and Bourne 1972). The veliger (straight-hinge stage) develops in the next 24 hours. A ciliated velum develops that helps the larva swim and maintain itself in the upper water column. Larvae feed on phytoplankton and are about 0.15 mm long after 1 week. The veliger develops an umbo on its prodissoconch (shell) and may reach a length of 0.26 to 0.28 mm in 2 weeks (Shaw 1985). The umboned larvae are rather easily identified by their shape and the yellow ventral margin of the shell (Quayle and Bourne 1972).

Depending on food supply and temperature, the planktonic larval stage generally lasts about 3 weeks (Quayle and Bourne 1972). Breeding success or failure is frequently determined during this critical larval stage (Quayle and Bourne 1972). The larvae are at the mercy of currents and may be carried away from settling areas and consequently die. Prior to metamorphosis, the veliger develops a foot, moves to the bottom, and searches for a suitable surface on which to settle. Once such surface is found, the larva undergoes metamorphosis and attaches itself to the surface by secreting byssal threads.

Postlarvae and Recruitment

When the larvae settle they are called spat. At spatting, considerable anatomical changes occur, and larval organs such as the velum are lost (Quayle and Bourne 1972). The postlarvae are epifaunal, and mortality may be high (Paul and Feder 1973). Mortality is highest during or at the end of the first year after settlement, especially in winter (Schmidt and Warme 1969). Unlike the butter clam, Saxidomus giganteus, which remains permanently at the site of settlement, a young common littleneck clam can use its foot to crawl to a new location (Shaw 1985).

The extent of annual recruitment of common littleneck clams varies greatly between areas. Peterson (1975) reported that variation in recruitment was higher for common littleneck clam than other clam species collected during 10 sampling periods over a 3-year period.

Experimentally increased adult densities had no significant effect on recruitment in sand, but reduced recruitment as much as 60% in mud. In Prince William Sound, Alaska, the clam's northern limit, recruitment was erratic and little recruitment occurred from 1967 to 1971, probably because spawning or recruitment conditions were poor (Paul and Feder 1973; Paul et al. 1976a).

Maturity and Life Span

Male and female common littleneck clams were nearly equal in number and no appreciable sex-related difference was apparent in their size or growth rate at any time (Fraser and Smith 1928). In Sidney, British Columbia, the sex of clams under 1-year-old could not be distinguished by examination of their gonads. Half of the 2-year-old clams were still immature. Half of the clams spawned for the first time at the end of the second year at a length of about 25 mm, and most spawned at the end of the third year when about 35 mm long. Size seemed to have much to do with the time of maturity. At beaches where density was high and growth was slow, maturity was often delayed (Fraser and Smith 1928).

At Ladysmith Harbor, British Columbia, sexual differentiation was apparent when clams were 15 to 35 mm long, or during their 2nd or 3rd year of life (Quayle 1943). Mature clams were usually 22 to 35 mm long. In Prince William Sound, Alaska, the youngest sexually mature clam collected was 3 years old and 13 mm long (Nickerson 1977).

Shaw (1985) summarized the life span of the common littleneck clam, which varies at different locations. The maximum life span in years, lengths, location, and sources of information follow: 13 years (62 mm), Porpoise Island, Alaska (Paul et al. 1976b); 10 years (54 to 63 mm), British Columbia (Fraser and Smith 1928; Quayle and Bourne 1972); 16 years (42 to 50 mm), Olson Bay, Prince William Sound, Alaska (Paul et al. 1976a); 15 years (48 to 50 mm), Galena Bay, Prince William Sound, Alaska (Paul and Feder 1973; Nickerson 1977); and 7 years (37 mm), Mugu Lagoon, California (Schmidt and Warme 1969).

GROWTH CHARACTERISTICS

Growth of the common littleneck clam varies throughout its range and may change from year to year (Fraser and Smith 1928). Even within a given area, the growth rate may differ in adjacent bays. In general, beaches situated near strong tidal currents are those most favorable for growth, and those at the head of quiet bays are the poorest (Smith 1928).

Fraser and Smith (1928) noted that the rate of growth was affected less by the composition of a beach than by its position in relation to tidal currents and exposure to or protection from storms (which are related to the extent and constancy of the food supply). However, on some beaches which were more exposed to storms and covered with shell or gravel, strong tidal current and waves moved the surface substrate repeatedly and impaired growth. They also noticed that young clams on these exposed beaches grew much slower than the large clams. Growth was slower in young clams because they were unable to burrow down very far below the surface to get away from the disturbance caused by the surf. Although such exposed places might be good in food supply, in the early years the disturbances more than counterbalance this advantage.

In Mugu Lagoon, California, growth rate of common littleneck clams was consistently depressed at experimentally induced high densities. Linear growth declined more in mud than in sand as density of the animals increased (Peterson 1982).

In Alaska, clams at the higher tidal levels had the faster growth rates (Nickerson 1977); however, at Kiket Island, Washington, growth was fastest near mean lower low water and slower at the higher and lower tidal levels. Growth was also better on the north side of the island than on the south side at the same tidal level. Several hydrographic features, such as a higher and more stable regime of temperature and salinity on the north side, may account for the better growth rate there (Houghton 1977).

