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DEPARTMENTS

COVER PHOTO

• This month's cover photo shows an aerial view of the 1,000 acre Sea Pool mariculture facility in Nova Scotia. The beginning of large-scale mariculture marks a new and exciting era in fish farming. The story begins on page 8.

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• Raising Catfish in Cages

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Experiments Show Feasibility

Salmon Mariculture Potential Assessed

By Conrad V. W. Mahnken, Anthony J. Novotny,

and Timothy Joiner

THE FEASIBILITY OF salmon culture is demonstrated in this photograph of a net full of six-month-old Coho salmon which were reared in the net enclosure shown below.

SALMON, HISTORICALLY, have been an important food resource in the Pacific Northwest. To supplement natural production, various governmental agencies operate an elaborate system of freshwater hatcheries where young salmon are reared until they are ready to migrate downstream to the sea.

Rearing salmon to maturity in salt water would extend our control over the entire life cycle of these fish, thereby enhancing our capability for breeding selectively for characteristics best suited to market demands.

Our initial experiments with rearing salmon in Puget Sound show that the energy in the tidal currents or protected coastal waters is a valuable resource that can be used effectively for saltwater aquaculture. The almost continuous flow of water through floating enclosures allows large numbers of salmon to be grown in relatively small areas. Although we have not yet been able to determine experimentally the optimum density of fish for our saltwater holding facilities, our initial experiments suggest that a conservative estimate of loading density would be one pound of fish per cubic foot of water.

Environment and Facilities

The research facilities of the NMFS Aquacultural Experiment Station at Manchester, Washington, are located alongside a pier projecting 800 feet into Clam Bay on the western shore of central Puget Sound. The area of Clam Bay is about 200 acres; the depth of the water in the vicinity of the floating pens, depending on the tide level, ranges from about 30 to 45 feet. (Tidal range is 10 to 16 feet.) Two tidal cycles per day produce currents which reach speeds in excess of 3 knots just outside the mouth of the bay and about 1/2 knot inside. The water in the bay is flushed and replaced by water from the main body of the Sound every 6 hours. Water temperatures range from 46° to 57°F, and salinities from 27 to 31 parts per thousand. The water in the floating pens, which are placed to take advantage of the tidal currents, is almost always saturated with oxygen which — even with crowding up to 2 pounds of fish per cubic foot — rarely drops by more than one part per million during the brief intervals of slack water.

The floating fish husbandry units consist of small, wood-framed nursery cages with nylon screens and larger pens made of weighted knotless nylon netting, suspended between walkways supported on styrofoam floats. Recently, we found that 1/8 to 1/4-inch mesh knotless nylon netting, weighted with rectangles of 1-1/4 inch PVC pipes filled with sand, make effective nursery cages.

Newly hatched fry are placed in circular tanks of fiberglass or of steel lined with polyethylene sheeting. The tanks are supplied with fresh and salt water. Salinity is adjusted by regulating the flow of each.

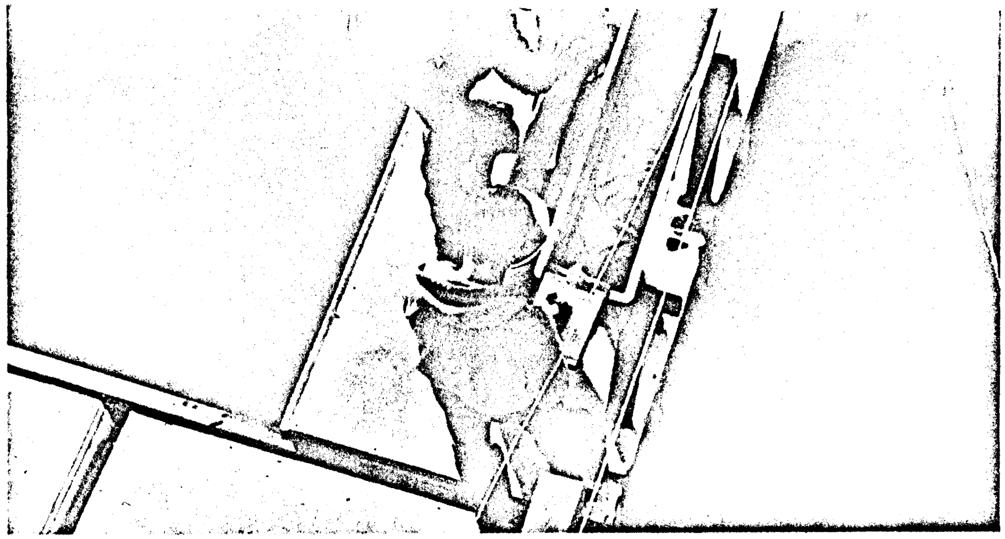
The "Brown Bear," a 110-foot, wooden-hulled vessel which is moored alongside the pier, provides laboratories and freezer space.

