Part 2 of Part 1.

Farming Pacific salmon in the sea: from the "womb to the tomb"

In the December Fish Farming Industries, Part 1 of this story appeared. Here's the second half of that story. And with the story comes a note from author Anthony Novotny, who writes: "The harvest has begun — 15,000 pounds per day of 11-month-old fish at 12 ounces each. And good news, too — " a very large portion of the crop is going to foreign markets at top prices. I was almost laughed out of my profession when I said the United States could become a major exporter of fishery products through efficient methods of aquaculture, but I will prove it's possible yet." Coming next in Fish Farming Industries in the Farming Pacific salmon series is: Recent progress in the operation of a large scale pilot farm. — Editor.

Diseases and survival: Fish diseases and disease associated problems are with us virtually all seasons of the year, and we must observe the feeding behavior and mortalities daily. A very close watch is kept on the water temperatures, especially when they begin to rise in the spring. The first serious symptoms of disease can appear as early as mid-May, when the water temperatures reach 48° to 50° F. Diseases probably are the most critical problem to be solved to obtain maximum survival of stocks in salt water rearing.

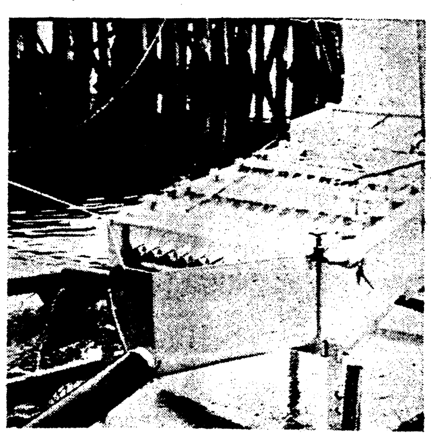
Parasitism has been almost nonexistent, but we have had outbreaks of three diseases of bacterial origin. Two appear to infect the fish in fresh water, are carried by the fish into salt water, and may break out at some later date. One of these diseases is a gram positive bacterial rod (*Cornybacterium sp.*) commonly referred to as "kidney disease." The other is a gram negative bacterial rod (*Aeromonas salmonicida*) which causes the disease called "furunculosis" in fresh water. Kidney disease does not appear to be transmittable in sea water, although healthy fish presumably could become infected if allowed to "pick" at dead or dying diseased fish.

Our recent studies suggest, however, that a freshwater form of furunculosis has been transmitted to salmon in the saltwater cages.

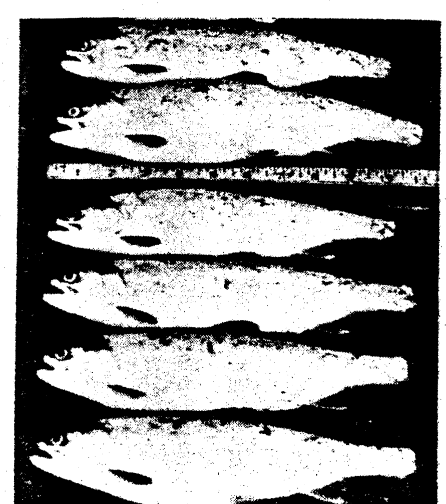
The third disease, of salt water origin, is caused by gram negative bacterial rods of the genus *Vibrio* and is commonly called vibriosis (or "red tail" in herrings).

Kidney disease: This is not a serious problem because it can be taken care of in the planning stages. We try to obtain eggs from stocks of fish known to be free of the disease and then incubate the eggs and rear the fish in fresh water that is free of the disease. If disease-free eggs cannot be obtained, they can be disinfected. Thus, the major concern becomes one of finding a fresh-water supply that is free of kidney disease. Outbreaks of kidney disease in infected fish in salt water can be held in check by treatments with tetracycline antibiotics added to the diet. It is extremely doubtful (in our view) that infected fish can be completely rid of kidney disease using the presently known treatments.

Furunculosis: Kidney disease and furunculosis can be dealt with using similar precautions and treatments, but several differences have caused us some concern. We have found, for example, that furunculosis does not respond uniformly to treatment with the tetracycline compounds (Terramycin). We soon will begin to experiment with combinations of sulfa derivatives and tetracyclines. This disease also seems to be a major problem in chum salmon and to some extent in pink salmon. We've had losses exceeding 50 percent in chum sal-



Salmon are graded during both the fresh and salt water phases of culture. A fish grader that is light enough to move about the salt water rafts is used to sort fish up to about ¼ pound in size. A portable pump supplies the flushing water.



Here are some of 200 farm-raised coho salmon that were served at the U.S. House of Congress restaurant in the summer of 1971.

mon due to furunculosis and, in our estimation, the disease may be the most difficult to control. A great deal of research on this disease in salt water lies ahead of us.

Vibriosis: The virulence of vibriosis varies with the species of fish, season of the year, and water temperature, and undoubtedly is due to the presence of several species of **Vibrio**, or different strains of the same species. If allowed to progress without treatment, it can be devastating and has caused over 90 percent mortalities in chinook fingerlings at temperatures over 57° F. without antibiotic foods. Thus far, however, we have been able to control the disease with tetracycline compounds in the diet.