The growth of the common littleneck clams at different locations is shown in Figure 4. Shell lengths, time needed in years, location, and source of information follow: 30 mm (8 to 10 years), Galena Bay, Prince William Sound, Alaska (Feder and Paul 1973); 30 mm (4 to 5 years), Porpoise Island, southeast Alaska (Paul et al. 1976b); 37 mm (3.5 to 4 years) and 63 mm (10 years), British Columbia (Quayle and Bourne 1972; Glude 1978); 38 mm (4 to 6 years), Washington; and 37 mm (3.5 years), Oregon (Lukas 1973); 38 mm (7 years), Mugu Lagoon, California (Frey 1971).

Annual shell rings can be evaluated as an aging tool by marking the shell and then recovering the clams for examination at a later date (Paul and Feder 1973). Rings are much closer together when growth slows in winter because of reduced food availability and lowered metabolism. However, disturbance checks are often present in clams south of Alaska and sometimes make reading of annual rings difficult (Fraser and Smith 1928).

Berta (1976) and Hughes and Clausen (1980) expressed caution about aging common littleneck clams by shell rings. They observed excessive variation in ring patterns between specimens in the same population from Newport Bay, Oregon. Peterson and Ambrose (1983) discovered that in muddy-sand habitat, one additional growth line appeared during the final 12 months for each common littleneck clam, a finding consistent with the hypothesis that strong growth lines are annual. In clean-sand habitat, however, all common littleneck clams have more added growth lines than would be expected from the numbers of additional years of growth. The extra lines are probably disturbance checks. They suggested that more sand movement occurs in clean sand than in muddy-sand habitat, and that this additional movement leads directly or indirectly to deposition of extra disturbance checks in the shell.

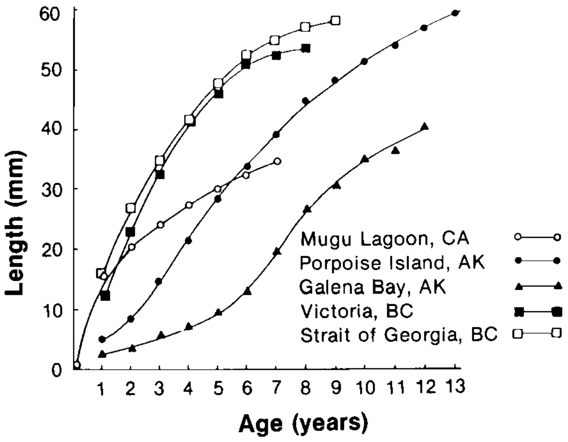

Figure 4. Ages and corresponding shell lengths (mm) of the common littleneck clam from Porpoise Island, southeast Alaska; Galena Bay, Prince William Sound, Alaska; Victoria, British Columbia, Canada (Paul et al. 1976b); Strait of Georgia, British Columbia, Canada (Quayle and Bourne 1972); and Mugu Lagoon, California (Schmidt and Warme 1969). (taken from Shaw 1985.)

COMMERCIAL AND SPORT FISHERIES

Even though the Pacific Coast clam industry is small, about 1% 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. Of the annual commercial catch of clams, about 95% comes from Washington and most of the rest from Alaska. 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 and unpolluted clam habitats. Oregon and California lack large bays, estuaries, and coastal clam habitats necessary for significant clam production. Recreational clam harvesting accounts for most clam production in those States. Although clams are abundant along the extensive coastline of Alaska, harvest is restricted by paralytic shellfish poisoning (poison from toxic phytoplankton, *Gonyaulax* spp., accumulated by filter-feeding shellfishes, harmless to the animal but fatal to humans) and certain socio-economic factors (Schink et al. 1983).

In the early 1900's, common littleneck and butter clams were the most important commercial species in Puget Sound, Washington (Kincaid 1919; Nightingale 1927). Common littleneck clams are the smallest of the commercial species, average market size being about 51 mm (2 inches). They are also commercially important in British Columbia (Amos 1966). The U.S. catch along the west coast in 1963 was about 214,400 pounds of meats worth about $107,000. In British Columbia, annual commercial landings ranged from 21,300 to 521,900 pounds in 1951-1969 (Quayle and Bourne 1972). Many factors directly or indirectly affect the production and overall management of clam stocks along 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 others (Schink et al 1983).

Common Littleneck Clam Fishery in Washington

In Washington, protected estuaries along Puget Sound, Grays Harbor, and Willapa Bay support extensive intertidal and subtidal stocks of common littleneck clams. In addition, there is a tradition of private ownership of intertidal beaches and private leasing of State-owned subtidal land that provides a favorable environment for commercial harvest.

The annual production of hard-shell clams (which include common littleneck clam; Manila clam, *Venerupis japonica*; butter clam, *Saxidomus giganteus*; cockle, *Clinocardium nuttalli*; and horse clam, *Tresus nuttalli*; but not geoducks, *Panope generosa*) from Washington's publicly owned beaches, once the major source of the commercial supply, declined gradually after 1940. Public beaches were heavily dug during the depression of the 1930's, and subsequent lack of major setting reduced the standing stock. In addition, fewer people harvested clams during and after World War II because employment opportunities in other businesses improved. During the 1940's, the accelerated purchase of tidelands by private citizens effectively eliminated many tidelands as public clam harvesting areas (Schink et al. 1983).