Experimental Stocks

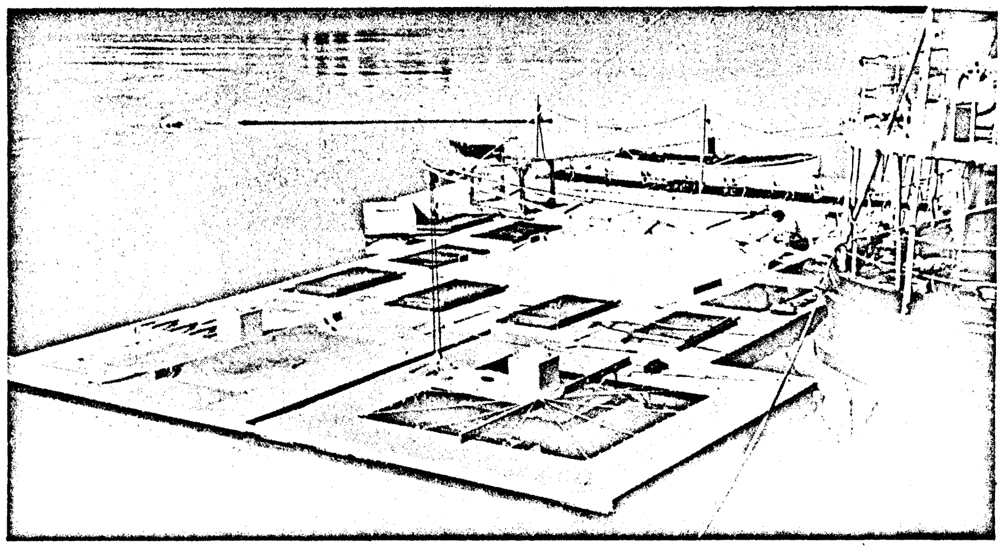
There are thousands of races of the five North American species of Pacific salmon, each one adapted to a specific set of conditions belonging to its native environment. Since it is possible to cross breed between races and between some species, a great wealth of genetic characteristics are available to potential breeders.

The stocks we are rearing are listed in Table 1. Most stocks were not selected for specific suitability for stock development but were available from hatcheries or other research projects when we started our program.

In our experiments with early adaptation to salt water, the initial response and subsequent growth of different stocks of the same species has varied with their origin, condition,



A V-SHAPED measuring trough is used here to measure the growth of salmon fingerlings. Growth data was of great importance in the salmon culture experiments.



AN OVERVIEW of the National Marine Fisheries Service experimental facility on Puget Sound shows the floating enclosures which were used in the intensive salmon culture experiments.

Table 1.—Stocks of Pacific Salmon and trout being reared at the NMFS Aquacultural Experiment Station at Manchester, Washington, August 1970.

