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Aquaculture in Washington State

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This pamphlet describes aquaculture operations in Washington State. It provides an overview of this industry and tells how various aquatic animals and plants are farmed.

The Seafood Supply Problem

In the United States, seafood supplies are limited because fishery resources are being harvested at or over maximum sustainable yield levels. At the same time, demand for seafood continues to rise because of increasing population and a greater awareness that seafood is important for good health.

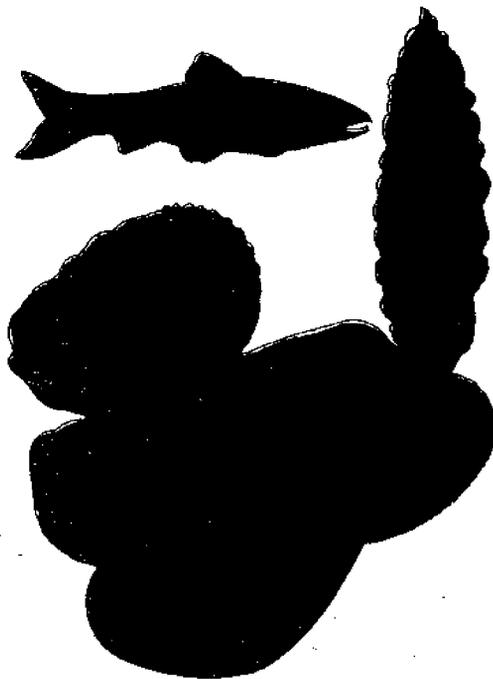
To meet growing consumer demand, the United States has gone from being a net exporter to being a large importer of seafood. In 1987, the United States imported \$8.7 billion in seafood products, while its total exports were valued at only \$1.6 billion. This places fishery products second only to oil as the largest factor in the U.S. trade deficit. But world demand for seafood is also growing and may eventually limit amounts available for import.

Seafood supplies can be greatly increased through modern aquaculture techniques. Currently, 10 percent of the world's seafood production comes from aquaculture. The United Nation's Food and Agricultural Organization expects this proportion to rise to 25 percent by the year 2000. Further imbalances in seafood trade can be expected unless the United States reduces imports or improves seafood supplies. Aquaculture is the most promising means for achieving the latter goal.

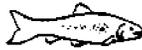
Washington State Aquaculture

The inland waters of Washington provide excellent conditions for aquaculture. They are said to have the best combination of clean water, good tidal currents, and suitable temperatures of any state in the nation.

Perhaps more than any other industry, aquaculture depends upon superior water quality. Aquatic farms cannot survive in polluted waters. Recognizing that good water quality is fundamental to fish farming, Washington



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Governor Booth Gardner stated, "Clean water is essential for aquaculture production, and promotion of this industry with appropriate environmental safeguards can actually lead to improvements in environmental quality."

Conditions in Washington are especially good for the farming of salmon, shellfish, and seaweed. Currently, there are about 460 commercial aquatic farms and about 170 non-commercial aquatic farms in the state. In 1986, more than 15 million pounds of seafood were produced with a farm value of more than \$24 million (*1986 Fisheries Statistical Report*, Washington Department of Fisheries) and a wholesale value of nearly \$44.5 million.

In addition to private efforts, Washington's state resource agencies have a long history of aquaculture. The largest publicly funded salmon and trout hatchery systems are located here. Washington agencies coordinate more than a hundred salmon and trout enhancement projects throughout the State. Moreover, the Washington Departments of Fisheries and Natural Resources frequently use aquaculture techniques to replenish overharvested public tidelands with clams and oysters.

Salmon and Trout

In Washington there are long-established commercial hatcheries for farming trout and salmon. All these operations require fresh water, which is necessary for salmon and trout development, from the fertilizing and hatching of eggs through the growth of juvenile fish.

The water for these installations is not used just once and then discharged into sewers as it is in a city. Instead it is obtained from an aquifer by way of a well, or less often from a stream. After it passes through the trays, tanks, or ponds, the

water is repurified and then returned to the ground or to a stream.

Hatcheries sell their products at varying stages of development to growers:

Eggs which have been obtained from superior broodstock of trout or salmon are raised from the initial stage just after spawning (green eggs) to the "eyed" stage where the fish embryos are visible within the eggs. At this stage, but not before, the eggs can be shipped successfully to growers around the world.

Juveniles: Alevins or fry of trout or salmon may be sold to stock commercial or private freshwater ponds.

