PROSPECTS FOR SEA FARMING IN PACIFIC NORTHWEST

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The sheltered bays, sounds, and estuaries of the world's coastal zones have much potential for increasing the production of quality seafood. By development of appropriate systems of "sea farming," or mariculture, such waters can be used for the production of seafood in the same way that the flood plains of river basins have been used for agricultural production.

The products of mariculture can be expected to stimulate expanding markets as their production, processing, and distribution become more efficient. Perhaps even more important: by providing an economically attractive incentive for clean water, the orderly growth of mariculture can help prevent further despoilment of coastal waters by uncontrolled urban and industrial growth.

PUGET SOUND--A POTENTIAL SITE FOR SEA FARMING

Puget Sound, in the State of Washington, is an inland sea with over 2,300 miles of shoreline, much of it protected from strong winds by high bluffs. Its deep waters are well flushed by strong tidal action and enriched in nutrients by abundant runoff. In the main channels, the temperature is remarkably uniform throughout the year (7°-13° C.), whereas in the shallow, less saline waters at the heads of inlets, it ranges from 4° to 18° C. Salmon, oysters, clams, and crabs were once plentiful and provided abundant food for early Indian populations. These resources have since declined under population pressure and indiscriminate land-use practices. The native oysters, for example, have been virtually wiped out.

To recover the capacity of the Sound for high, sustained yields of valuable sea products, it will be essential to prevent further deterioration of its waters and to restore their pristine quality. In planning water uses for the Sound, it must be recognized that mariculture can play a major role in restoring and expanding the yield of living resources from this unique inland sea.

MARICULTURE SYSTEMS

The basic properties of water areas that must be considered in mariculture planning are essentially the same as for other life-support systems: Space, temperature, and availability of oxygen and suitable food--not to mention the means for disposing of, or recycling, wastes. For any given system, requirements for these properties will vary according to the organisms to be cultivated, the "loading" capacity of the system, and the extent to which the system is open or closed. Consider the following examples:

Feed Lots

In this type of system, the cultured organisms are held in enclosures, such as cages or pens, in which they are given prepared feed while being grown to marketable size. Such a system requires a high flow of clean water to carry in fresh oxygen and to carry away unwanted wastes and bacteria. The temperature of the water should be sufficiently high to sustain an economically satisfactory rate of growth relative to amount of feed supplied, yet sufficiently low to discourage the proliferation of disease.

Grazing

These usually are systems in which space is not a major constraint and in which natural feed is a component of the water supply. Suspended culture systems for molluscs fit into this category, as do systems in which small fish and shrimp are held in tidal rearing ponds to feed on natural food. In such systems, the

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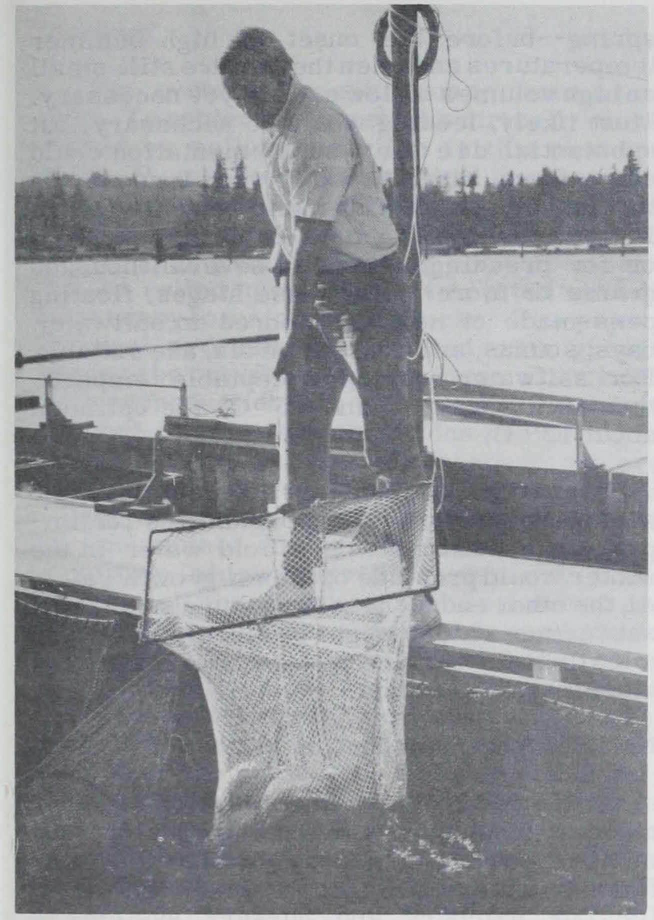

Fig. 1 - Many marine fishes normally range thousands of miles through the rich pastures of the sea. However, some of them can be grown in dense concentrations in large floating or submerged pens and diked ponds. Some species, such as the salmon in this pen, must be fed specially prepared foods to produce rapid growth.

