SMALL-SCALE CLAM FARMING FOR PLEASURE AND PROFIT IN WASHINGTON

According to one Native American tale, the first humans arrived in the Pacific Northwest by stepping out of a clam shell. Since those ancient times, clams have had central roles in shaping the cultures and economies of the Pacific Northwest.

For many shoreline property owners or leaseholders in Washington, clam farming is an enjoyable and sometimes profitable way to remain connected with the rich aquacultural legacy of the state. It is also a good way for them to become more aware of coastal processes such as sedimentation and erosion and to be vigilant for *Spartina* cordgrass, European green crab and other unintentionally introduced marine organisms.

Two clam species — native littleneck clams and Manila clams — are routinely farmed in Washington. This publication introduces shoreline property owners and leaseholders to these two species and describes methods for growing clams for consumption.

Introducing Two Popular Clams

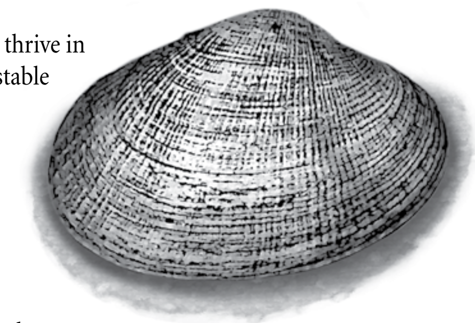
Three clam species — native littleneck clams (*Protothaca staminea*), Manila clams (*Venerupis japonica*) and geoduck clams (*Panope abrupta*) — are routinely farmed in Washington. Successful cultivation of geoduck clams entails different farming strategies and, as such, is not described in this introductory document.

Native littleneck clams have been an important food source of Northwest coastal Indian tribes. These clams have relatively thick shells that can attain a length of three inches. They can grow to a harvestable size in four to six years, depending on local environmental conditions. They thrive in areas of good water flow on stable beaches with a mixture of gravel, sand and mud. Native littleneck clams are most often found in middle to lower intertidal zones; their upper range overlaps that of Manila clams. Native littleneck farming is solely based on wild stock, as hatchery seed is generally unavailable in Washington.

Manila clams are not native to Washington state. It is believed they were accidentally introduced along with shipments of Pacific oyster seed from Japan in the early 1930s. They have become established throughout many portions of Puget Sound and Hood Canal and, today, are the dominant intertidal clam commercially grown and harvested in Washington. Because they are relatively fast-growing and easy to harvest, Manila clams are well suited for culture. Depending on localized conditions, they can grow to a harvestable size (about 2.5 inches in shell length) in approximately two to three years.

Native littleneck clam

On Washington beaches, Manila clams thrive in protected bays and inlets on relatively stable beaches with mixtures of gravel, sand, mud and shell. They are commonly found in the middle intertidal zone, between three and six feet above mean lower low water (MLLW). Farmers in recent years have discovered Manila clams also grow well in sand beaches at lower tidal elevations if predators can be excluded with netting (described on page 10 of this document). Without the netting at the deeper tidal elevations in sandy substrate, predators are able to forage very efficiently and eat all of the clams.



Manila clam

Clam Farming in Washington

Clam farming methods have changed significantly over time. Initially, the industry was based primarily on harvests of naturally occurring stocks of native littleneck clams and butter clams (*Saxidomus gigantea*). Gradually, the focus shifted to harvests and culture of Manila clams, which are easier to harvesting and, when cooked, to process.

Methods to produce clam seed in shellfish hatcheries were developed in the late 1970s, providing a consistent source of juvenile Manila clams for the fast-growing industry. Also around that time methods of predator control were developed to increase the yields from Washington's clam-farming beaches. The two innovations enhanced survival of both seeded and naturally recruited clams and enabled clams to be grown in areas with no natural recruitment.

In the mid-1980s, methods to modify beach substrates and to raise clams in bags were developed to further extend the Manila clam's cultivatable range. Today, the Manila clam remains the primary clam species cultured in the Pacific Northwest.

The Basics

Clam farming is structured to take advantage of the clam's biology and life cycle. A basic understanding of both will greatly improve the productivity and marketability of one's product.

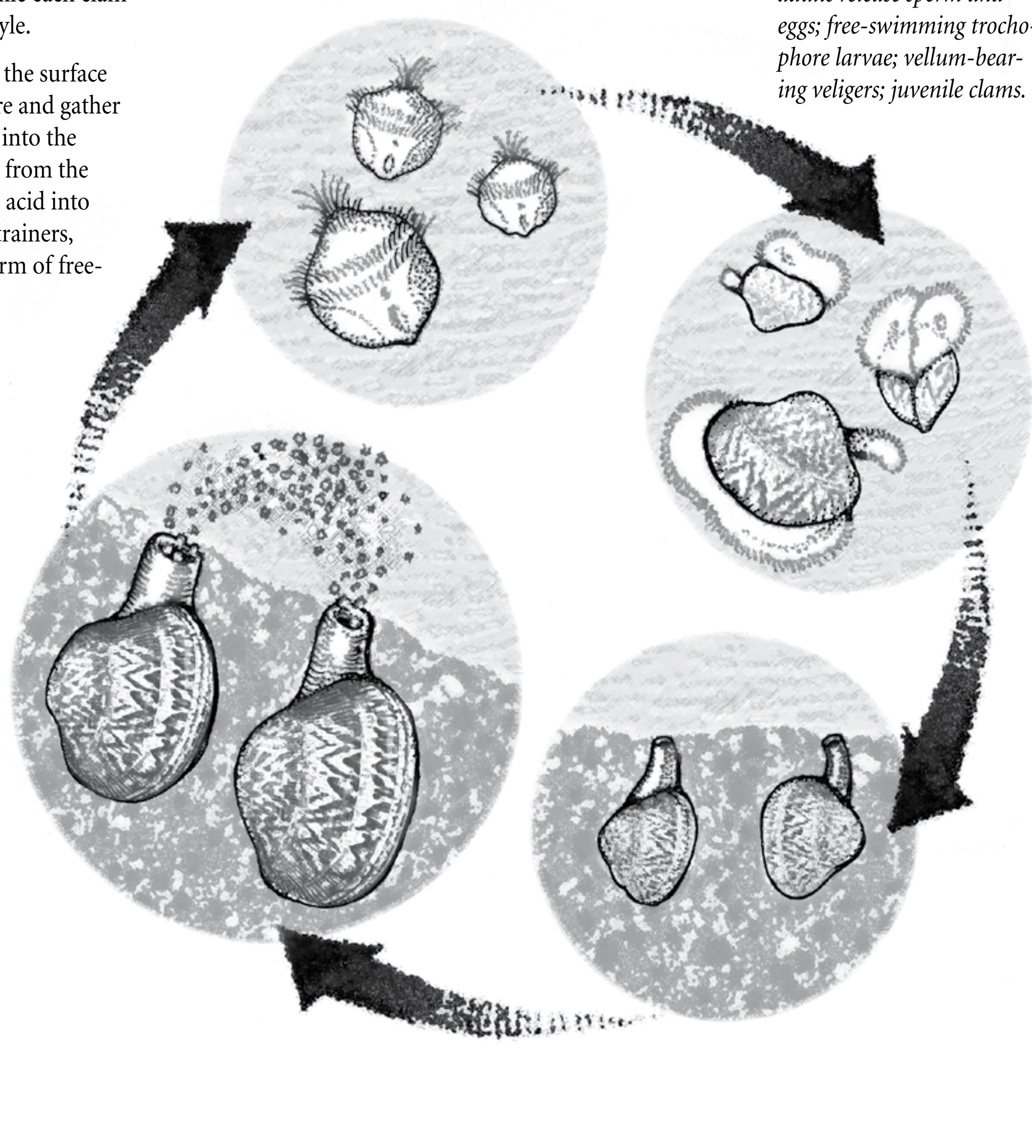
Clams are bivalves — shelled invertebrates (or animals without backbones) in the same zoological class, Bivalvia, as the oyster, mussel, cockle and scallop. The shells of these animals consist of two parts, or "valves," held together by an elastic ligament hinge. There are over 7,500 species of bivalves worldwide, but only a few species are well suited for culturing in Washington state.

All clams are "broadcast" spawners. That is, they release eggs and sperm into the water column and let nature (and the law of averages) take their course. In Washington, spawning occurs in late spring to early summer, when water temperatures are warmer and food is readily available. Fertilized eggs develop into microscopic, free-swimming larvae that both propel themselves and feed with a ciliated appendage called a vellum. After two to four weeks, they settle to the bottom and feel around for a good place to live. When they find a suitable place, they secrete sticky byssal threads to hold on while each clam digs with a foot to begin a sedentary lifestyle.