In general, total production of hard-shell clams from privately and publicly owned beaches remained relatively stable at 1 to 2 million pounds per year from the beginning of this century to 1975. The annual production of common littleneck clams declined from about 1 million pounds in the late 1950's to 500,000 to 600,000 pounds in the late 1970's (Figure 5). Its leading position has

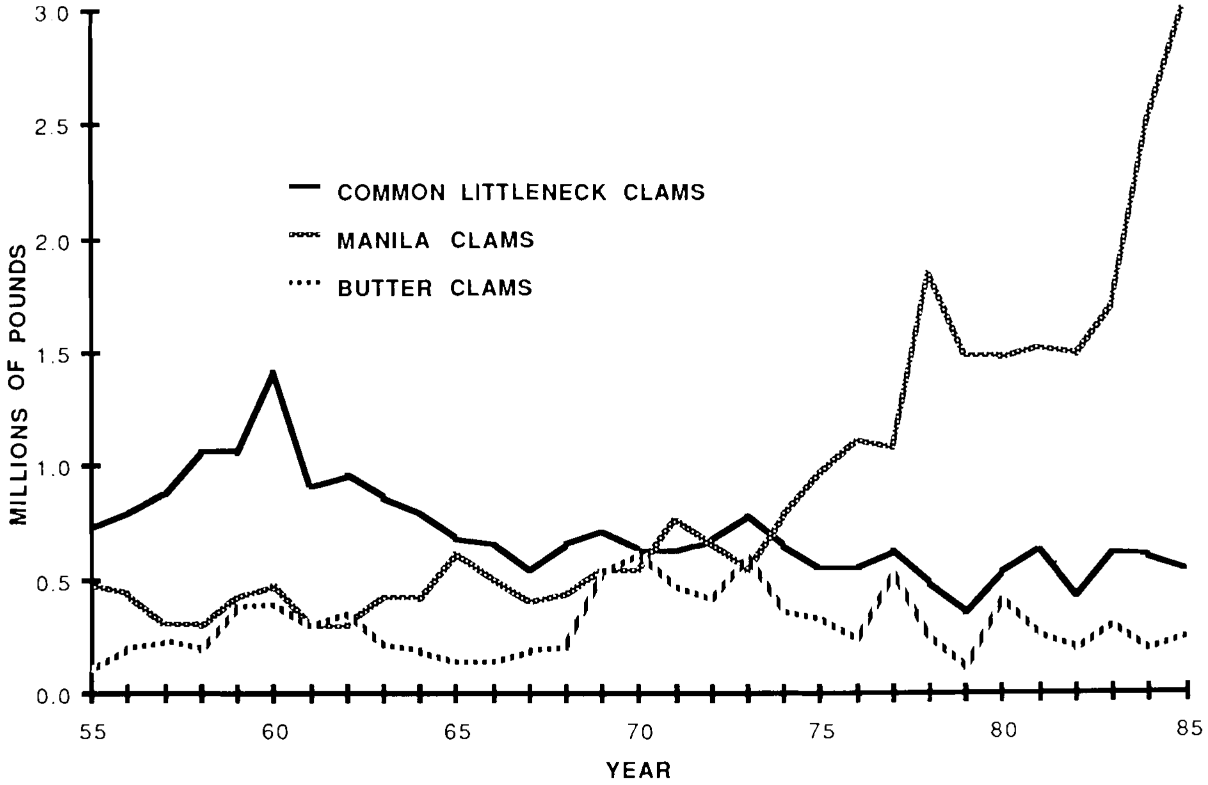

Figure 5. Landings of the common littleneck, Manila, and butter clams in Washington State, 1955-85 (updated from Schink et al. 1983)

been replaced by the increasing production of Manila clams from private farms, (Schink et al. 1983; Washington State Department of Fisheries 1984) .

Most common littleneck clams are sold fresh, unshucked, to wholesale fish houses. The price to the producer for hardshell clams (mostly common littleneck and Manila) was about $1 per pound in 1980 (Schink et al. 1983). Common littleneck clams are frequently placed in clean saltwater after they are harvested, so that sand and mud are purged from the gills and viscera before these clams are eaten. Specially designed sink floats are used for the purging operation (Schink et al. 1983).

Common littleneck clams are able to close their valves tightly when exposed to air, thus preventing loss of liquid over their soft parts. If kept at low temperatures, they may safely be kept out of water for several days and be transported fresh over long distances (Quayle and Bourne 1972).

The market for common littleneck clams is expected to remain favorable, but supply will depend on a number of factors. These include reproductive success in clam-producing areas that have a history of marked variation in setting, continued prevention of pollution in productive intertidal beaches, and continued production in subtidal areas. Common littleneck and

Manila clams harvesting is closely associated with the oyster industry of southern Puget Sound and Hood Canal. In central Puget Sound, there is intertidal harvesting of common littleneck, Manila, and butter clams, as well as subtidal harvest of common littleneck, butter, and horse clams by mechanical harvesters (Schink et al. 1983).

Intertidal Harvesting

The common littleneck clam is one of the most popular species harvested intertidally for recreational purposes in Puget Sound and along the Washington coast. It is estimated that an annual average (1972 to 1978) of 2.3 million pounds of clams were harvested from Washington's publicly owned beaches during 774,000 user trips. Since much of the intertidal area in Puget Sound is privately owned, recreational harvest there is not included (Solomon 1983).