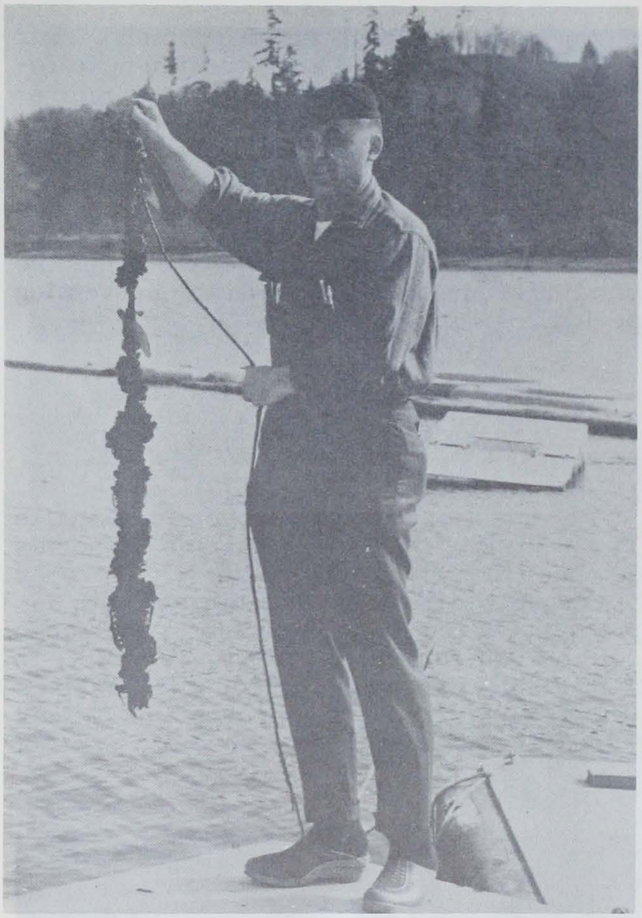

Fig. 2 - Valuable shellfish can be cultivated in great densities in our estuaries, where they "graze" on the plankton-rich waters. In Spain, bay mussels are grown on ropes 6 times longer than the one shown here, and produce "crops" of over $\frac{1}{2}$ million pounds of whole mussels per-surface-acre in 1 year.

new water must carry, in addition to oxygen, either sufficient food organisms or nutrients. Flushing must be adequate to remove or dilute wastes to tolerable levels.

One variant of grazing is open-range culture in which spatial restraints are unnecessary. In mariculture, an open range is possible with anadromous species, such as salmon, which undertake predictable homing migrations. Young, hatchery-reared fingerlings, imprinted by the fresh water in which they have been reared, return to the rearing site after several years of growing and fattening in the sea. Fishery scientists are now armed with new insights into the effects of juvenile rearing conditions on the behavior and survival of adults at sea. They believe that it may be feasible--by carefully controlling rearing conditions for juvenile salmon--to increase significantly the number returning to homing sites and, to a limited extent, to influence the distribution of adults at sea.

For example, recent studies by the Washington State Department of Fisheries lead us to suspect that coho salmon from Puget Sound hatcheries, held and fed beyond their normal release date in April until July 1, do not migrate to the ocean as do their siblings released earlier. Instead, they stay in Puget Sound to grow to adulthood, thereby becoming more accessible to local sport and commercial fishermen.

Hatcheries

For hatchery production of eggs, larvae, and small organisms requiring neither large amounts of space nor large volumes of water, methods have proved useful in which part of the water is recycled after treatment to remove wastes, inactivate deleterious microorganisms, and to replace oxygen. An advantage to be gained from recycling is the relative ease and economy of controlling the water temperature, thus allowing control over the rate of development of eggs and larvae. This makes it possible to stagger the planting of juveniles to extend the harvesting period.

PRODUCTS OF SEA FARMING

Salmon

Recent experiments have been conducted in Puget Sound by the National Marine Fisheries Service (NMFS). In salt water of the proper temperature and sufficient flow, and with appropriate feed, it was possible to rear coho salmon from fingerlings weighing 5 to 10 g to marketable fish weighing 300 g in 6 months with negligible losses. Conversion of feed was efficient--better than one unit weight of growth for each two of feed.