Each young mollusk extends its siphon to the surface of the seafloor, enabling the clam to respire and gather food. Water is drawn through the siphon into the clam's interior. Here, gills retrieve oxygen from the water and release carbon dioxide and uric acid into the environment. The gills also serve as strainers, capturing small particles of food in the form of free-floating plants, called phytoplankton.

While most clams are adapted to a life in salt water, they must also endure periodic exposure to the air during low tides. To do his, these bivalves must "clam up." Retracting its siphon inside its shell, a clam uses muscles attached to the inside of its shell to pull the shell closed. This allows the clam to retain enough moisture within the shell to survive for several hours when the tide is out. Fortunately for shellfish farmers interested in reaching distant markets, some clams can survive for several days out of water.

As a clam grows, it adds material to its shell, making it longer, wider and thicker. During winter, when water temperatures drop and less food is available, the clam's growth rate slows. Such seasonal slowing creates a growth ring around the shell. Shell rings are also made during times of stress or disturbance. As such, these rings are not reliable indictors of a clam's age.



Manila clam life cycle (clockwise, from bottom left): broadcast-spawning adults release sperm and eggs; free-swimming trochophore larvae; vellum-bearing veligers; juvenile clams.

Getting Started

A variety of factors will influence the selection of sites for small-scale clam farming. Beach characteristics can vary considerably, and certain criteria may aid a prospective grower to assess the potential for success.

Tideland Ownership

Tideland rights should be established before embarking on any clam farming enterprise. Prospective farmers should check the deed of their property and should double-check with their county assessor and/or the Washington Department of Natural Resources' Aquatic Lands Division. It is not necessary to own the property that will be farmed, as the Department of Natural Resources also leases state-owned tidelands for aquaculture activities.

Human Health Concerns

Shellfish are filter feeders, straining phytoplankton from the water column. Some species are capable of filtering up to 65 gallons of seawater per day. Besides taking in plankton, they have the potential to concentrate harmful bacteria, viruses or marine biotoxins associated with some of the plankton species. This can render the shellfish unfit for human consumption.

The Washington State Department of Health (DOH) certifies the growing waters of commercial aquaculture operations to assure their products are safe and uncontaminated by pollution sources. They also test commercially produced shellfish to assure they are free of any marine biotoxins. Some recreational beaches are also certified by DOH.

The DOH Office of Food Safety and Shellfish Programs (*www.doh.wa.gov/ehp/sf/default.htm*) or the local/county environmental health specialist should be contacted for information concerning water quality in a particular area. Regulations are in place to protect against contamination from sewage outfalls, marinas and other so-called point sources of pollution and from failing septic tanks and other non-point sources.

If a prospective farming site is not already part of a certified shellfish-growing area, DOH must collect at least 30 water samples and conduct a shoreline survey to classify the beach. DOH currently classifies growing areas as "Approved," "Conditionally Approved," "Restricted" and "Prohibited."

> "Approved" growing areas are those where clams may be directly harvested for commercial purposes.
>
> "Conditionally Approved" areas meet the state public health standard but require closures when affected by predictable levels of pollution (rainfall closures, seasonal mooring areas, etc.).
>
> "Restricted" areas are those where limited amounts of fecal coliform bacteria are present, indicating contamination that would make the shellfish unsafe to eat. Shellfish from these areas could be moved to an "Approved" area for a period of time sufficient to cleanse the bacteria.
>
> "Prohibited" areas are those where pollution conditions prohibit the harvest of shellfish for commercial consumption.

To register your tidelands for clam farming, you will need to apply for an Aquatic Farm license from the Washington State Department of Fish and Wildlife (DFW). For commercial enterprises, an annual Shellfish Operating License from the DOH's Office of Food Safety and Shellfish Programs is also required. There are fees associated with this second license, including those for paralytic shellfish poisoning testing.

There are three categories of licensing to consider:

> Shellstock shippers are people who grow, harvest, buy or sell shellstock but are not authorized to shuck shellfish or repack shucked shellfish.
>
> Shucker packers are shippers who shuck and package shellfish and may also act as shellstock dealers.
>
> Harvesters are commercial shellfishers whose activities are limited to harvesting and selling shellstock to licensed dealers in Washington.

What You Can Do

As a shellfish farmer, one must be aware of the health risks associated with contaminated shellfish. If you are growing the shellfish for personal consumption, the beach you are using may not have the same level of oversight and monitoring that commercial beds have. If the beach is not in an area certified by DOH, you should only consume the shellfish if they are thoroughly cooked. Althouogh cooking will destroy harmful bacteria and viruses associated with pollution sources, it will not destroy biotoxins.

If you are not already, you may consider getting involved in efforts to keep the marine waters of the state clean and safe for shellfish culture. Get involved in local shoreline and growth management planning, maintain your septic system in good working order, collect and dispose of pet waste in areas where it can not wash into surface waters, fence your horses or cows out of streams, recycle used motor oil and dispose of household hazardous wastes at appropriate facilities, not in your yard or septic system.

Tidal Level

Choosing the most appropriate planting zone on a beach may require a degree of trial and error.

In general, the lower range for native littleneck and Manila clams on a beach is limited by predation. Their upper range is limited by exposure to air or temperature extremes in winter or summer. In general, the lower limit of Manila clams is established by competition with other clams and by predation, while the upper range is limited by exposure to air.

The amount of food available to clams is, in part, dependent on the length of time they are covered by water. When exposed at low tide, the clams cannot feed. Therefore, clams that are buried at a higher tide level will have less time to feed. This may result in slower growth rates for the clams. While exposed, the clams are also subjected to temperature fluctuations, which can cause higher mortalities for clams in the upper end of their range. However, because they are exposed for longer periods, clams in upper intertidal areas will be more readily available for harvesting and for longer periods during a workday. They will also have slightly better shelf lives than clams grown in the lower intertidal zone, because they have been "trained" to stay closed tightly for longer periods of exposure.

Conversely, growing clams lower in the tidal range will result in faster growth; however the clams will have thinner shells, poorer shelf lives and will be exposed to more intense predation. It should be noted that certain predators and competitors occupy specific ranges and should be taken into consideration when looking at tidal levels. For example, larger predatory crabs are normally found lower on a beach, so clams higher on the same beach may have greater survival rates. Beware, however: even tiny shore crabs can prey on small-sized clam seed.

Wave Exposure

The severity of wave action will affect the stability and composition of a beach. Clam seed will probably not survive on beaches exposed to a high degree of wave action. The fine sediment that holds together the gravel and sand can be washed away, leaving a loose deposit of sediment without cohesion. As beaches shift, clam seed can be washed away, buried or crushed.

Sheltered beaches with minimal wave action will retain silt and other fine sediment, resulting in a more compact mix of larger gravel, sand, mud and shell. These more stabile beaches have shown higher yields of farmed clams. Another advantage of a gravel/shell substrate is that it is difficult for predators to forage in. It can provide a degree of protection from crab and diving duck predation but not as much as covering beds with predator exclusion netting.

Ground Type

Native littleneck clams and Manila clams are found in stable, loosely packed substrates that contain a mixture of gravel, sand, mud and shell. In Japan, the most suitable habitat for growing Manila clams was found to contain 50 percent to 80 percent sand. Beaches comprised of tightly packed cobble, hardpan and soft mud are unsuitable for clam culture. If a site does not have a suitable substrate, a prospective clam farmer may add gravel and crushed oyster shell to provide adequate growing conditions. Information about this technique is contained in this document's section on Substrate Modification.

Sand beaches can also be good for clam culture but usually require predator exclusion netting. In sand, predators can forage extremely efficiently; losses as high as 100 percent have been reported from some sites. It is important that the sand beach is stable. Wave-generated ripples in the sand are signs that the beach may not be stable enough for clam farming.

If there are no clams present, one shouldn't assume the substrate is inappropriate for shellfish farming. It may be that predation has eliminated the clams and all that may be needed is predator netting to exclude the predators. Before investing in substrate enhancement, a prospective clam farmer may want to experiment with predator exclusion netting.