Species	Brood year	Hatchery source	Time of hatching	Size in August 1970	Salinity (parts per thousand)
Coho	Late 1967	Minter Creek, Wash.	Early 1968	1-3 lbs.	30
Coho	Late 1968	Leavenworth, Wash.	Early 1969	1-4/lb.	30
Coho	Late 1968	Eagle Creek, Oreg.	Early 1969	10-12/lb.	30
Coho	Early 1970	Cowlitz, Wash.	Spring 1970	300/lb.	15
Sockeye	Fall 1969	Lake Union, Wash. (NMFS Biol. Lab.)	Early 1970	400/lb.	10
Chum	Late 1969	Quilcene, Wash.	Early 1970	15-20/lb.	30
Chinook	Late 1969	Dungeness, Wash.	Spring 1970	40-50/lb.	30
Chinook	Fall 1969	Spring Creek, Wash.	Late 1969	15-20/lb.	30
Chinook	Fall 1969	Hoodsport, Wash.	Late 1969	15/lb.	30
Chinook	Fall 1969	Little White Salmon, Wash.	Late 1969	20-25/lb.	30
Hybrids, Chinook x Pink (wild)	Fall 1969	Big Creek, Oreg. Lovers Cove Creek, Alaska	Late 1969	10/lb.	30
Hybrids, Steelhead x Rainbow trout	Fall 1969	Lake Union, Wash. (Univ. of Wash.)	Early 1970	20-25/lb.	

and size at entry into sea water. For example, the 1967 brood-year Cohos from Minter Creek, our oldest stock, were 1-1/2 years old and retarded in development when acquired. Weighing 20 to the pound when put into salt water in July 1969, they weighed from 1 to 3 pounds each in August 1970.

By contrast, 1968 brood-year Cohos from the Leavenworth hatchery were put into salt water in December,1969, at 11 months, weighing 25 to the pound. By August,1970, they weighed from 4 to the pound up to 1-1/4 pounds each. By August, 1971, when they are as old as our Minter Creek stock was in August,1970, they should weigh over 5 pounds each.

In the development of stocks for our saltwater rearing program, we will be working to enhance the following traits: (1) appropriate spawning time, (2) early adaptability to salt water, (3) rapid growth, (4) resistance to disease, and (5) pleasing external appearance, flesh color, and taste.

During the first year at Manchester, most of our fish were fed with Oregon Moist Pellets, a wet high-protein feed, originally compounded for salmon hatcheries. The pellets are made of dry meals and wet fish wastes with oil and vitamins added. The meal mix is mostly cottonseed and herring with smaller amounts of kelp, shrimp or crab wastes, wheat germ, and corn solubles. The wet component, about 40% of the pellet, consists of two or more of the following: albacore viscera, turbot, salmon viscera, dogfish, and herring.

Feeding Schedule

The fish were fed four times each day. Daily rations varied between 0.5 and 4.0% of body weight, depending on the season and the requirements of the experiment.