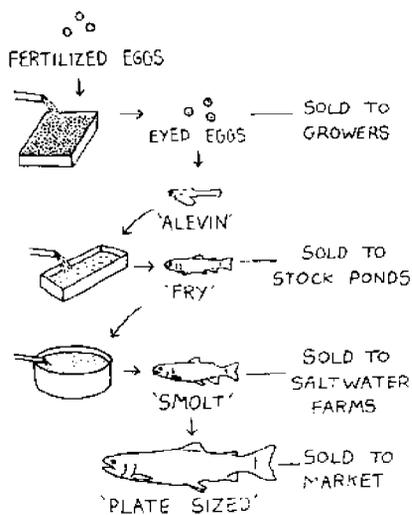
Smolt: These young fish, at the stage of development which allows transfer to salt water, are sold to growers to be raised to market size in salt-water net pens.

Plate-sized trout or salmon are raised in fresh water and sold to markets and restaurants, usually at one pound or less in size.

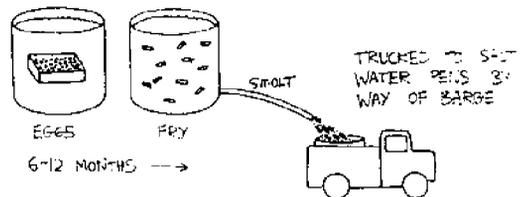
Salmon farming is the process whereby young salmon are obtained from freshwater hatcheries and are raised to market size in floating saltwater net pens or in freshwater tanks. Atlantic salmon appear to be the hardiest variety for net-pen culture. The broodstock for the farmed fish are the largest and fastest growing adults. After eggs are taken, they are fertilized and then incubated in trays in fresh water. The tiny fish (alevins) which hatch are moved to circulating freshwater tanks where they are fed for a year, or until changes in their physiology and appearance indicate their readiness to go into salt water as smolts.

The smolts are then moved by tank truck and barge to seawater floating net pens. These pens must be placed on sites that are protected from severe storms, yet have good circulation and deep

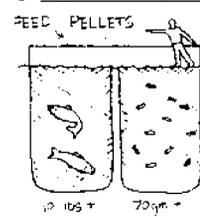
SALMON AND TROUT HATCHERIES (FRESH WATER)



A FRESH WATER HATCHERY



B SALT WATER NET PENS



C. PROCESSING PLANT



TO MARKET



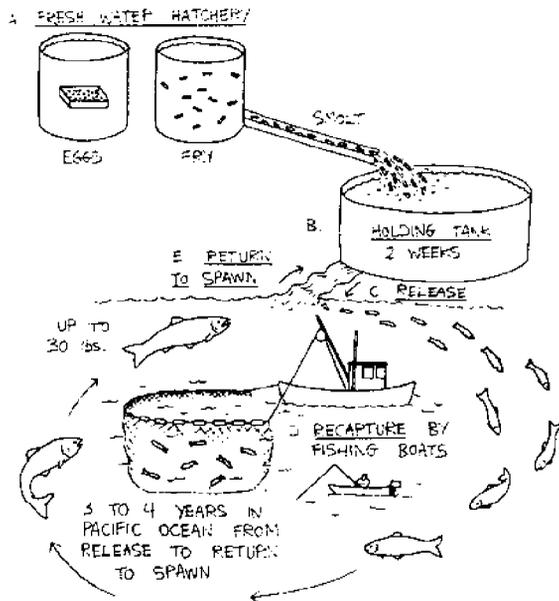


water. In the net pens, the fish, which are highly efficient in their feed conversion, are fed formulated pellets. Proper densities are maintained by moving some fish into empty pens as they grow and gain weight. After about two years of saltwater growth, the adult fish are ready for market.

Salmon farming produces superior fresh fish for the market all through the year, instead of just during the fishing season. Thus the salmon industry—like the meat industry—can supply fresh products for consumers year round.

Salmon enhancement: Salmon runs are enhanced by raising juvenile salmon in a freshwater hatchery and releasing them into salt water when they become smolts. This involves sending fish of the appropriate size down a raceway to a freshwater holding tank at the edge of the salt water. Here sea water is gradually pumped into the tank so that the fish will become acclimated to the sea as they would if swimming down a river. They are held in the tank for two weeks and then released to feed and grow in the North Pacific Ocean.

In three to four years the surviving salmon (2-6 percent of those released) return to spawn at their place of origin—in this case it is to the hatchery fish ladder and holding tank. Many of the returning adult fish can be caught by commercial or sports fishermen. Two percent should be allowed to return up the fish ladder to the holding tank. There the females are stripped of their eggs, which are then fertilized and become the start of another generation of fish.