Movement and Dispersal

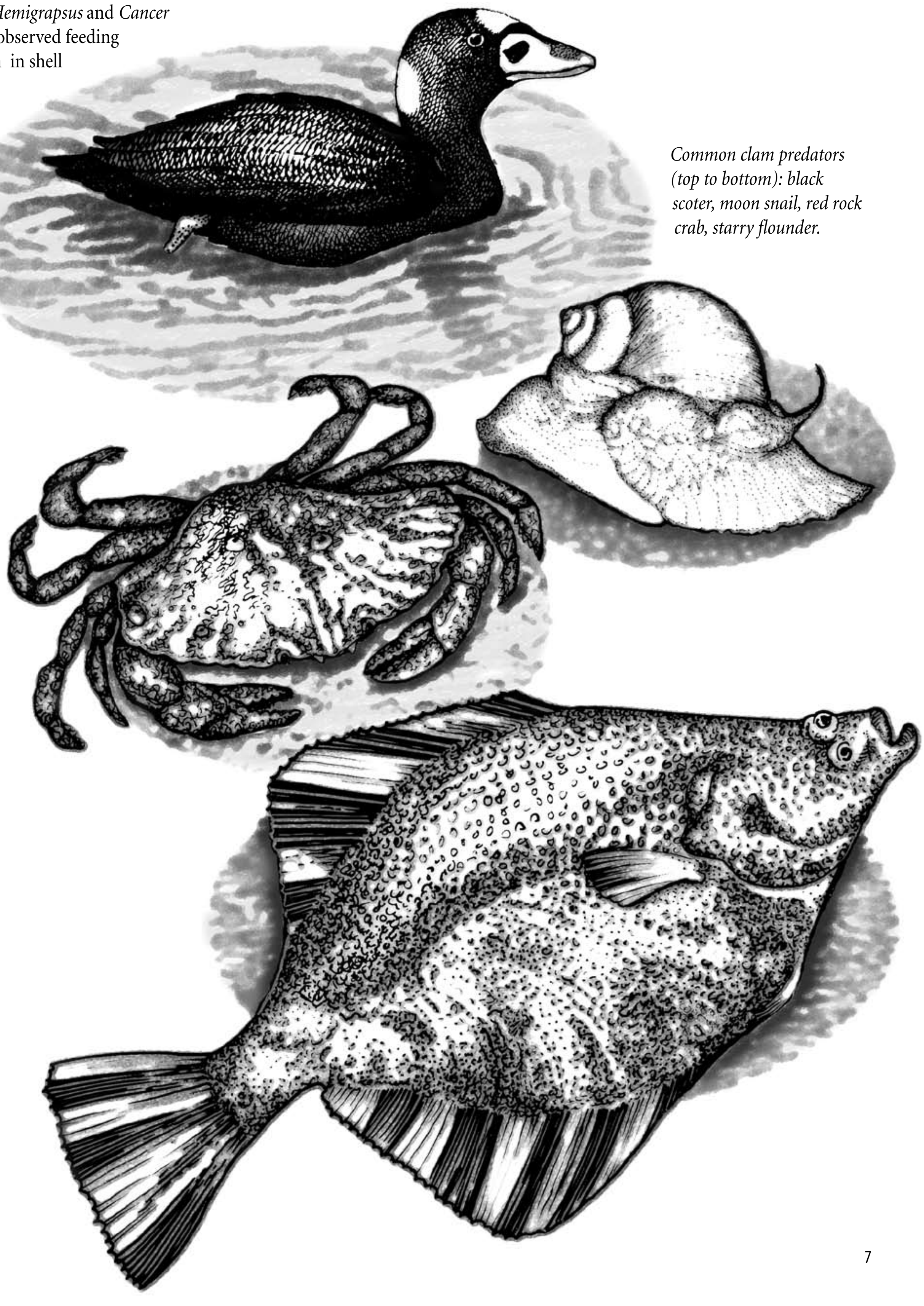
Clams do not always stay in one place. Experiments have shown that individual clams may relocate themselves outside of the areas in which they were planted. Clams may move in response to high densities predation pressure or poor substrate. Movement can also be caused by wave or current action.

Predators and Pests

A variety of clam predator and pests exist in Washington waters. Sometimes, the signs of predation — for example, broken or chipped shells — are easily spotted. At other times, the only indicators are empty clam shells.

The moon snail (*Polinices lewisii*) drills a countersunk hole in the clam shell before feeding on the clam's meat. The larger the clam shell, the more difficult it is for a moon snail to drill into it, and a small moon snail cannot prey on a large clam. Moon snails are often found subtidally, with a large portion of the population dwelling in waters adjacent to intertidal areas. Clams that are grown lower on a beach are more likely to fall prey to these snails. Growing clams in mesh bags (described on page 11 of this text) is one way to fend off the advances of moon snails. This method is not foolproof, however, as juvenile moon snails can enter through the bag mesh and feed on the clams within. Another technique involves growing clams above a tidal level (+2 to +4 feet MLLW) where moon snails are less common.

Several crab species can be serious clam predators. The red rock crab (*Cancer productus*) is common throughout central and southern Puget Sound and Hood Canal and is one of the most serious predators of both clams. The graceful crab (*Cancer gracilis)* and Dungeness crab (*Cancer magister)* can also cause significant losses in clam beds. Shore crabs (both *Hemigrapsus* and *Cancer* species), have been frequently observed feeding on freshly seeded (up to 12mm in shell length) Manila clam beds. One non-native, the European green crab (*Carcinus maenas*), is also a serious predator of farmed clams. As of this writing, European green crabs do not exist in Puget Sound; however they have gradually spread northward along the Pacific Ocean coast, reaching Washington's shores in recent years.



Common clam predators (top to bottom): black scoter, moon snail, red rock crab, starry flounder.

Certain fish species are reported to prey on clam beds. These include the rock sole (*Lepidopsetta bilineata*), English sole (*Parophrys vetulus*), starry flounder (*Platichthys stellatus*), shiner surfperch (*Cymatogaster aggregata*) and pile perch (*Rhachochilis vacca*). Clams eaten by fish tend to be less than an inch in diameter. In many areas, planted clams may grow large enough to escape fish predation by the end of their first growing season.

Gulls and crows are known to feed on clams when the tide is out. Even more significant predators include sea ducks, especially the white-winged scoter (*Melanitta fusca*), surf scoter (*M. perspicillata*) and black scoter (*M. nigra americana*), which travel through Washington's inland waters during seasonal migrations. Scoters are the most damaging to smaller (less than one-inch-diameter) clams but have been known to eat clams up to two inches in diameter. Numerous small pits and depressions in the substrate indicate that these ducks have been feeding on clam beds. On sandy substrate, duck feces containing ground-up shell is powerful evidence — that the ducks are eating the clams whole. Duck feces is not readily visible on gravel substrate.

Seastars are also common predators in clam beds. Four species — the sun star (*Pycnopodia helianthoides*), mottled star (*Evasterias troschellii*), pink star (*Pisaster brevispinus*) and ochre star (*P. ochraceus*) — are occasionally found on Puget Sound beaches. Because they exist in lower intertidal zones, well below the productive areas for Manila clams, they are more likely to have a greater effect on native littleneck clam beds.

Ghost shrimp (*Neotrypaea californiensis*) and mud shrimp (*Upogebia pugettensis*) are abundant in sandy and fine sediment beaches. Their burrowing activities contribute to sediment instability, which causes poor survival in clams. The shrimp can also change the sediment characteristics of a clam bed by bringing up fine sediment to the surface. The burrowing activities of sand dollars (*Dendraster excentricus*) can also loosen the substrate, undermining and displacing any shellfish in the lower portions of a productive area.

Fouling, Disease and Other Non-Predator-Related Impacts

Fouling occurs when marine organisms attach themselves to the substrate or the equipment used to grow clams. In some cases, this can block the water flow, seriously affecting the growth and survival of the clams. Primary fouling organisms include algae and other types of seaweed, mussels, barnacles and tunicates. Periodic cleaning of the equipment can control these fouling organisms.

Clams lying on the surface of the sediment are a sign of stress and may be an indicator or disease. Samples may be sent to private laboratories or the University of Washington for analysis.

To date, no major diseases have seriously affected Puget Sound clam beds. There have been several isolated cases of shellfish disease, without any widespread impacts. This, however, does not rule out the possibility of future outbreaks of greater magnitude.

Clams can also be killed by fresh water during flood events and by freezing or cooking during extreme cold or hot weather coupled with big low tides. Winter mortalities associated with flooding or freezing are not always immediately apparent. These events typically damage the clams' gills but may not result in death until spring, when the water warms and the clams' metabolisms increase.

Natural Recruitment

In Washington, seed clams come from two sources: natural production and hatchery production. Natural spawning and setting of clams occurs annually on beaches with suitable substrates and low predation throughout Puget Sound. The degree of natural recruitment may vary greatly among beaches and from one year to the next. Unless an area is known for consistent and heavy recruitment, additional seeding with hatchery-produced clams may be needed to augment natural recruitment.

Technologies

Relatively recent advances in aquaculture have made small-scale clam farming more viable, expanding the range of suitable beaches and increasing yields of marketable clams.

Hatchery-produced clam seed is available from several sources on the West Coast. While most offer Manila clams, there is one hatchery in Alaska that is actively selling commercial quantities of native littleneck clam seed. As of this writing, however, native littleneck seed is not available for import from Alaska into Washington due to disease concerns. Production involves the conditioning of adults, spawning, larval rearing and settlement. For most small-scale clam farming, it is more cost-effective to purchase clam seed from hatcheries rather than attempting to spawn and settle your own clams. A list of clam seed suppliers is listed in this document's "Resources" section.