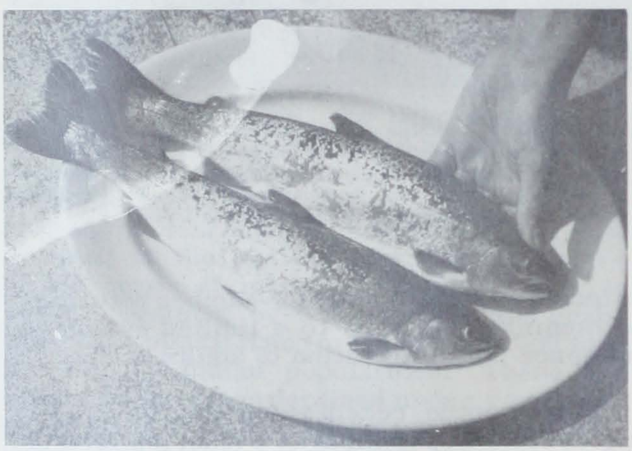

Fig. 3 - These coho salmon were "farm-grown" in the sea at a NMFS research station near Manchester, Wash. When placed in saltwater pens, they weighed $\frac{1}{20}$ of a pound. Fourteen months later, when "harvested," they weighed over a pound. More than 700 of these fish have been shipped to many sections of the United States to test consumer reactions.

Clear, fresh water is required for the incubation of salmon eggs and for the rearing of young until they start feeding. Ideally, the water temperature should be between 9^{o} and 12^{o} C. Partially recycled water can be effective at this stage. The fry can be reared to about 10 g most efficiently in slightly brackish water. Brackish lagoons might be used in the spring--before the onset of high summer temperatures and when the fish are still small so high volumes of flow are not yet necessary. Most likely, feeding would be necessary, but substantial dietary supplementation could come from natural food in such lagoons. In the final stages, the fish would be reared from 10-g fingerlings to a marketable size of 300 g, or for breeding (reared to several thousand grams or more). For these stages, floating pens made of netting, moored in saltwater bays, sounds, and tidal estuaries, are suitable. For saltwater rearing, acceptable temperature limits are 5^{o} and 15^{o} C, the optimum about 12^{o} C.

Heat from the discharges of electric power stations could provide opportunities for improving conditions where cold water in the winter would preclude optimum growth rates. At the other end of the temperature scale, cool subsurface waters might be circulated economically to the surface where summer temperatures are too warm.

NMFS Experiment Station

At the NMFS Experiment Station at Manchester, Wash., ways are being developed to utilize the energy and food naturally available from the waters of Puget Sound. Fresh water for our hatchery and nursery systems is drawn from a creek and piped for about 800 m beneath a small bay to a delivery site at the end of a pier. Since the annual temperature range of the salt water at the bottom of the bay is considerably less than that of the creek, the piped creek water is cooled in the summer and warmed in the winter. To take advantage of tidal currents, saltwater rearing pens are placed where current velocities fall between 0.05 and 0.5 knot; this is sufficient to give a good exchange of water in the pens without exerting excessive lateral pressure on the nets, or stress on the mooring system. During periods of the growing season when there is an abundance of plankton suitable for food, underwater lamps are used to attract the plankton either directly into the pens or to the intake of a plankton pump.

On the basis of the salmon feed lot experiments, it appears that the western shore of the Sound's central part, including Admiralty Inlet, has the best potential for rearing salmon in salt water. High bluffs provide excellent protection from the southwesterly storms that prevail in winter. Moreover, there are relatively few large communities and industrial developments on the western side.

Oysters

For oysters, the situation is more complex. To replace native stocks virtually eliminated by pollution earlier in this century, most Puget Sound oystermen import seed from Japan and Korea. Although water conditions are generally favorable in Puget Sound, appropriate spawning conditions cannot be relied upon. So the imported seed is necessary to maintain the stocks. The physiological processes associated with growth seem to be out of phase with those associated with reproduction in these oysters, which are attuned to different conditions prevailing in Asian waters. In maturing Japanese oysters planted at the heads of inlets in southern Puget Sound, physiological stresses appear to accumulate during the second summer, resulting in high mortalities. Otherwise, the waters of these inlets are well suited for them. Recent studies show that delayed planting, better preparation of oyster beds to reduce turbidity close to the bottom, moving oysters before their second summer from beds at the heads of the inlets to cooler waters near the entrances, and suspended culture techniques to take advantage of deeper water should significantly reduce summer mortalities and promote production of higher quality oysters.

Current construction by the Lummi Indians of a shellfish hatchery on their tribally owned tidelands near Bellingham, Wash., is very encouraging. If successful, it should improve the prospects for mass production of the seed of mortality-resistant stocks. The basic techniques for producing oyster seed are applicable to other molluscs such as clams, scallops, abalone, and mussels. Commercial shellfish hatcheries have recently been established in Long Island Sound and in California. Their development in the Pacific Northwest should lead to better husbandry practices by the shellfish industry--with resultant improvements in the quality and diversity of its products.

Prawns

Prospects for the culture of the spot prawn, a delectable crustacean native to Puget Sound, have been enhanced by recent advances at the University of Washington. Artificial culture of this species to postlarval stages was successfully accomplished in a recirculating saltwater system. Further development of the technique, designed to extend the product to market size, is planned by University researchers with the cooperation of NMFS, which will provide running saltwater facilities at its Manchester Experiment Station. The spot prawn, a scavenger, could have much promise as a component of multiple-culture systems. Wastes from the rearing of fish and molluscs might be used effectively by the prawns.