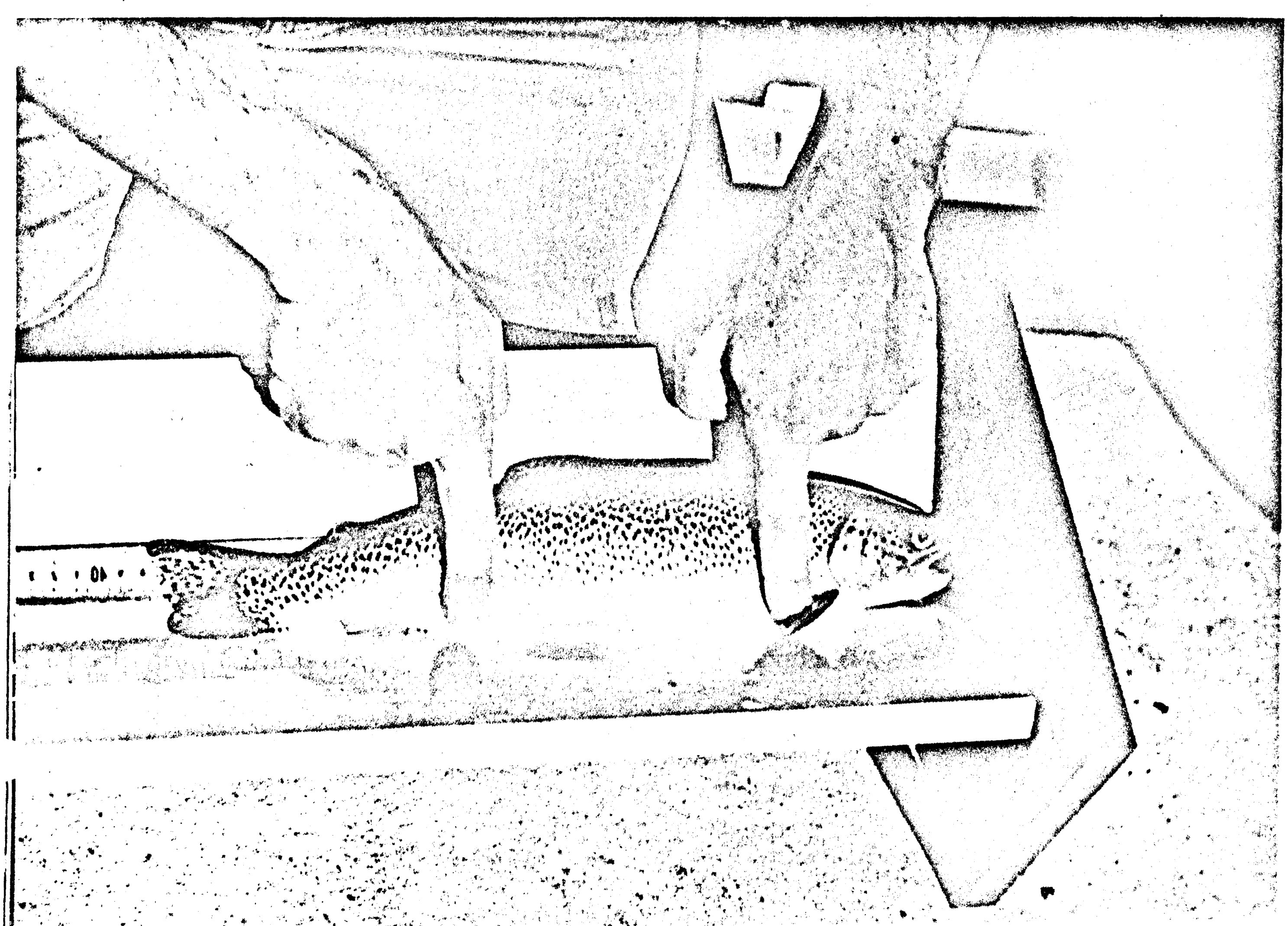
During the spring plankton bloom, submerged lights were used at night to draw plankton into the pens to enrich the diet. Coho, weighing from 15 to 5-to-the-pound, fed selectively on amphipods attracted to the light beam. In one experiment, two lots of 15 to 5-to-the-pound Coho were fed Oregon Moist Pellets at a rate of 2% of body weight per day. One pen was lighted at night with an underwater lamp. the other was not. The fish in the lighted pen grew about 12% faster. After 45 days, they were comparable in size to another test lot fed at a daily rate of 3% of body weight.

Growth Rate Measured

The growth rate and conversion of feed by our Minter Creek Coho stock from 1969 to 1970 are shown in Table 2. Growth is expressed as the percentage increase in body weight per day and conversion as pounds of feed (Oregon Moist Pellets) to produce 1 pound of fish. The spread in the conversion values and growth rates is the result of individual experiments with daily food rations ranging from 0.5% to 4.0% of body weight. The highest rate of growth (3.3% of body weight per day) occurred in the first summer with the highest ration. During the colder months of winter and early spring, the fish would not accept the higher rations, and the growth rate dropped to less than 0.5% of body weight per day.

The fish were much larger by the second summer and would not accept

THE CHINOOK SALMON being measured here is one that was raised for six months in the floating pens near Manchester, Washington. Information was gathered to evaluate the growth rates of these fish under intensive culture methods.



a ration much over 2% of body weight per day. Growth rates were not as high as the first summer, and it required more food to produce a pound of fish. This poor conversion can be partly attributed to the rapid development of gonads. Growth and water temperatures during the experimental period are shown in Figure 1. This Minter Creek stock will reach maturity in December 1970, at which time we will attempt to spawn the fish directly from sea water.

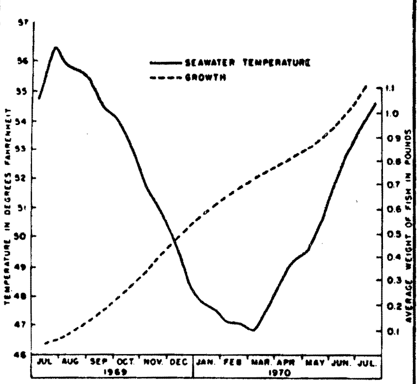


FIGURE 1-Comparison of growth and water temperatures.