The cost of clam seed varies, depending on the size and quantity of clams ordered. Although less expensive to purchase, small seed may need to be held in a nursery system until the young clams have reached the desired size for planting. As such, the costs associated with operating the nursery system must be added to any economic calculations.

When calculating the quantity of seed to be ordered, one must consider the method of planting, the size of area and the density of clams to be planted. For example, if a 12-foot by 50-foot beach is to be seeded with 60 clams per square foot, then a total of 36,0000 seed clams are required. If using in-ground bag culture (as described in this document's In-Ground Bag Culture section) , a total of 30,000 seed clams would need to be ordered to seed 50 in-ground bags with 600 clams per bag

Nursery Systems

With a nursery system, newly settled clams are reared in protected containment systems from approximately 0.25 mm up to a variety of planting sizes, ranging from 2 to 12 mm. While it varies by farm and farmer, a common size planted is 5 - 7 mm. It can take several moths for the clams to reach this size. Both land-based and floating upwell systems are commonly used for this purpose. With either form of upwell systems, seed clams are held in chambers on mesh netting. The seed clams feed on naturally occurring phytoplankton in sea water that is pumped through the mesh.

There are two main advantages to an upwell system:

Seed clams can be kept at higher densities than in traditional culture.

Because they will be entirely immersed in water at all times, the clams can over-winter in the system.

Cost is the major drawback to such a system. Capital improvement costs and the expense of on-going maintenance can reach thousands of dollars. In addition, sources of sea water and electricity must be available to operate the upwell system's pumps, although there are designs for tidally powered systems. Upwells require frequent cleaning and sorting of seed for good results.

The cost associated with building the floating upwell nursery, coupled with permits for a floating structure and the high maintenance required for successful operation make such nurseries prohibitive for small-scale operators. Intertidal trays or bags may be more financially feasible nursery systems.

Nestier trays are two-foot by two-foot trays with ¼-inch diameter openings that permit water to flow through them. Nylon window screen or mosquito netting is glued to the bottom of each tray so that small clams will be retained. The trays are employed in stacks of six or seven, placed in the lower intertidal area. For the stacks to function effectively, the bottom and top trays are kept empty. The stacks are secured to the beach, using rebar or anchored with sand bags.

Approximately one quart of seed should be placed into each tray. (The number of clams in a quart will vary depending on the size of the seed.) The trays should be checked periodically and any fouling organisms or predators removed. As the clams grow, their densities can be reduced by dividing the seed among two or more trays.

Seed should not overwinter in the trays, as it may be exposed to freezing weather during the seasonal low tides. When the desired size is reached, the seed clams can be removed from the Nestier trays and planted. If the clams are held for too long after they have attained a size of 15mm, the clams' shells can become misshapen.

Seed clams can also be stored in bags anchored to the beach. Clam bags (as described in this document's In-ground Bag Culture section) can be used to hold clams in a nursery system. The clams are placed in a bag made of window screen or mosquito netting, which is then placed within the clam bag. This second bag can be anchored at an appropriate tidal level.

Clam bags must be checked periodically and the clams sorted by size. As is the case with Nestier trays, the bagged clam seed should not be left to overwinter in the intertidal area, because of exposure to freezing temperatures.

Acquisition and Care of Seed Clams

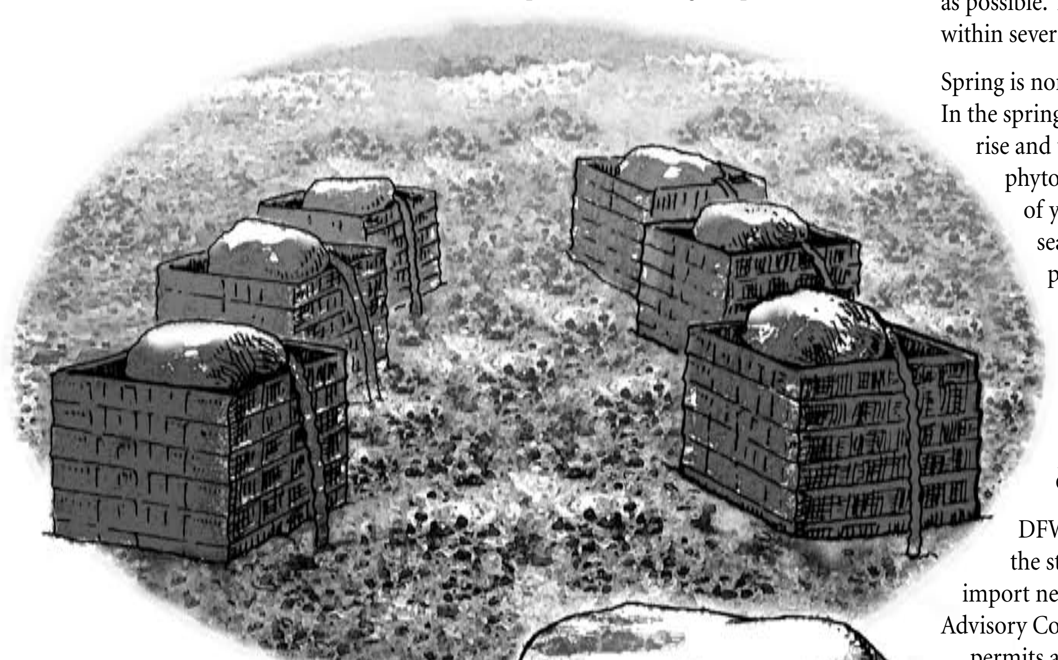
To ensure that supply can meet customer demand, most hatcheries request that orders be placed at least three months prior to the expected delivery date. The seed is placed in plastic bags and shipped in coolers containing gel ice packs. Orders are usually shipped via airfreight or express mail and usually arrive within 24 to 36 hours.

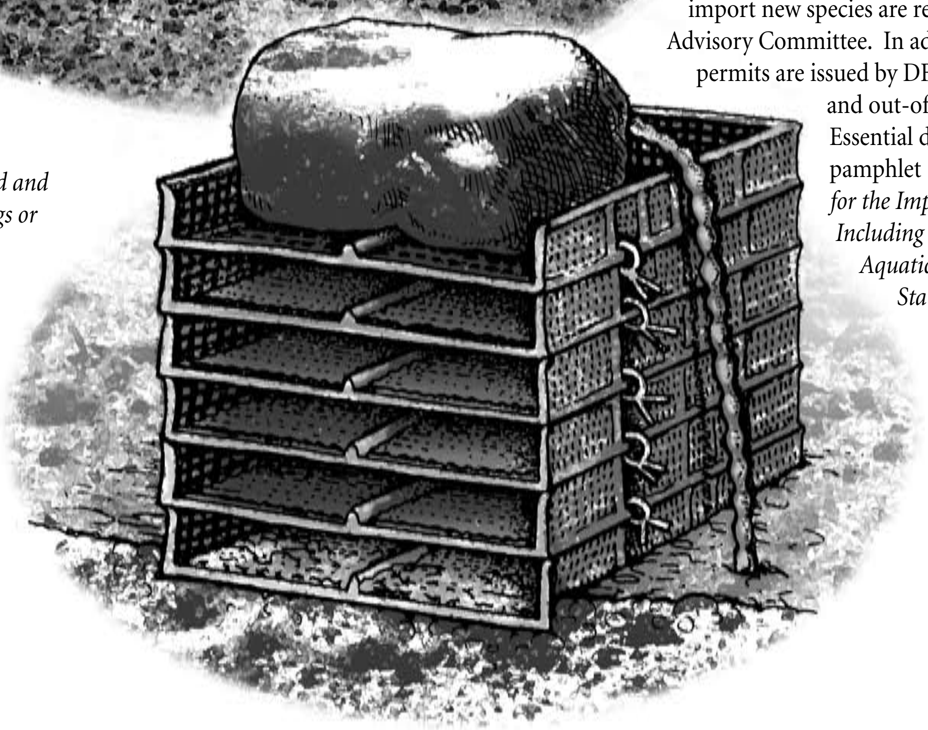
When the clams arrive at the site, the clam seed should be free of foul or rotten odors. The seed should be moist, but not wet. Standing water provides no oxygen for the clams and may create conditions for bacteria to proliferate. The temperature within the shipping container should be cool, usually between 40 degrees and 46 degrees F. Upon arrival, the clams should be planted or placed in a holding facility (or nursery system) as soon as possible. A healthy clam will start probing with its foot within several minutes of being placed in seawater.

Spring is normally the best season to plant clam seed. In the spring, the water temperature is beginning to rise and usually corresponds with an increase in phytoplankton productivity. Plantings at this time of year takes advantage of the summer growing season, and the clams have a season of growth preceding the winter months. Clams planted in the fall do not grow during winter and are subject to winter storms and mortality.