The commercial harvesting of intertidal common littleneck clams is also a vital component of Washington's clam fishery. Major clam farms are located in southern Puget Sound, Sequim Bay, Discovery Bay, Port Townsend, Port Gamble, Hood Canal, Willapa Bay, and Grays Harbor. The intertidal lands used for commercial production are either owned by the harvester or leased from other private owners or the State. Harvesters who lease these lands are assessed a royalty or "stumpage fee" of $0.03 to $0.25 per pound on the clams harvested (Schink et al. 1983).

Most intertidal common littleneck clams are harvested by hand with an ordinary potato fork (called a clam rake or hack), a shovel, or a four-tine clam hack. The best method is to dig in rows, spreading the ground out evenly along the rows. Hand harvesting is inefficient compared with harvesting with mechanized hydraulic devices, but it may enhance clam populations by thinning adult clams without eliminating them. Reduction of the population reduces competition for food and space and increases growth rate (Schink et al. 1983).

Hydraulic clam rakes are also 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 1 foot into the substrate. Clams float to the top of the resulting slurry water substrate and are picked by hand from the trench created by the rake (Schink et al. 1983). As many as 2,500 clams per hour can be collected with a clam rake in areas of high density (Nickerson 1977). Hydraulic rakes are not only faster and more efficient than hand digging, but reduce shell breakage (Schink et al. 1983).

Subtidal Harvesting

In Washington, subtidal clams are also harvested commercially with mechanical clam harvesters from publicly owned beds leased by the State for this purpose. In 1980, the Department of Natural Resources assessed a minimum lease fee of $5 per acre per year; the harvester also paid a royalty of $0.05 per pound for common littleneck clams. The price then paid to harvesters for common littleneck clams from subtidal tracts was $0.50 per pound; most were sold fresh in markets (Schink et al. 1983).

The hydraulic dredge used in subtidal harvesting is attached to a boat that 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 surface. Small clams, gravel, and other debris fall through the mesh and are redeposited on the bottom (Schink et al. 1983). Although there are some concerns about noise pollution, turbidity, and siltation associated with the escalator harvester, this machine is probably the most efficient method available for harvesting clams in the subtidal area. Hydraulic dredges used in Puget Sound operate only in shallow water and are efficient only on relatively smooth bottom terrain. Many subtidal and intertidal clam beds are too small and too rough for mechanical harvesting of any kind, thus necessitating hand harvest.

The "Long Island" or hydraulic jet cage harvester, which can operate in deep water, has been tested in Washington, British Columbia, and Alaska. It is towed behind a boat, and clams, after being loosened by the water jet, are collected in a steel-ring bag or collecting device. The dredge is hoisted out of the water periodically and the catch is emptied on deck (Schink et al. 1983). Evaluation by the Washington Department of Fisheries, however, has shown the efficiency of this gear to be poor when it is operated in the Puget Sound area because of the presence of large amounts of rocks, shells, and debris as well as complex water currents and rough bottom topography (Goodwin 1973).

Industry Problems and Constraints in the Pacific Northwest

Domestic pollution in Washington waters has reduced the potential areas for harvesting subtidal hardshell clams by 25%, because clams from affected areas do not meet certification standards of the Washington Department of Social and Health Services (Schink et al. 1983). Although slightly polluted clams can be cleaned by flushing them with purified seawater for a few days, this process adds to the cost and has not been accepted by the industry. Subtidal clam beds have also been destroyed by dredging and dredge material disposal that accompanies various marine construction activities.

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 the siltation of clam beaches. The loss of productive intertidal beaches may increase as the Puget Sound region continues to develop.

In addition, there are some concerns that mechanical harvesters used on subtidal and intertidal clam beds will suspend and deposit fine sediments and smother clams and other benthic organisms (Goodwin and Shaul 1980; Schink et al. 1983). However, an investigation by the Washington Department of Fisheries indicated that a mechanical harvester produces only a little silt during operation and does not affect the dissolved oxygen and inorganic phosphate concentrations in the water. It does reduce the abundance of attached kelp on the sea bed and moves large amounts of old clam shells and sand to the substrate surface (Tarr 1977). Nevertheless, the recruitment of seed clams was not affected by the dredging (Goodwin and Shaul 1978, 1980). Despite these findings, subtidal clam dredging has declined in recent years and could disappear as a result of adverse public opinion and an increasingly complex and unpredictable regulatory environment (Ritchie 1977).

Common Littleneck Clam Fishery in Oregon

Only a few areas along Oregon's 300 miles of coastline support populations of bay clams (which include cockle, butter clam, common littleneck clam, gaper (*Tresus capax*) and softshell clam (*Mya arenaria*)).

Although there are a number of protected bays and estuaries, each is relatively small and only a small stretch of northern ocean beach has a productive habitat for common littleneck clams (Ritchie 1977). Approximately 200,000 pounds of bay clams were harvested annually in Oregon for the years 1943-49; the highest production (over 664,000 pounds) was in 1938. The commercial harvest of bay clams is composed of gaper, cockle, and softshell clams. The recreational harvest of bay clams is composed of the gaper, cockle, softshell, butter, and common littleneck clams (Marriage 1954). Common littleneck clam, being scarce in Oregon's estuarine areas, is not commercially important. It is taken only incidentally by harvesters while they raking for cockles. Common littleneck clams taken by sport diggers commonly average 63 mm (2.5 inches) in length (Marriage 1954).