For commercial salmon farming, feed would probably be the greatest single expense. With a conversion of 1.5 and feed at 16.5 cents per pound (Oregon Moist Pellets), it would cost about 25 cents for the feed to produce 1 pound of fish. We are currently testing less expensive commercial feeds.

Diseases and Predators

A source of trouble with some of our experimental stocks has come from freshwater disease organisms

(Continued on page 27)

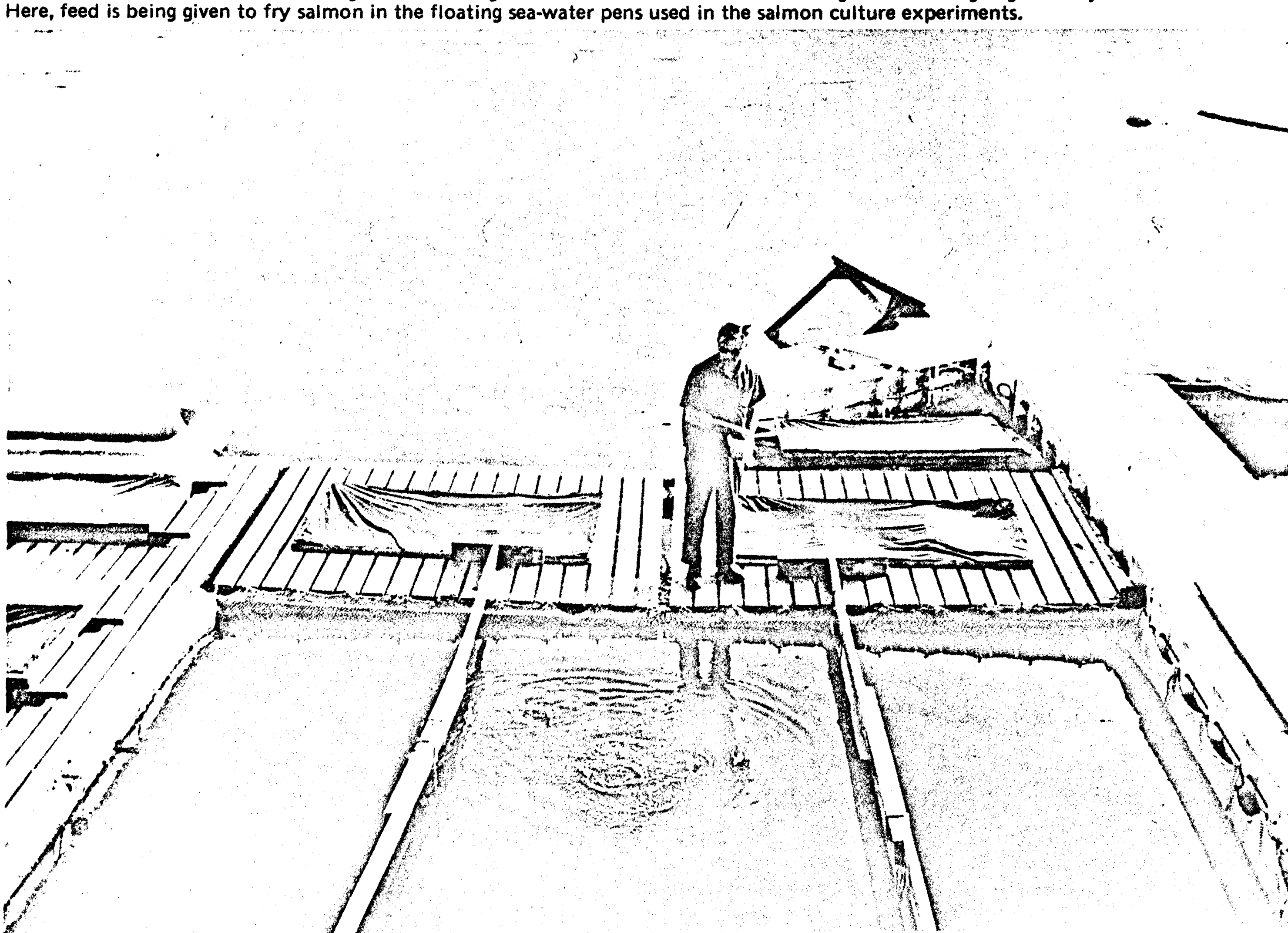
Table 2. — Growth and conversion of Minter Creek coho salmon reared in sea water.