Shellfish Introductions and Transfers

DFW controls the importation of shellfish into the state and between growing areas. Requests to import new species are reviewed by the DFW Import Advisory Committee. In addition, shellfish transfer permits are issued by DFW to monitor both in-state and out-of-state transfers of oysters. Essential details are presented in a DFW pamphlet *Guidelines and Requirements for the Import and Transfer of Shellfish Including Oysters, Clams and Other Aquatic Invertebrates in Washington State.*





Stacked Nestier trays (above) can be weighted and anchored with sand bags or rocks (right)

Growing Methods

Choosing the best technique for growing clams will be influenced the specific conditions of a beach. If productivity is limited by high rates of predation, various predator exclusion methods can be employed.

Beach Culture

The least complicated method of growing clams is employed on a natural beach without any protective netting or bags. When adult clams are harvested, the substrate is loosened and the crop is thinned to improve the growth of the remaining clams.

The next level of clam culture involves supplementing the crop with seed clams from a hatchery. After a beach is harvested, hatchery clam seed can augment the existing natural recruitment of clams, resulting in a more abundant crop when the beach is next ready to harvest. Because of variations in site characteristics, the exact relationship between growth, survival, planting density and seed size may need to be determined on a case-by-case basis. Clams planted at lower densities (30 to 60 clams per square foot) may have better growth and survival than clams planted at higher densities. In order to determine an appropriate planting density, experimental plots with varying densities (20, 40, 60 and 80 clams per square foot) can be constructed. The plots should be checked every couple of months to determine growth and survival rates at the different densities.

A beginning clam farmer may want to experiment with various-sized seed. In general, larger-sized seed has a better chance of survival but is more costly than smaller-sized seed. The right balance of seed size and planting density must be found for each particular site.

To determine the density of clams at a particular site, conducting a population estimate based on size frequency. Randomly select and dig out one cubic foot of the substrate within a clam-growing area. Carefully sieve through the substrate and pick out all of the clams. Count the clams and measure their shells, estimating the average size of the clams in this sample.

Such a population estimate is an important tool for documenting one's clam inventory in case of loss following an oil spill or other shellfish-damaging event.

Planting Clam Seed

Planting usually involves scattering clam seed over a plot by hand. The best way to ensure even distribution of clam seed is to divide the batch of clams to be planted into smaller, equal-sized units. The beach can be divided into the same number of sub-units and planted with one portion of clams. Two people can easily plant an acre of ground in one low tide.

When planting a beach that is barren of clams, a seeding density of 60 - 80 clams per square foot is appropriate for smaller (3 - 5 mm) seed or 40 to 60 per square foot for larger (5 - 10 mm) seed. With this approach, if one wants to harvest clams annually, a fresh crop must be planted each year. To seed a beach that already has clams, a more common planting density is 30 to 40 clams per square foot. These beaches are often dug every two or three years and reseeded after the harvest of mature clams.

Clams are best planted on an incoming tide. This allows them to dig into the substrate before they are covered by water. It also protects them from prolonged exposure to sun and predators such as seagulls. Clam farmers should start planting the clams at the lowest tidal level and work their way up the beach as the tide comes in.

It is important to keep the clams moist. If the shells of the clams are allowed to dry out, the clams will become buoyant and float away from the beach plot. Planting on windy days can also pose problems, as wind-driven waves can carry off the clams before they have had chances to dig in. Planting from a boat over a marked area also works very well and helps to evenly disperse the seed. This procedure may help in avoiding any concentration of shore crabs, which appear to follow the edge of incoming tides.

When littleneck clams attain a size of 1.5 inches (38 mm), they are ready to be harvested. Because they are relatively shallow burrowers, they can be harvested by hand with clam rakes, clam forks or shovels. Clam forks work best in loose gravel that is small enough to pass through the tines of the fork. Rakes and shovels are better suited for compacted sediments.

Freshly harvested clams can be submerged in floating rafts (called sink floats), where they can purge themselves of sand. After a day or more in the floats, the clams can be packed and sold.

Predator Exclusion Netting

As its name suggests, predator exclusion netting keeps bivalve-eating animals from devouring farmed clams. Such netting has been shown to be effective against crabs, birds and fish; however it will not prevent predation by moon snails, which can burrow under the mesh unless the net edges are buried several inches deep. In-ground bags (described in the next section) are a better solution to thwarting these pests.

In some areas of Puget Sound and Hood Canal, there is considerable natural recruitment of juvenile clams each year. At these locales, all that may be required are securely installed predator nets. Adding hatchery-produced seed may not be necessary.

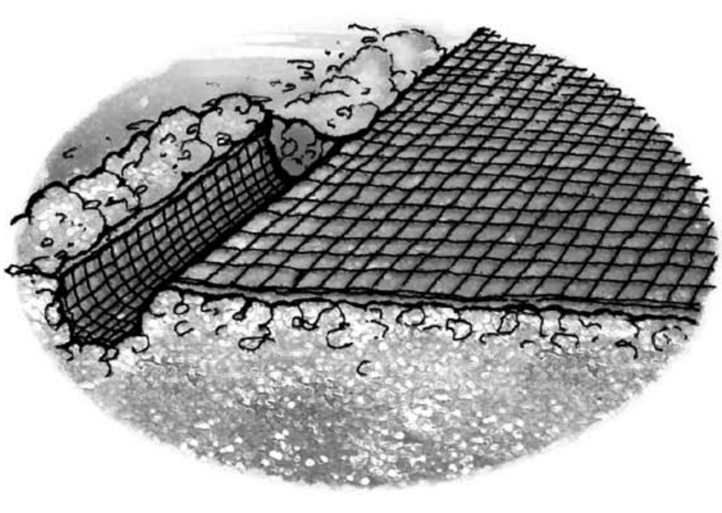
Lightweight, plastic mesh netting is available in a range of mesh sizes from suppliers (listed in the "Resources" section). It is most suitable for a mixed gravel, shell, sand and mud substrate where currents are negligible. Each site is unique in regards to siltation and predators. Trial and error is often the only way to find what net materials and mesh sizes work best on a particular beach. Netting with a smaller-sized mesh tends to trap fine sediment and become clogged. Mesh that is larger than one inch does not exclude many predators. Heavier-weight netting on a mixed gravel beach provides the same protective measures as the lighter-weight netting but is more expensive and difficult to handle. Planting larger clam seed, while more expensive, can thwart some predatory crabs. This strategy can allow the use of larger mesh predator netting.

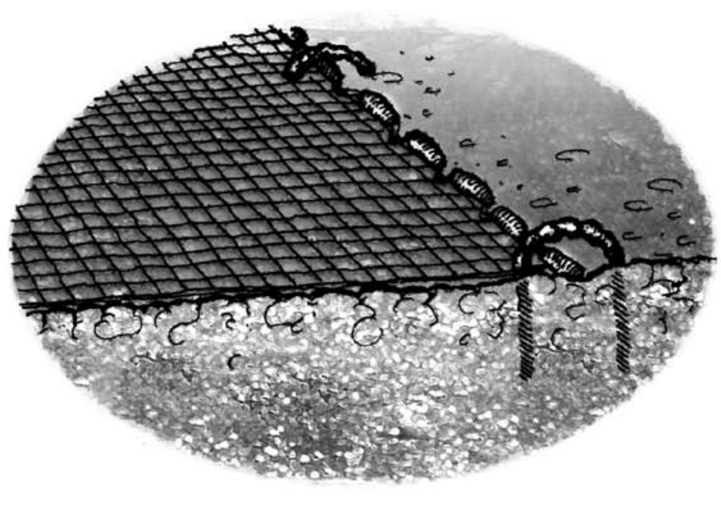
Lightweight netting is sold in 12-foot wide rolls that can be cut to length. Separate sections of netting can be sewn together with nylon thread or held together with plastic ties, creating wider sections to cover large plots. Nylon thread will not deteriorate in seawater but will break down under anoxic conditions. Plastic ties are long-lasting and easier to use. Whatever method is used to hold the nets together, it is important not to leave openings large enough for predators to enter.

Netting must be anchored to the beach. This is most easily done by digging around the perimeter of a plot, then burying the edges of the net in the trench. If seed clams are larger than the mesh size used, the clams must be planted before the net is laid and anchored. Otherwise, seeding can take place after the setting and anchoring processes are completed. Securing a lead line around the perimeter of the net is an alternative to digging. Lead line is weighted rope used on the bottom of salmon gill nets in the Pacific Northwest. It is available from commercial fishing supply outlets. Anchoring the lead line tautly and frequently to the beach with ½-inch diameter U- or T-shaped rebar stakes will generally preclude crabs and moon snails. If the slope of the beach is relatively steep, the netting should be oriented parallel to shore. On a gently sloping beach, the orientation of the netting is less critical.