Coos, Tillamook, and Yaquina Bays supplied 60% to 97% of Oregon's commercial landings of bay clams in 1943-50. Umpqua, Siuslaw, Nehalem, Alsea, Coquille, and Netarts Bays produced the rest (Tollefson 1948; Marriage 1954; Gaumer and Lukas 1975; Gaumer 1976).

After the mid-1950's, the production of bay clams declined steadily and was negligible by the late 1970's (Oregon Department of Fish and Wildlife 1978-82). Cleaver (1951) attributed the early decline to reduced digging activity brought about by the improved economy after World War II, and to an increase in oyster farming in Tillamook, Yaquina, and Coos Bays, which caused the loss of some traditional clam producing areas. Commercial clam landings in 1975 were less than 27,000 pounds (Ritchie 1977). Furthermore, there appears to be little potential for intertidal private clam farming, since land is in short supply in Oregon's estuaries.

AQUACULTURE

The farming of common littleneck clams is closely associated with the oyster industry in southern Puget Sound. Common littleneck clams and butter clams are also farmed in the intertidal zone in central Puget Sound (Ritchie 1977). Production of clams in these areas might be increased through better clam bed management and the conversion of low profit oyster grounds into clam grounds. Beaches could be improved to provide a more suitable habitat for clams: mussels could be removed from clam beds to prevent accumulation of silt on the substrate, or pea gravel could be worked into the sand or mud to provide a better substrate for adult clams and added protection for the juveniles (Schink et al. 1983). In Washington, more than 1,000 miles of public shoreline are potentially usable for commercial intertidal clam culture.

To reduce the problem of setting variability in common littleneck clams, researchers at the School of Fisheries of the University of Washington evaluated the idea of planting beaches with hatchery-reared clam seed (Miller et al. 1978). In 1978 about 139,000 hatchery-reared young common littleneck clam were purchased and planted on publicly owned beaches by the Washington State Department of Fisheries as part of the plan to increase productivity of the public beaches (Goodwin 1978). However, the effectiveness of this project has not yet become apparent.

The use of plastic netting on intertidal clam beds to stabilize substrate and reduce predation was also investigated. A pilot study on Manila clams indicated that the netting was not only economical, but dramatically increased survival of both hatchery clam seeds and natural sets. The same technique may also be beneficial for common littleneck clams (Anderson and Chew 1980).

ECOLOGICAL ROLE

Food and Feeding Habits

The common littleneck clam is a filter feeder, collecting anything in the plankton small enough to ingest (Schmidt and Warme 1969). The size of particle ingested is controlled by the size of the mouth opening or the life stage. Postlarval clams can feed only on particles less than 10 µm in diameter -- primarily benthic diatoms and perhaps sediment bacteria (Peterson 1982).

The common littleneck clam has four highly specialized gills (ctenidia), two on each side of the visceral mass. The gills are used for filter feeding as well as respiration. Thousands of hairlike cilia on the gill surfaces produce water currents that draw water in through the inhalant siphon and circulate it over and through the gills, where the blood is oxygenated. Simultaneously, food particles, mostly phytoplankton and detritus, are entangled in food grooves of the gills and transported by cilia to the labial palps and mouth. Particles of suitable size are ingested, and the rejected material is expelled, usually through the inhalant siphon, when periodic valve closure forces water out (Schink et al. 1983).

After ingestion, food enters the digestive system, which is composed of a short esophagus, stomach, crystalline style, digestive diverticulum (liver), and intestine. 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 strands of mucus into the stomach from the esophagus. 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, but other particles are processed by the crystalline style and passed by cilia through small ducts into the digestive diverticula. Fine particles are directed into the digestive glands, where they are absorbed and digested. Wastes are later conducted to the intestine and eliminated (Schink et al. 1983).

Smith (1933) noted that clams feed most actively during the flow of the tide and that usually little food is found in the stomachs of clams taken during low tide. The bulk of the intestinal contents consists of plant forms, largely diatoms. Animal material is less abundant and is variable in composition. Protozoa constitute the greater portion of animal forms. As a rule, the digestive tracts of clams contain considerable detritus or dead organic matter. It is believed that this material plays an important role in the diet of clams. The composition of the contents of the digestive tract is similar to that of the plankton in the water column. Clams seem to ingest anything in the plankton that is sufficiently small, and apparently show little tendency to select food. Thus, the amount of ingestable living plankton and dead organic matter available is an important factor in clam growth.

Clams, like oysters, absorb dissolved substances from the water such as calcium for shell formation and amino acids. The clam *Spisula solidissima* readily removes glycine, glutamic acid, tyrosine, methionine, phenylalanine, and arginine from seawater (Stephens and Schinske 1961). Other clam species probably also have this ability (Glude 1978).