Date	Conversion*	Growth rate**
1969 July August September	1.4 - 3.6	2.2 - 3.3
1969 October November	1.4 - 2.7	1.6 - 2.0
1969 December 1970 January	2.5 - 2.6	0.9 - 1.0
1970 March April	3.3 - 3.7	0.2 - 0.4
1970 May June	3.0	0.6

* Pounds of feed (Oregon Moist Pellets) to produce 1 pound of fish. Includes results from experimental rations ranging from 0.5 to 4.0% of body weight per day.

**Percentage increase in body weight per day.

FEED CONVERSION DATA were gathered through the careful measurement of feed given and weight gained by the fish. Here, feed is being given to fry salmon in the floating sea-water pens used in the salmon culture experiments.



Salmon Culture

(Continued from page 15)

harbored in certain tissues since incubation and carried with the fish to salt water. Disease is likely to break out when the fish are stressed by early entry into salt water or from being weighed and measured, and medication may be required to prevent heavy mortalities. This was the case with some of our chinook and chum stocks in which an outbreak of *furunculosis* occurred several months after they had been in salt water and immediately after they had been weighed and measured.

In another instance, a stock of Coho fry from eggs infected at the hatchery with the bacterium *Cytophaga psychrophila* suffered an outbreak of coldwater disease while they were still being held in fresh water. The symptoms of the disease disappeared almost immediately when we transferred the fry to brackish water of 5 parts per thousand salinity.

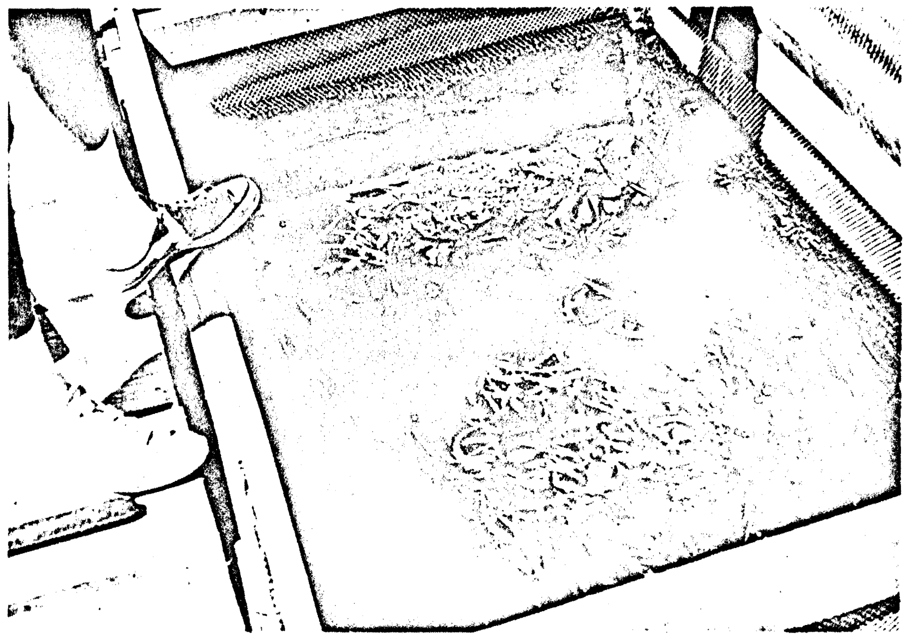
Vibrio, a bacterial saltwater disease that has affected our stocks, is common to marine fish kept in impoundments and aquaria. Locally, it is known to herring fishermen as "redbelly." It has been the chief source of trouble in most previous attempts at rearing salmon in salt water, having frequently become epidemic as water temperature approached 59°F. Although evident during two successive summers in our floating pens at Manchester, mortalities from *Vibrio* have never averaged more than 5% per month. We believe that rapid flushing of the pens by tidal currents, and temperatures less than 57°F. holds down the level of infection.