The estimation of seed and planting methods is similar to that described earlier in the beach-seeding section. Seeding can be done the day after the netting is anchored, when the plots have settled. Clam seed should be planted with the incoming tide, working up the beach as the tide comes in. About 30 minutes before the tide returns, the clam seed is placed in a bucket of sea water, which will make the clams active. (The clams' feet will be extended as the animals attempt to dig down into the sand.) As soon as the tide covers the net, one should begin spreading the seed. While it is tempting to plant seed before the tide returns there are good reasons not to. Throwing seed on a gravel beach can crack a significant portion of the seed. Also, if the day is sunny or breezy, the surface of the seed could dry out or be carried away with the incoming tide. If planting is properly carried out, the clams will work their way through the mesh and start digging into the substrate within several minutes.

The netting should remain in place for the duration of the grow-out phase — typically, about three years. During this time, any rips or tears in the netting should be repaired as soon as possible, as predators that enter the nets can cause significant damage in short amounts of time. Small tears are easily mended with nylon line or plastic ties, while larger tears can be patched with scraps of mesh.





Edges of predator exclusion netting can be buried in a trench (left) or weighted with a lead line and secured with U-shaped rebar stakes (right).

Biological fouling of netting (described on page 6) may cause problems on some beaches, especially during spring and early summer months. Algae can also grow on or under the netting and form thick mats at low tide. Extremely thick mats of algae can create anoxic conditions in the sediments beneath them, negatively impacting the clams. Should this occur, the mats can be removed with a brush or other tool.

Prior to harvesting, the edges of the netting are unburied or the stakes or ties removed and the netting rolled back. If the entire plot will not be harvested during one tidal cycle, the netting should be re-anchored to exclude predators. Depending on the time of year and level of predation at a particular site, nets may be able to be removed for extended periods during the summer without significant mortalities.

Harvested plots of 100 to 150 square yards could easily be managed on clean, firm substrates during a single low tide. With muddier substrates or in areas of high fouling, smaller plots may be harvested during a tide in areas.

In-Ground Bags

On beaches where moon snails are serious predators, experienced clam farmers enclose their clam seed in mesh bags partially buried in the substrate. Known as in-ground bag culture, this technique allows growers to raise native littleneck or Manila clams at lower tidal levels, where other predator avoidance methods are usually ineffective. Although in-ground bag culture is more expensive than other growing methods, it may become more cost-effective by extending clam culture to a broader tidal range.

In-ground culture bags are made of heavy (typically 1/2-inch) plastic mesh. This size mesh facilitates water flow through the bags while excluding moon snails and other predators. There is still some risk from juvenile moon snails or crabs entering through the mesh and growing up while feeding on the contents of the bags.

Ready-made bags can be purchased by growers who don't want to make their own. A common bag size is 32" x 18" x 4" — a dimension based on the size of a roll of thick mesh netting. The edges are sealed with plastic ties or sewn together with nylon thread.

Clam seed is placed in the bags before they are sealed. The bags are placed in rows, with individual bags spaced approximately two feet apart. An aisle should exist between the rows to facilitate harvesting.

Seed should be large enough (about 6 - 8 mm) so that it won't fall through the ¼-inch holes in the mesh. An optimal planting density ranges between 500 and 700 clams per bag. Both density and beach conditions will influence growth rates, so a degree of experimentation may be necessary before the optimal planting density is attained.

The seeded bags are placed in shallow depressions in the beach sediment and secured with metal rods or rebar pins. The depressions should be deep enough so that only the top inch of each bag sticks above the substrate's surface. The bags will naturally fill with sediment. After the bags have filled, the pins can be removed. Proper placement of the bags in the depressions is critical, and may vary from beach to beach, depending on the sedimentation rates. If the bags become completely covered, the clams will not have access to food. If the bags are not deep enough, they may not fill with sediment and, instead, become washed away. It may be necessary to monitor the bags to ensure that they are not being covered or exposed.

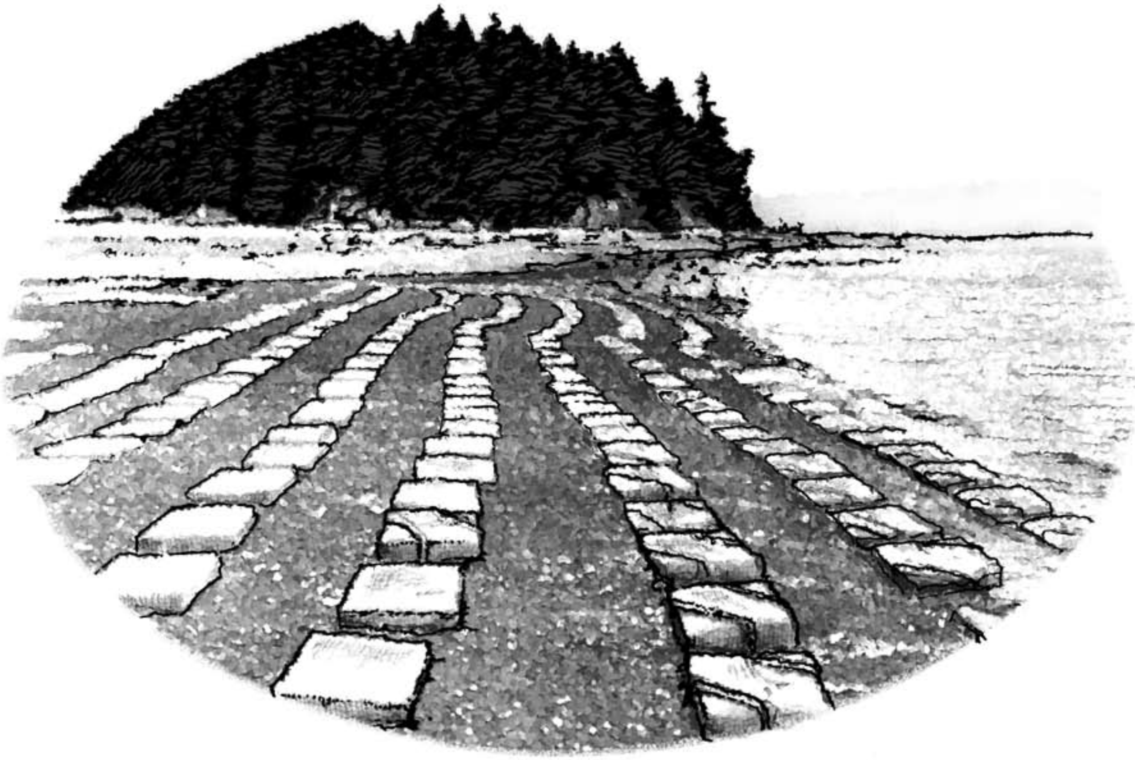
Clams And Harmful Algal Blooms

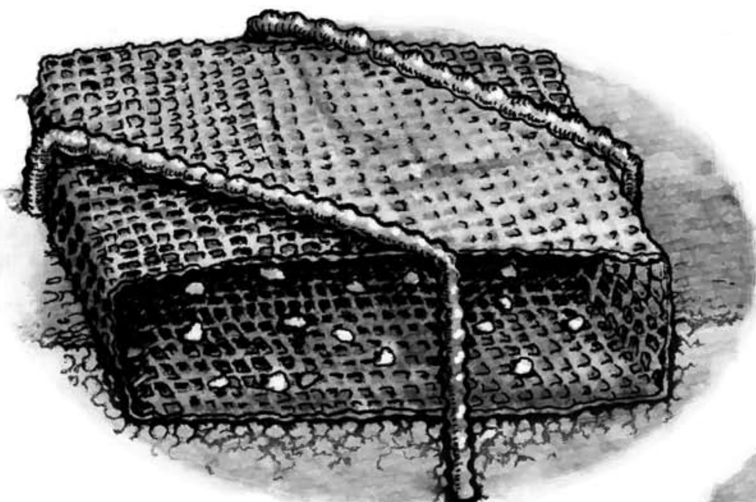
Harmful algal blooms (or HABs) in Puget Sound are unpredictable, usually occurring when environmental conditions and other factors are favorable to the growth of organisms that produce the toxins. All filter-feeding bivalves, including clams, may concentrate the toxins in their bodies. Shellfish growers, through DOH testing, routinely monitor harvests from commercial shellfish beds for unsafe levels of HAB toxins. If concentrations of the toxin reach a minimum (that is, "action") level, the growing area is closed to commercial harvests. If levels are significantly high, then a recall of the product may be issued. The growing area is re-opened after subsequent testing indicates that the toxins are below the closure limit.