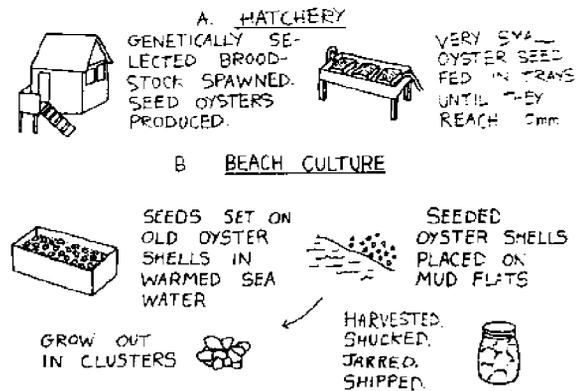


Oysters

Oysters are the oldest and best-known form of aquaculture in Washington State. They are grown for sale as fresh singles for the half-shell trade or shucked and jarred oysters for volume sales. Either way they must start life as free-swimming larvae and then as seed. These can be produced in *hatcheries* or can be *captured* in bays (where many oysters naturally spawn and the larvae aggregate) such as Dabob Bay or Willapa Harbor.

In an *oyster hatchery*, broodstock are carefully selected and preserved. They are conditioned and spawned, and the tiny larvae are fed a special algae grown in tanks. Then the larvae are set on old oyster shells in groups or, to produce single seed, singly onto small particles of shell. When the oysters are large enough, they are moved to grow-out areas.

Beach culture: In Washington, oysters are usually grown out on large tidal flats. A number of seed are set on old oyster shells which are then planted near the low tide level on mud flats whose bottoms are fairly firm. The tiny oysters must survive possible attacks by oyster drills, crabs, and starfish. Sometimes, burrowing ghost shrimp soften the ground so that the oysters sink, suffocate, and die.



When fully grown, the oysters are harvested in clusters still attached to the original oyster shell. The harvested oysters are cleaned, shucked, placed in jars according to size standards, and sent to market.

Off-bottom culture: These methods offer the advantages of greater survival, faster growth, and high-density farming. They include:

- Long line culture
- Lantern net culture
- Rack and bag culture

Long line culture: Ropes are strung along the tops of posts set in mud flats in the intertidal zone. To grow out oysters, the seed are first allowed to set on old oyster shells. The shells are then attached by hand to the long lines. Great clumps of oysters grow from each shell. These oysters are excellent for shucking because the



yields are high and the shells are not so hard as those of oysters grown on beaches.

Lantern net culture: After the hatchery phase, single oyster seeds are moved to nursery trays which are stacked in lines in the deep waters of a bay. As the oysters grow, the trays are graded several times to prevent crowding. When the oysters are about 35 mm (1.5 inches) in length, they are moved to Japanese lantern nets fastened to buoys and suspended from long lines in the bay. Here they grow to market size. Because the shells of oysters grown in this way are fragile, the oysters are conditioned for market by hanging them under a dock. When the tide goes out each day, they are exposed to air for a few hours—hardening the shells and toughening the adductor muscles. After about two weeks, the oysters are packed carefully and shipped live to the market.

Rack and bag culture is another means of growing single oysters for the half-shell trade. These oysters are grown in nursery trays for a while and then put into stout net bags which are placed on a rack two feet above a beach near the low tide level. The bags are turned from time to time. The mature oysters are harvested, cleaned, and shipped in the shell to market as live single oysters.

C LONG LINE CULTURE



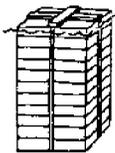
SEEDS SET ON OLD OYSTER SHELLS AS IN B.

SEEDED SHELLS ATTACHED TO ROPES ON TOP OF POSTS DRIVEN INTO MUD AT LOW TIDE LEVEL



OYSTERS GROW IN CLUSTERS. HARVESTED BY HAND, SHUCKED INTO JARS AND SHIPPED

D. LANTERN CULTURE



TRAYS OF SMALL OYSTER SEED ARE STACKED TOGETHER AND PLACED IN DEEP WATER TO GROW TO 35 mm



JAPANESE LANTERN NETS HOLD 500 OYSTERS EACH WHILE THEY GROW TO MARKET SIZE

OYSTERS HARVESTED, EXPOSED TO TIDAL CHANGE TO HARDEN SHELLS, PACKED, SHIPPED

E. RACK AND BAG CULTURE



OYSTER SEED SET ON TINY FRAGMENTS OF OYSTER SHELL. GROW TO 25-35 mm IN TRAYS UNDER SALT WATER

PLACED IN FINE MESH PLASTIC BAGS. BAGS STAY ON RACKS PLACED ON BEACH AT LOW TIDE LEVEL. BAGS TURNED OVER AT INTERVALS.