Unlike the young of many species of clams, young common littleneck clams can move by using the foot (Peterson 1982), and then reburrow (Quayle and Bourne 1972). Clams in heavily populated areas may move elsewhere, and clams exposed by dredging can reburrow after the dredging ceases. Over 88% of the clams of less than legal size that were exposed by dredging reburrowed in both "soft" and "hard" bottoms (Quayle and Bourne 1972). The ability of the common littleneck clam to reburrow was demonstrated by a mark and recapture study conducted by Feder and Paul (1973).

Parasites

Epizoic growth on common littleneck clams is rare. Peterson (1982) stated that fouling organisms are either scraped off during reburrowing or are smothered. No epidemic disease has been found in common littleneck clams (Quayle and Bourne 1972). Two species of tetraphyllidian cestodes were found in common littleneck clams in Humboldt Bay, California, and common littleneck clams often contained large numbers of larval tapeworms of the genus Echeneibothrium (Sparks and Chew 1966; Warner and Katkansky 1969). These parasites are killed by cooking and even live ones do not infect humans (Shaw 1985).

Predation

In Puget Sound and in British Columbia, common littleneck clams are prey for many predators -- especially the moon snail Polinices lewisi -- because common littleneck clams live in the tidal range occupied by this predator. The moon snail uses its radula (a toothed device protruding from the mouth) to drill a countersunk hole through the valve of a clam to reach and consume the body. The only effective control is to hand-harvest the snails (Quayle and Bourne 1972).

In Mugu Lagoon, California, Peterson (1982) observed fatalities caused by the moon snail Polinices reclusianus and the crab Cancer anthonyi. Common littleneck clams made up 16% of the diet of the octopus, Octopus dofleini (Hartwick et al. 1982). Clams eaten were 15 to 70 mm long, but most were 40 to 50 mm long. The intensity of predation was directly related to the distance between the den of the octopus and the gravel beaches where the clams lived. In the same area, Peterson and Quammen (1982) found that the growth of common littleneck clams in sandy beds was retarded when their siphons were nipped off by at least three species of benthic fishes: the Pacific staghorn sculpin, Leptocottus armatus, the diamond turbot, Hypsopsetta guttulata, and the California halibut, Paralichthys californicus. The amount of siphon nipping decreased significantly in muddy beds, where the predators switched to the more abundant deposit-feeding bivalve Macoma nasuta.

Pearson et al. (1981) found that the Dungeness crab, Cancer magister, uses its antennules as distance chemoreceptors and can detect extract of the common littleneck clam at a concentration of 10^{-10} g/l. Higher concentrations of clam extract initiated probing with the chelae and walking legs, and other feeding behaviors. Predation rates were higher in patches where density of clams was high -- probably because the greater concentration of metabolites released by the clams attracted more crabs to their location (Boulding and Hay 1984). Observations of crabs congregating in dug-over areas of the beach suggest that they use distance chemoreception to find prey. It may also explain why mariculture projects that artificially increase the local density of a prey species may be economic failures because the mortality caused by crabs is extremely high (Mottet 1980). Predation experiments with the common littleneck clam and the red rock crab, Cancer productus, showed that the crabs prefer to consume the smallest clams first when the clams are plentiful (Boulding 1983, 1984).

Two carnivorous gastropods, *Forreria belcheri* and *Shaskyus festivus*, prey on common littleneck clams (Schmidt and Warme 1969), and the sea stars *Pycnopodia helianthoides* and *Evasterias troschellii* prey heavily on them in Prince William Sound, Alaska (Paul and Feder 1975; Feder 1980). The sea star *Pisaster brevispinis* feeds on common littleneck clam in Puget Sound (Smith 1961; Feder 1980). The sea otter *Enhydra lutris* also is a major predator of clams in Prince William Sound, Alaska (Feder and Paul, pers. comm.).

In the Strait of Georgia, British Columbia, three species of wintering scoter ducks feed in the intertidal beach area -- white-winged scoter, *Melanitta fusca*; surf scoter, *M. perspicillata*, and occasionally, black scoter, *M. nigra*. Common littleneck and Manila clams compose about two-thirds of the gut contents of the white-winged and surf scoters. Bourne (1983) estimated that a wintering flock of 200 scoters in southern British Columbia could remove 5 to 14.5 metric tons of common littleneck or Manila clams from only two beaches within 6 months.

ENVIRONMENTAL REQUIREMENTS

Temperature and Salinity

The common littleneck clam is subjected to temperatures of less then 0 °C to about 25 °C within its range from the Aleutian Islands to lower California. The clams occur from about the middle of the intertidal zone to a depth of 12 m (40 feet) in the Pacific Northwest. Those in the intertidal zone are exposed to high temperatures during daytime low tides in summer, and low temperatures during nighttime low tides during winter. Young common littleneck clams, 1.5 to 20.0 mm in length, are restricted to the upper 2 cm of sediment (Paul and Feder 1973) and are subject to freezing at low tide in midwinter (Feder et al. 1979). However, adult clams burrow to a maximum depth of about 20 cm and are thereby protected from most temperature extremes (Glude 1978).

For larval common littleneck clams near Newport, Oregon, the optimum water temperature and salinity ranges were 10 to 15 °C and 27 to 32 ppt, respectively (Phibbs 1971). The salinity tolerance of adults ranged from about 20 ppt (or less) to 30 ppt in Prince William Sound, Alaska (Glude 1978), and British Columbia (Quayle and Bourne 1972).