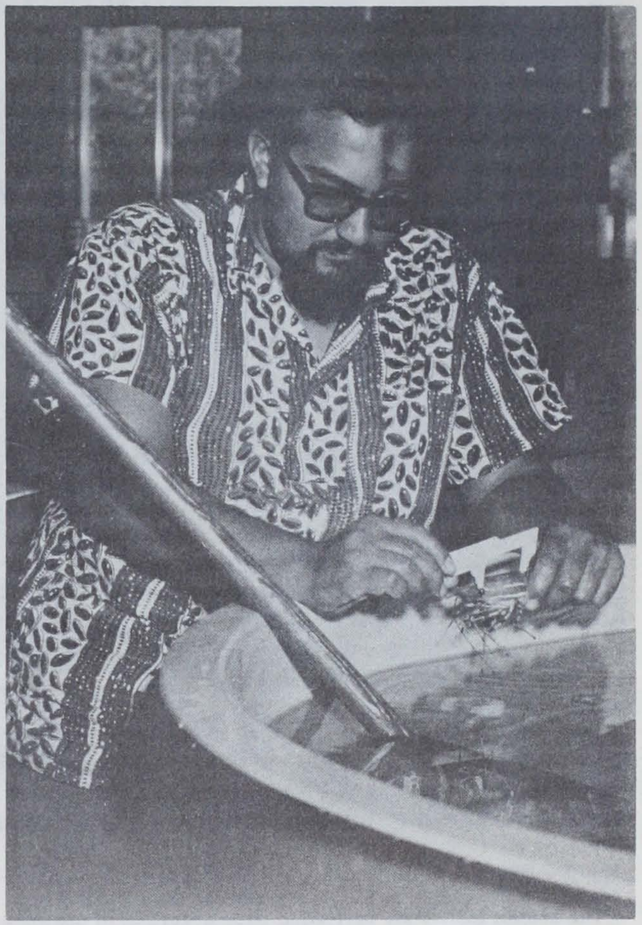

Fig. 4 - NOAA's Sea Grant Program supports research in marine aquaculture. These Puget Sound spot prawns are one of many valuable shellfish in the region that are being cultivated. Although research demonstrates that this crustacean is very hardy and relatively easy to culture in small numbers, techniques required for rearing the prawn for U.S. markets have not been determined.

Seaweed

The Pacific Northwest does not have a well-established seaweed industry, although its miles of coastline and inland waterways support one of the world's most diverse marine flora.

The Lummi Indians are experimenting with the harvesting of the red seaweed, Iridea

Fig. 5 - The Washington State Department of Natural Resources is studying the potential of marine plants native to Puget Sound. The Lummi Indians are harvesting large quantities of one species of marine plant in northern Puget Sound. If the proper substrates are placed in the water, young, free-floating plants will attach themselves and can be grown in dense profusion. These kelp attached themselves to a partially submerged board and grew over 4 feet long in less than 6 months.

cordata, in the San Juan Islands. If successful, this experiment may point the way to a valuable new industry for the region.

The Washington State Department of Natural Resources seeks to encourage the introduction of seaweed harvesting to supplement shellfish and salmon aquaculture. It has estimated that the standing crop of naturally occurring seaweeds in state waters is worth about $500,000 a year. Algologists at the University of Washington have suggested that this figure could be doubled, at least, by the development of appropriate culture methods.

SEA FARMING'S ROLE IN PREVENTING WATER POLLUTION

Other estuarine areas in the Puget Sound region can increase their potential for aquaculture by abating and controlling pollution and by a rational system of water-use zoning. Willapa Bay, Wash., the Columbia Estuary, and the estuaries of many coastal streams in Oregon could be considered for the development of sea farming.

Open-range salmon ranching appears to be an excellent prospect for the estuary of the Columbia and the Oregon coastal streams. Other types of sea farming in brackish water, in the mud flats, and in the channels of larger estuaries should be investigated.

Willapa Bay already supports an extensive oyster-farming industry. The quality of the Bay water, however, is being threatened by seepage of groundwater contaminated by a rapid increase in septic tanks from new residential developments. The adequacy of existing zoning regulations and authority to protect the oyster grounds is questionable.

Although severe inroads have already been made on the quality of the estuarine waters of the Pacific Northwest by unfortunate land-use practices, there still remains an enormous potential for aquaculture. We believe it is critical that a firm foothold be established in the shortest possible time. Extensive, privately controlled aquacultural crops will provide an economic incentive to abate and prevent pollution--and a sensitive and powerful tool for the continuous surveillance of water quality.