HARVESTED AS SINGLE OYSTERS. CLEANED, PACKED AND SHIPPED.

Clams

Clams are farmed on intertidal beaches in bays and coves sheltered from the prevailing southerly winds. These beaches usually consist of a mixture of mud, sand, gravel, and shell. Currently, the only clam species produced by Pacific Coast shellfish hatcheries is the Manila clam because of its popularity in the steamer clam market and its adaptability to hatchery and farming conditions.

A. HATCHERY



CLAMS SPAWNED. LARVAE TO SEED CLAMS.



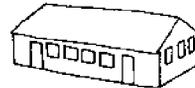
B. CLAM SEED PLACED ON BEACH UNDER PROTECTIVE NETTING. CLAMS BURY THEMSELVES.

GROWN 3 YEARS

C. CLAMS HARVESTED



D. PLACED UNDER WATER 2 DAYS TO PURGE TO SAND.



E. CLAMS PACKED AND SHIPPED



Adult clams showing good growth characteristics are chosen as broodstock. They are brought to a hatchery and placed in heated seawater tanks where they are conditioned for spawning. After they spawn, the free-swimming larvae are grown in large tanks and fed a selected diet until they settle to the bottom of the tank. The young clams are then transferred to a nursery where they continue to grow until the desired seed size (about 0.25-0.50 inch) is attained.

A beach is prepared by raking or tilling and removing large rocks. When the clam seed is sprinkled on the beach, the tiny clams immediately dig into the mud and cover themselves. The whole area is then covered with a plastic mesh whose edges are buried to keep out predators.

After two or three years, a professional clam digger pulls back the mesh cover and digs the clams by hand. He places the clams in a sink-float underwater where they will purge themselves of all mud and silt. About two days later, the clams are pulled from the water, packed, and shipped to market alive.

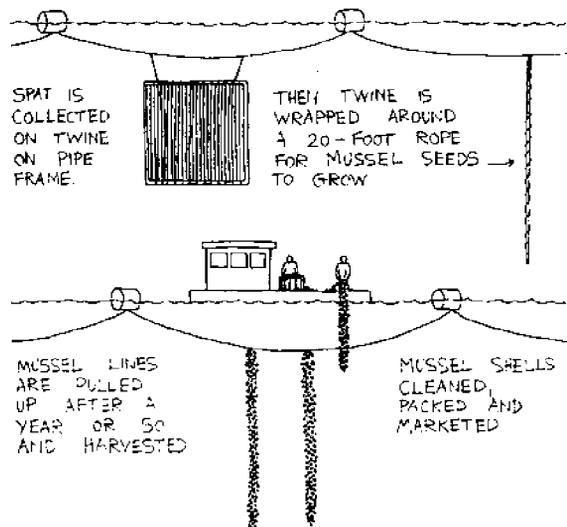
The plastic netting method originated at the University of Washington School of Fisheries. Scientists found that netting increases the yields of clam beaches because it protects growing clams from predators. This method might be considered not only by commercial growers but also by owners of beaches who plant clams for their own use.



Mussels

Mussel culture has been carried out in Washington since the late 1970s. The "long line" method of growing is used successfully. Wherever mussels grow profusely, they release free-swimming larvae into the water. At the time and place where this release is expected, mussel culturists stretch twine across five-foot pipe frames and suspend the frames in the water just below the surface. The larvae attach to the twine. When the larvae are firmly set, the twine is wrapped around 20-foot ropes that are either suspended from a line held between floats at the surface or hung from beneath a floating wooden frame. The mussels then grow out on the hanging ropes. As they grow, they must be thinned so that large growing clumps do not fall off.

At the end of a year, more or less, the mussels are harvested by pulling up the rope, removing and separating the mussels, cleaning the shells, and grading and packaging. The live mussels are then ready for market.



Abalone

Abalone are marine gastropods (snails) which inhabit shallow rocky coastlines in many areas of the world. They prefer temperate waters of moderate-to-high wave or current action where their preferred food, brown and red kelp, is abundant.