Substrate

Early studies showed that common littleneck clams often live on small beaches in pockets along rocky shorelines, or in small patches on large beaches. The best beaches for common littleneck clams are those with coarse sand or fine gravel mixed with mud, stones, or shells. Common littleneck clams usually do poorly in fine sand (Fraser and Smith 1928). Adults may burrow to a depth of 20 cm (8 inches) but are usually within 15 cm (6 inches) of the surface, and occasionally are on the surface (Amos 1966).

In Washington, intertidal common littleneck clams concentrate in a porous mixture of gravel, sand, and mud firm enough to resist wave action (Washington State Department of Fisheries 1978). In Puget Sound, standing crops of subtidal common littleneck clams are highest in shell substrate and lowest in mud and sand. However, average sizes are about the same in the two substrates. It is suggested that the substrate affects standing crops by influencing the set or survival of seed clams and thereby determines the density of adult clams (Goodwin 1973). In California, common littleneck clams live in the sediments of coarse sand to mud in bays, sloughs, and estuaries (Fitch 1953). On the open coast, they live in nearly any area having rocky points or reefs made up of small cobbles over coarse sand. In southeastern and south-central Alaska, common littleneck clams are found on sandy and muddy gravel beaches (Paul and Feder 1973; Paul et al. 1976a, 1976b). In some coastal waters of California, clam abundance widely fluctuates because the extensive siltation of cobble beaches, caused by heavy runoff from creeks, destroys clam habitat (Frey 1971). Clam populations smothered in areas that have undergone heavy siltation may require 5 years to recover (Frey 1971).

Some intertidal beaches that have become unproductive because of a change from gravel to sand have been restored to full productivity by the deposition of a layer of gravel over the beach. The coarse gravel provides small clams with protection against wave action and predators (Glude 1978).

It is difficult to separate the effects of substrate types on clam distribution and abundance from effects of current velocity. Basic materials in any particular area, plus the current velocity over the area, are two important factors in determining substrate type. Normally, the greater the current speed, the coarser the surface materials and the more desirable the area for common littleneck clams. Current velocity affects clam abundance by exposing different numbers of larvae in any particular area, thus affecting the amount of clam setting. The greater the current, the greater the number of larvae that come into contact with any particular spot. Also, the greater the current speed, the greater the potential number of food organisms that become available in the area (Goodwin 1973).

Depth

Common littleneck clams are usually found in the intertidal zone between -1.0 and +1.3 m (-3 and +4 feet) of the mean lower low water datum plane. Although they are found with butter clams, they usually occur at a slightly higher tidal level (Nickerson 1977; Figure 6).

In Washington, common littleneck clams are concentrated in the intertidal zone between -0.9 m and +1.2 m (-3 and +4 feet), but were seen in water as deep as 18 m (60 feet). The average size and standing crops of common littleneck clams decrease rapidly as water depth increases (Goodwin 1973; Washington State Dep. Fish. 1978). In British Columbia, Quayle and Bourne (1972) observed common littleneck clams from the lower three-quarters of the intertidal zone down to a depth of 13 m. They wrote that clams there burrow to a maximum depth of 16 cm.

Smith (1933) found that young common littleneck clams 2.4 to 12.6 mm long were found only at the lowest level of the tide, although most of the population was at a higher level. Similar observations were made in Prince William Sound, Alaska, by Paul and Feder (1973). These observations suggested that young clams probably make their first attachment in deeper waters, and then move up the beach as they grow. This behavior may occur partly because it is difficult for free-swimming larvae to settle on the parts of the beach that are frequently exposed by the ebb of the tide.

The preference of common littleneck clams for certain tidal levels was well demonstrated during and after the 1964 Alaska earthquake, which subjected the Olsen Bay area in Prince William Sound to an uplift of 0.9 to 1.2 m (Plafker 1969). Maximum density of common littleneck clams also changed from the normal 0-m tidal level to about the 1.2-m tidal level.