Survival: We have been able to raise coho salmon from a size of 23 per pound to a size of 10 per pound with 99 percent survival, and chinook and coho salmon to brood stock size (several pounds or more) at 50 percent survival or higher. Once the chinook or coho salmon reach about 3 or 4 per pound, the survival to market size or maturity should be 90 to 95 percent, even without the use of medicated diets. The larger fish apparently are quite hardy because we have some coho going into their 4th year with no mortalities in 8 months.

We are forced to handle our experimental fish all too frequently to obtain necessary growth information. Any handling, especially when the water temperature exceeds 50° F., increases the possibility of disease outbreaks or mortalities due to a physiological stress or scale loss. On a production basis, the survival of chinook or coho salmon (in the proper seawater environment) from first introduction to the sea as fingerlings to harvest at 1 or 2 fish per pound should exceed 85 percent and more likely 90 percent. In Puget Sound, we recommend growing areas where the water temperatures range from a low of 45° to a high of 60° F., and preferably 45 to 55° F.

Floating pen design and capacities: Our salmon begin their life in the sea in floating pens of many sizes. All our research floats are attached to the side of an old research vessel (which serves as our floating laboratory), which in turn is tied to a dock extending 850 feet out into Clam Bay. The maximum water depth is 45 feet at the high tide, 30 at the low.

The two basic materials used in our system are Styrofoam for flotation and knotless nylon webbing for pen enclosures. Without those two materials, the entire operation probably would be uneconomical.

The floating pen enclosures are of two types: "nursery" pens for fry and fingerlings, and "growing" pens to carry the larger fingerlings to a marketable size. The meshes of the nursery pens range from ⅛-inch stretched mesh to ⅜-inch mesh. The present growing pens are all of ⅞-inch stretched mesh.

THE NMFS RESEARCH project at Manchester, Wash. has hosted foreign visitors from every continent. Here, author Novotny (left) discusses the possible applications of the pen culture of finfish in the Gulf of Aden with Dr. Hillel Gordin of Israel.

Nursery pens: The smallest floating nursery enclosure (for our experimental research) is made from 2 x 6 lumber and Styrofoam billets with an "off-the-shelf" nylon pen that is 6 x 4 x 4 feet deep. The pen is hung from the inside "well" on pantry cup hooks and is weighted with a rectangular frame made of plastic pipe filled with beach sand and dropped in the bottom. These pens easily hold 20,000 fish of 400 per pound size and, for lack of research space, we have raised as many as 100 fish weighing between ½ and 1 pound each with no difficulties. The cost of each unit is about $85, and they can be linked together to provide a perimeter for hanging a large growing pen from the rectangular opening that is formed.

The largest nursery pen is being used for a pilot farm study and is made of ⅜-inch stretched mesh knotless nylon. Dimensions of the pen are 30 x 30 x 15 feet deep, and the cost was approximately $1,600. Our experience suggests a safe limit of 1 pound of fish per cubic foot of water. The large nursery pen contains about 13,000 cubic feet of usable space. Chinook salmon fingerlings (395,000 fish weighing 5,500 pounds) were transferred to this pen from fresh water in mid-May. The maximum capacity of 13,000 pounds was reached by late July and the fish were transferred to two growing pens of 60,000 cubic foot capacity each. Mortalities in the large nursery pen were about 5 percent, mostly due to an early outbreak of vibriosis.

When the large nursery pens are crowded to capacity, we must pump air to the bottoms of the pens to force circulation of the water. The small meshes inhibit the free circulation of tidal currents, and dissolved oxygen may be reduced 3 to 4 parts per million (ppm) below the ambient levels, especially during the slack tides.

Growing pens: Problems of reduced circulation and reduced dissolved oxygen have not occurred in the large growing pens with the ⅞-inch mesh. We have raised fish at a density of 1 pound of fish per cubic foot of water with no forced air in a 30-foot diameter, 12-foot deep hexagonal pen containing 8,500 cubic feet of usable space. The greatest reduction in dissolved oxygen was 0.3 ppm measured during a slack tide, and no differences occurred when the water was moving. The larger openings allow a much freer circulation of water; even the constant swimming motion of the fish causes some water movement through the pens.

The calculated quantities of water moving through these pens at a normal tidal cycle are considerable. Example: The water flow through the 60,000-cubic-foot capacity growing pen, which is 50 x 50 x 25 feet deep, ranges between 500 and 800 cubic feet per second, even when the tidal currents are as low as ½ knot. Currents in the bay frequently exceed 1 knot. Obviously, the force of this mass of moving water presents serious problems in float and pen construction and anchoring systems for large production operations.

The engineering aspects of salmon culture in salt-water pens still are in the early stages and need to be pursued further. For example, we have raised coho salmon in a pen enclosure which was totally submerged and resting at a depth of 45 feet on the bottom of the bay. The fish were fed through a long tube and monitored on a television camera. After 10 weeks, the results were not far different from those obtained by surface culture.

As a direct result of our research in the culture of Pacific salmon in the sea, a large scale pilot farm research effort is being made conducted by a unique cooperative of private industry, various agencies of the State of Washington, and NOAA. The pilot farm work will be discussed in a second article. □