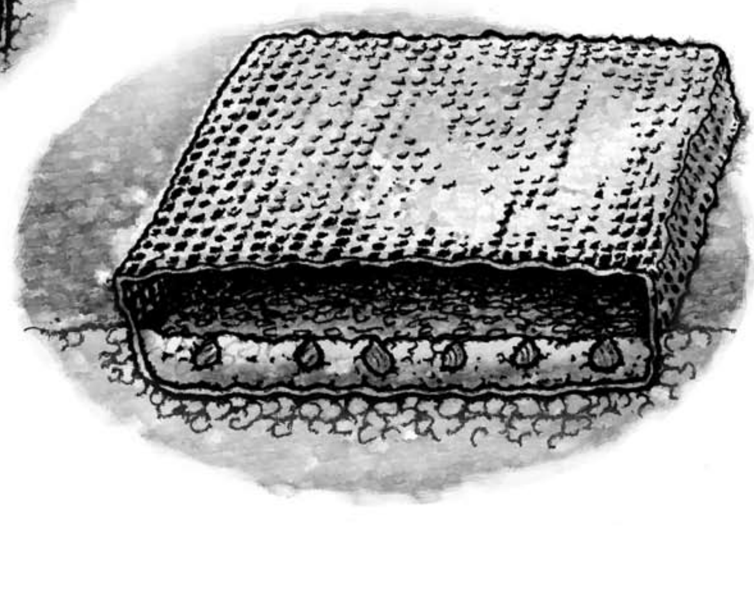
The planktonic organism *Alexandrium catenella* causes paralytic shellfish poisoning, or PSP. A natural toxin produced by *A. catanella* is concentrated by clams and other shellfish that feed on the plankton. While the toxin does not harm the shellfish, it can cause illness and death in humans and other warm-blooded mammals that eat these mollusks. PSP is a serious health problem that results in symptoms that include tingling of the lips, tongue, and fingertips, numbness, respiratory distress and death. When the plankton bloom is over, the shellfish can purge the toxin and, once again, become safe to eat.

Biotoxins in *Pseudonitzschia*, another planktonic organism, cause amnesic shellfish poisoning (or ASP). This organism occurs off Washington's Pacific Ocean coast and along the Strait of Juan de Fuca, where it has occasionally led to shellfish closures. To date, there have been no commercial shellfish closures because of ASP in Puget Sound. DOH routinely monitors shellfish for this toxin along with its sampling for PSP.

Counties and the state monitor popular public shellfishing beaches. This sampling coupled with testing done by commercial shellfish growers gives DOH a solid overview of any HABs occurrences in the state. They maintain a PSP hotline (toll-free: 1.800.562.5632), which is important to call before harvesting to assure a specific beach is not under a red tide closure.







Seeded in-ground culture bags are arranged in rows (top) and secured with rebar (center), which can be removed after the bags have filled with sediment (bottom).

As with predator exclusion netting, this farming technique is subject to fouling, both outside and inside the bags. As such, the outside of each bag should be regularly scraped to remove any plant and animal life. The inside of each bag can be cleaned after the clams are harvested.

Clams in in-ground bags are harvested by hand, usually during low tides. A shovel can be used to lift one side of each bag, breaking the suction, so the bag can be rocked back and forth to remove it from the depression. The bags are placed in the "aisle" between the rows and new bags with clam seed are then placed and anchored in the depressions. As the tide comes in, any sediment that settled in the original bags is washed away. The released sediment soon settles, helping to fill the newly planted bags. After this is done, the original bags are filled only with clams. The bags can be opened and the market-sized clams removed.

The market-sized clams can be placed in a sink float for several days prior to market to purge themselves of sediment. Any undersized clams can be sorted and replanted to allow additional growth.

Substrate Modification

Substrate modification can be used to enhance areas of a beach, turning marginally suitable clam-growing areas into more productive ones. This usually involves adding gravel or a combination of crushed oyster shell and gravel to transform mud and mud-sand beaches into more favorable clam grounds. Crushed shell is added in areas with natural seed recruitment. The presence of calcium in the substrate attracts new recruits to the beach. Substrate modification is expensive and is used primarily by larger clam-farming operations. It is often combined with seeding and the installation of predator netting to increase productivity.

Because substrate modification alters existing habitat and may have an environmental impact, permits from DFW, county planning departments and the U.S. Army Corps of Engineers are required before starting. The permit process evaluates potential impacts to the existing plants, animals and habitats such as eelgrass beds.

Legal Aspects

Federal, state and tribal programs work closely with clam farmers to protect the environment, nurture the economy and safeguard human health. In this section, some of those programs are introduced. A more detailed listing of relevant programs is contained in the "Resources" section of this document.

In April 1985, the Washington State Legislature declared aquaculture to be an agricultural endeavor, placing it under laws that apply to the advancement, benefit or protection of the agriculture industry. The Department of Agriculture was identified as the lead agency for all aquaculture within the state. Currently, this agency provides a supportive framework and coordinates marketing and promotional efforts for all aquaculture activities and products. However, issuing most licenses and permits is the responsibility of other agencies.

To engage in clam farming, several kinds of permit may be required. At a minimum, all commercial clam farming operations need an aquatic farm license from the Washington Department of Fish and Wildlife and a shellfish operation license and permit from the Washington Department of Health. Other permits (such as substantial development permits, or hydraulic project approval permits) may be required, depending on the growing methods to be used. The principal requirements for clam farmers are summarized in the appendices of this document. Prospective growers should contact each agency for further details to ensure compliance with current regulations.

Under federal treaties of 1854 and 1855, Washington tribes reserved the right to harvest fish and shellfish at all usual grounds and stations. Recent court decisions have upheld the Puget Sound tribes' rights to up to 50 percent of the sustainable yield from natural shellfish beds. The treaties included a shellfish proviso, in which the tribes are excluded from beds "staked and cultivated" by citizens. In 1994, Federal Circuit Court Judge Edward Rafeedie ruled that the beds staked and cultivated are defined in terms of the definitions of the day. He defined that "any beds staked and cultivated by citizens," refers to artificial beds created by private citizens and are not subject to the treaty right. However, natural beds, including shellfish under artificial beds, are subject to the treaty right.

In 1995, Judge Rafeedie issued an Implementation Order, which included implementation of his decision on private, non-commercial tidelands and commercial grower's shellfish beds. This Implementation Order included provisions for creation of new artificial beds as well. However, it contained several ambiguities that made it confusing to implement.

The Ninth Circuit Court of Appeals subsequently clarified that the tribes are entitled to half of the sustainable yield of natural beds where a commercial grower has cultivated a natural bed. Just "staking and cultivating" a beach is not adequate to exclude tribal harvest. The tribes, however, are not entitled to any portion of the harvest that is a result of the grower's enhancement efforts.

In April 2002, a Stipulation and Order further clarified several of the implementation ambiguities. For the purposes of this guide, it is important to note that, if creating new artificial shellfish beds, you are required to notify any tribes with usual and accustomed fishing areas that include your beach. To determine which tribes must be notified, contact the Northwest Indian Fisheries Commission. If the artificial beds will coexist with natural beds, a plan must be developed with the tribe or tribes affected, to assure they are afforded the opportunity to harvest their share.

At the time of this document's printing, all aspects of treaty rights to grower properties have not been fully resolved. Questions regarding treaty rights to shellfish growers can be addressed to the Attorney General office in Olympia.

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Glude, J.B. 1964. The effects of scoter duck predation on a clam population in Dabob Bay, Washington. Proceedings of the National Shellfisheries Assoc. 55:73-86.

Miller, M.B. 1982. Recovery and growth of hatchery-produced juvenile Manila clams, *Venerupis japonica* (Deshayes), planted on several beaches in Puget Sound, Washington. Ph.D Dissertation, University of Washington, Seattle. 250 pp.

Miller, M.B., K.K. Chew, C.R. Jones. L. Goodwin, and C. Magoon. 1978. Manila clam seeding as an approach to clam population enhancement. Washington Sea Grant Program Publications, WSG 78-2. 18 pp.

Nosho, T. (ed.) 1998. Seventh Conference for Shellfish Growers: Clam and Oyster Farming, Olympia, WA, 3-4 Mar 1997. Washington Sea Grant Program Publications, WSG-WO 98-01. 68 pp.

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Quayle, D.B. 1941. The Japanese "little neck" clam accidentally introduced into British Columbia waters. Progress Report. Fish. Resarch. Board, Canada 4:53-54.

Rogers, B.B. and D.A. Rogers. 1989. Can a small moon snail, *Pollinices lewisii*, eat a large clam, *Tapes japonica*? Northwest Environmental Journal 5:177.179.

Spencer, B.E. 2002. *Molluscan Shellfish Farming.* Fishing News Books, Oxford, U.K. 292 pp.

Spencer, B.E., D.B. Edwards and P.F. Millican. 1991. Cultivation of Manila clams. U.K. MAFF Directorate of Fisheries Research, Laboratory leaflet 65, Lowestoft, UK. 29 pp.

Thompson, D. 1990. Substrate enhancement of clam beaches in Washington. In Proceedings of the 1990 Manila Clam Culture Workshop, Aquaculture Industry Development Report 90-9: 59-64.