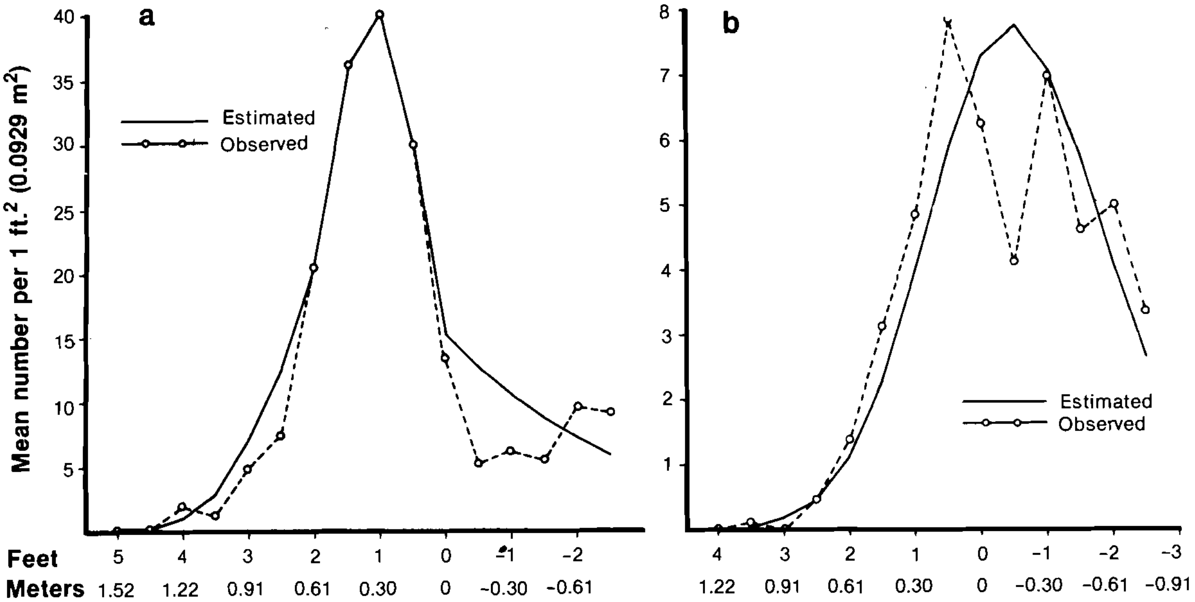

Figure 6. Frequency of occurrence of (a) common littleneck clam and (b) butter clam by tide level, Simpson Bay, Prince William Sound, Alaska (Nickerson 1977).

Ten years after the earthquake, the intertidal distribution of common littleneck clams at two of three beaches that were examined had returned to normal, the maximum densities again occurring near the 0-m tidal level. The third beach had become too muddy and was no longer a suitable habitat (Paul et al. 1976a)

Other Environmental Factors

Despite the fact that copper is known to be an essential trace element for biological processes, extremely low concentrations of copper have been shown to be lethal to several marine species. Ionic copper appears to be the toxic form.

Experiments conducted by Phelps et al. (1983) showed that the time taken for 50% of common littleneck clams to burrow into the substrate increased logarithmically with increasing copper concentration in the sediment. They suggested three reasons: (1) the toxic effect of copper on clams led to a debility in burrowing; (2) aversive behavioral conditioning occurred from exposure to copper in sediment; and (3) responses to noxious chemosensory cues increased.

Common littleneck clams are highly sensitive to copper, which is used in antifouling boat paints. The mortality of clams reported after 30 days of exposure was 15% at copper concentrations of 7 and 18 µg/l, and 86% and 97% at 39 and 82 µg/l respectively. Copper is concentrated in the gills and disrupts the regulation of cellular sodium and potassium (Roesijadi 1980a, 1980b). Heavy metals have also been found to be concentrated in common littleneck clams. However, the quantities of heavy metals are generally lower in common littleneck clams than in other shellfishes (Shaw 1985).

Augenfeld et al. (1980) noted that 85% of common littleneck clams in the field survived a 54-day exposure to sediment contaminated with Prudhoe Bay crude oil at a concentration of 1,237 ppm. However, only 17% of Macoma inquinata survived the same dose. Although survival, condition indices, and glycine level in the body tissues all decrease in treated common littleneck clams, the decrease is not as serious as in Macoma inquinata. The common littleneck clam, being a filter feeder, is probably affected less severely than Macoma inquinata, a detritivore, by oil pollution.

Common littleneck clams grow slower in oil-treated than in clean sediment. Anderson et al. (1981) inspected an oil-treated clam bed for 1 year. They noticed that the relatively rapid loss of petroleum components from the surface of sediments greatly reduced tissue contamination and the adverse effects on growth in the upper layer (3 cm or less); even though its initial concentration of oil was significantly higher than that in the deeper layer.

Seven years after one oil spill, oiled sediment still significantly affected predation on the common littleneck clam by the Dungeness crab, both in the field and in laboratory. On one hand, oiled sediment reduced the chemosensory ability of the crab to detect buried clams; on the other hand, the reburrowing of the clam was shallower and slower in oiled sediment. Although oiled sediment did not force the clams to emerge from the bed, they became more accessible to crabs and this greater accessibility led to a net increase in predation by the crabs (Pearson et al. 1981).

Hartwick et al. (1982) found that crude oil had relatively little effect on adult common littleneck clams, whereas a dispersant or a mixture of dispersant and oil had a significant effect. Also, siphon activities were significantly retarded when clams were treated with 1,000 ppm oil, were further retarded when treated with 100 ppm of dispersant (Corexit 9527), and were lowest after treatment with 1,000 ppm oil plus 100 ppm dispersant. The behavior of clams exposed to these chemicals changed. The first sign was a slow tactile response, followed by an extension of the siphon and a gaping of the shell during exposure to air. The siphons were eventually pinched off as the shells closed, indicating a loss of coordination of activity. Settlement of young common littleneck clams was not affected on the experimental plots treated with 1,000 ppm crude oil.

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16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, morphology, distribution, life history, and environmental requirements of coastal aquatic species. They are prepared to assist in environmental impact assessments. The common littleneck clam (Protothaca staminea) is important both in recreational and commercial fisheries in the Pacific Northwest region. This review describes the life history (spawning, egg and larval stages, postlarvae and juveniles, maturity, and life span), growth characteristics, commercial and sport fisheries, aquaculture, ecological role, and environmental requirements of the species. An updated literature cited section is also included.

17. Document Analysis a. Descriptors

Estuaries
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Temperature
Depth
Sediments
Feeding habits
Contaminants
Water pollution
Competition
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