Great Blue Herons have also been an occasional nuisance, but they can be prevented from raiding the stocks by covering the cages and pens with webbing.

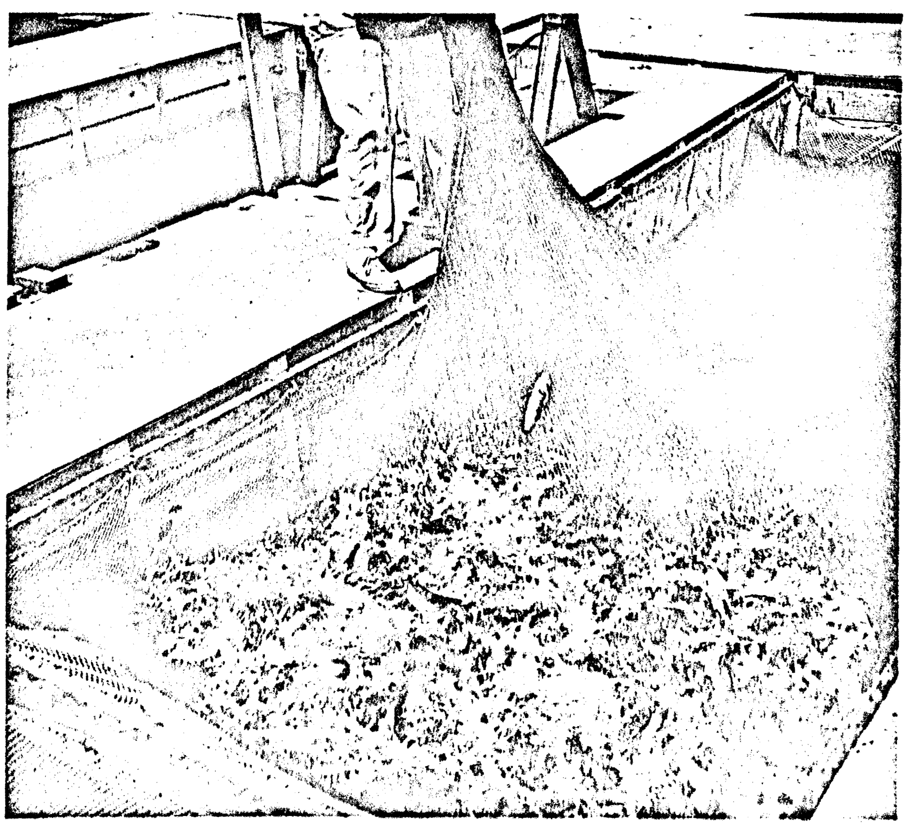
Possible Problems

The encouraging results from our first year of sea farming at Manchester and the technology developed over the years by successful freshwater hatcheries provide the basis for an optimistic outlook for the future development of intensive, egg-to-market culture of Pacific salmon. The technical problems to be faced are straightforward: design and construction of enclosures, determination of crowding tolerances, development of appropriate feeds and feeding regimes, disease control, and stock selection. By careful application of available technology and expertise, these problems should be readily solved.

For the would-be salmon farmer, however, a stickier problem exists. The demands made on protected marine waters by a host of activities (shipping and port facilities, waste disposal, marine mining and offshore oil drilling, recreation, and the creeping urbanization of shore lands) raise the very real problem of competition for available space. All too often, both land and water uses have been determined by the promise of short-term economic gain, while aesthetic values and ecological fitness, which are related to the quality of life and to long-term human survival, have been ignored. Whether salmon farming succeeds or fails may well hinge on the acceptance by zoning authorities of floating systems of fish culture as an appropriate use of inshore marine waters. ■



THESE SALMON FINGERLINGS were successfully reared in nursery cages suspended in sea-water near Manchester, Washington, during the summer of 1970.



PEN-RAISED COHO SALMON that have been brought to marketable size in the Puget Sound mariculture experiments are shown here in the sea-water enclosure in which they were raised.