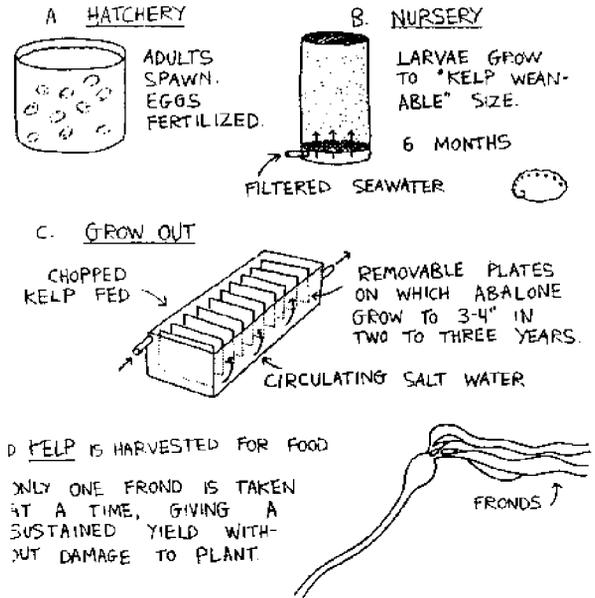
Current culture methods involve three basic phases:

Hatchery: Mature adults are conditioned for spawning through adjustment of their diet, photoperiod, and water temperature. After spawning, the fertilized eggs are placed in special incubation cells where larval development is completed.

Nursery: Newly settled juveniles consume the diatoms that coat the substrates on which they crawl. This phase lasts about six months, after which the small snails are "kelp-weanable."

Tanks: The abalone are held in tanks through

which seawater is circulated rapidly. Chopped kelp of several varieties is provided daily until the animals reach marketable size (3-4 inches in two to three years). The kelp for feed is harvested year-round on a sustained-yield basis without destroying the kelp plants.



Nori

Nori farming is the process of growing, processing, and marketing nori seaweed for human consumption. Nori is high in protein and rich in minerals and vitamins. The "farms" consist of nets, with small floats attached to their sides, which lie directly on the surface of the water.

In the United States, nori is primarily consumed as the dark brown or greenish wrapping around vinegared rice in a Japanese dish known as *sushi*. Nori is the second-largest seafood crop in the world!

The inland waters of Washington are especially suited to nori growth. Although, nori is the only seaweed that is farmed in Washington, other seaweeds are cultured elsewhere—for food, emulsifiers, and pharmaceuticals.

Site Characteristics: Nori plants are started in a glass-covered building similar to a greenhouse. Later, nets containing nori "seedlings" are moved to an offshore area where clean, fast-flowing, sheltered salt water fosters growth of high-quality nori blades.

Methods of Farming: In the first phase (greenhouse), cultures of microscopic bits of nori (*conchocelis*) are grown in saltwater trays inside a glass-covered building. Here they attach to clean shells. This requires four to six months in the spring and summer season.

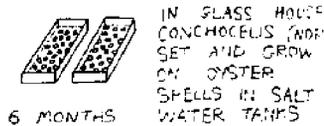
In September, the seeded shells are placed on tarps stretched over frames that are suspended



just below the surface of sea water. As many as fifty layers of 50-foot long netting are placed above the frames so that the nets will be seeded when spores are released by the conchocelis on the shells.

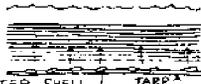
Some of the seeded nets are then spread out on long frames on the salt water. The remaining seeded nets are rolled up and frozen. With proper care, the nori grow long blades which are harvestable within about 25 days. During the fall and winter, a succession of frozen, seeded nets are taken out and cultivated. In this way, up to six crops can be grown and harvested annually.

Processing nori resembles paper manufacture, and, like paper, the product comes out in thin sheets which are bundled and shipped to U.S. markets.

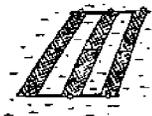


6 MONTHS

SPORES RELEASED BY
CONCHOCELIS RISE UP
TO SETTLE
ON 50
LAYERS OF
NET

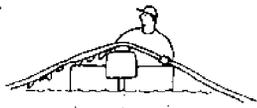


NETS RAISED AND LOWERED
DAILY TO GIVE EFFECT OF
TIDAL CHANGE FOR 2 WEEKS



NETS SPREAD OUT
NORI GROWN TO
HARVEST SIZE
25 DAYS

NORI HARVESTED
INTO SMALL SHEETS



PROCESSED INTO
THIN SHEETS BY
MACHINE, THEN
BUNDLED, SENT
TO MARKET

About This Pamphlet

The information in this pamphlet was provided by growers of commercial aquaculture products in Washington State. Contributors include:

Washington Aquaculture Council
Washington Fish Growers Association
San Juan Islands Aquaculture Association
Pacific Coast Oyster Growers Association

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