Toba, D.R. 1992. Impact of substrate modification on hardshell clams. M.S. Thesis, University of Washington, Seattle. 73 pp.

Toba, D.R., D.S. Thompson, K.K. Chew, G.J. Anderson and M.B. Miller. 1992. Guide to Manila clam culture in Washington. Washington Sea Grant Program Publication 92-01. 80 pp.

Williams, J.G. 1980. Growth and survival in newly settled spat of the Manila clam, *Tapes japonica.* Fishery Bulletin 77:891-900.

Resources

State Agencies

Washington Department of Fish and Wildlife (WDFW)
Natural Resources Building
1111 Washington Street SE
P.O. Box 47027
Olympia, WA 98504-7027
360.902.2200
wdfw.wa.gov/
Aquatic Farm Registration
Hydraulics Permit is required for substrate modification, or prior to any construction or modification work on or adjacent to a beach. Not required for other aquaculture methods. Wholesale Dealers License is required only for companies handling products produced outside the state.

Washington Department of Health
Office of Food Safety and Shellfish Programs
P.O. Box 72824
Olympia, WA 98504-1824
360.236.3330
Fax: 360.236.2257
www.doh.wa.gov/ehp/sf/
Shellfish Operation License and Certification required of all commercial shellfish operations: growers and harvesters; processors; wholesalers; re-packers. Certification is required for growing area and product. The agency will inspect growing grounds and adjacent uplands, and will secure water and meat samples for fecal coliform analysis. The agency will also test shellfish samples for biotoxins. The agency further requires labeling and record keeping for all product units and shipments.

Department of Natural Resources
Natural Resources Building
1111 Washington Street SE
P.O. Box 47027
Olympia, WA 98504-7027
360.902.1100
dnr.wa.gov/htdocs/aqr/
An Aquatic Land Lease is required for the use of state-owned tidelands. Lease fees are established through competitive bidding or negotiation.

Department of Agriculture
Aquaculture Coordinator
Natural Resources Division
1111 Washington Street SE
P.O. Box 2560
Olympia, WA 98501-2560
360.902.1976
agr.wa.gov/
Identification of Aquaculture products. Required labeling and sale documentation to cover products produced by aquatic farmers.

Department of Ecology (DOE)
300 Desmond Drive
P.O. Box 4760
Lacey, WA 98504-7600
360.407.6000
ecy.wa.gov/
Although small-scale clam growers are not required to contact DOE, they should check with this agency to determine whether it is necessary to apply for the following:
Statement of Consistency with Coastal Zone Management Act
Water Quality Certification
Water Quality Standards Modification
National Pollutant Discharge Elimination System (NPDES) Permit

Washington State Attorney General
1125 Washington Street SE
P.O. Box 40100
Olympia, WA 98504-0100
360.753-6200
Fax: 360.586-7671
emailago@atg.wa.gov
atg.wa.gov/
Information on treaty rights to grower tidelands and property.

County/Local Agencies

Check with the local shorelines permit administrator to determine exact requirements. The contact person is normally with the county planning department. A Substantial Development Permit may be needed if the project has a total cost or fair market value exceeding $2,500. Most small-scale clam farms will not exceed this amount.

Federal Agencies

U.S. Army Corps of Engineers
Regulatory Branch
P.O. Box C-3755
Seattle, WA 98124-3755
206.764.3742
nws/usace.army.mil/
Section 10 Permit (River and Harbors Act) is required for any structure that will be put over navigable waters, including piers, docks, piles, rafts, etc.

U.S. Coast Guard
13th Coast Guard District
915 Second Avenue
P.O. Box C-3755
Seattle, WA 98124
800.982.8813
uscg.mil/d13/default.htm
Navigational markings required for fixed or floating structures in or over water.

Tribal Information

Northwest Indian Fisheries Commission
Shellfish Coordinator
6730 Martin Way East
Olympia, WA 98516
360.438.1180
Fax: 360.753.8659
contact@nwifc.org
nwifc.wa.gov/shellfish/

Aquaculture Associations

Pacific Coast Shellfish Growers Association (PCSGA)
120 State Avenue NE, PMB #142
Olympia, WA 98501
360.754.2744
Fax: 360.754.2753
pcsga.org

Shellfish Suppliers

This list was compiled for the convenience of persons interested in growing shellfish on a small scale. Additional seed sources may be found by checking with other local clam and oyster farms. Also some materials may be obtained from various marine hardware companies. *Note: Washington Sea Grant Program does not endorse any of the companies or products listed.*

Seed Suppliers

Hilton's Coast Seafoods Company
14711 NE 29th Place, Suite 111
Bellevue, WA 98007
425.702.8800 or 800.423.2303
Fax: .425.702-0400
info@coastseafoods.com
coastseafoods.com
Manila clam seed and larvae; minimum order: $100

Kuiper Mariculture, Inc.
PO Box 507
Bayside, CA 95524
707.822.9057
Fax: 707.822.3652
kuimar@northcoast.com
Manila clam seed: 2-3 mm to 6-8 mm; minimum order: $250

Lummi Shellfish Hatchery
2616 Kwina Rd.
Bellingham, WA 98226
360.384.2303
Fax: 360.380.1205
shellops@memes.com
lummishellfish.com
Manila clam larvae and seed, geoduck seed, basket cockles and soft-shelled clams; special orders welcome

Taylor Shellfish Farms, Inc.
Headquarters and Farm
130 SE Lynch Rd
Shelton, WA 98584
360.426.6178
Fax: 360.426.0327
daved@taylorshellfish.com
taylorshellfishfarms.com
Manila clams and geoduck seed. Seed sales for small-scale farms, three days per year; check with the company for dates.

Clam Aquaculture Material Suppliers

Alaska Aquafarms
P.O. Box 7
Moose Pass, AK 99631
907.288.3667
jjh@seward.net
Plastic grow-out trays, pearl nets, lantern nets, shellfish grow-out nets

Aqua-Pacific Wire Mesh & Supply Ltd.
2220B McCullough Road
Nanaimo, BC V9S 4M8 CANADA
1.877.751.3772 or 250.751.3772
Fax: 250.756.3864
aqua-pacific@telus.net
aquapacificwire.com
Shellfish grow-out trays, PVC wire mesh rolls, cages, beach fencing, clam netting, rope, bungee cord, accessories

Cards Aquaculture Products Ltd.
2551 Kenworth Road
Nanaimo, BC V9T-3M4 CANADA
1.888.902.2737 or 250.949.2380
Fax: 250.949.2381
cardsaqua.com
Shellfish grow-out nets, plastic grow-out trays

Coastal Aquacultural Supply
100 Glen Road, P.O. Box 8066
Cranston, RI 02920
401.467.9370
Fax: 401.461.9520
bbowes@coastalaquacultural.com
www.coastalaquacultural.com
Rope, powered upweller systems, grow-out trays, custom racks to hold bags

DelStar Technologies, Inc.
220 East Saint Elmo Road
Austin, TX 78745-1218
1.800.259.7950 or 512.447.7000
Fax: 512.447.7444
sales@delstarinc.com
delstarinc.com
Oyster trays, shellfish grow-out nets, cages, plastic netting

Englund Marine Supply Co., Inc.
101 15th Street, P.O. Box 296
Astoria, OR 97103
800.228.7051 or 503.325.4341
FAX: 503.325.6421
astoria@englundmarine.com
englundmarine.com

Fablok Mills
140 Spring Street
Murray Hill, NJ 07974
908.464.1950
Fax: 908.464.6520
info@fablokmills.com
fablokmills.com
Polyester and nylon netting in bulk rolls, mesh bags with different types of closures

Fukui North America
PO Box 669,
110-B Bonnechere Street W.
Eganville, ON, K0J 1T0 CANADA
613.625.1704
Fax: 613.625.2688.
fukui@fukuina.com
www.fukuina.com
Clam grow-out cages, floating upwell systems, ropes, buoys, other supplies

Norplex, Inc.
111 3rd Street NW Bldg. C
P.O. Box 814
Auburn, WA 98071-0814
253.735.3431
Fax: 253.735.5056
norplex@aol.com
Clam grow-out bags, plastic bird netting, cultch netting, orange plastic safety net, ladder ties and plastic bags

Sea Grant
Washington

The text for this publication was written by Derrick Toba, with assistance from Bill Dewey of Taylor Shellfish and Teri King, Water Quality Specialist with Washington Sea Grant Program. Special thanks are extended to Brady Blake, Washington Department of Fish and Wildlife, and Steve Harbell, Washington Sea Grant Program, for their review of the manuscript.

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WSG-AS 03-02

September 2005

Illustrations by Kate Sweeney

A Washington Sea Grant Program publication.
This report is published in part by Grant #NA76RG0119, Project A/PC-5, from the National Oceanic and Atmospheric Administration to Washington Sea Grant Program, University of Washington. The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its subagencies.