COMMERCIAL SALMON CULTURE ON THE MAINE COAST UTILIZING HEATED WATER FROM A POWER PLANT

by

Evelyn S. Sawyer and Frederick G. Towle

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Maine Salmon Farms, Inc. Co-principal Investigators:
Evelyn S. Sawyer and Frederick G. Towle

Introduction:

The concept of rearing pan-size Pacific salmon in floating net pens originated in 1969 with the National Marine Fisheries Service in Puget Sound, Washington. Their project has become a 13 million dollar salmon raising industry (Novotny, 1974). Using many of the findings obtained by these mariculturists, we sought to modify them and develop new methods to deal with our East Coast conditions. In 1973 Maine Salmon Farms was incorporated following a pilot project in which several hundred coho salmon (*Onchorhynchus kisutch*) were reared from smolt to market size (227 g) in the Sheepscot River estuary in Wiscasset, Maine. Each winter since that time the company has purchased West Coast coho eggs. Maine Salmon Farms has hatched and reared them through 6 months of freshwater stages first at a private hatchery, and more recently at the University of New Hampshire's Sea Grant hatchery and at the company's own shoreside facilities. The fish are transferred to saltwater in early summer, and grown to market size during the next 6 to 14 months in floating net pens. They are then harvested and marketed fresh directly to restaurants from Maine to New York. The grow-out area was chosen near a Central Maine Power Company power plant, as we hoped that the heated effluent would accelerate fish growth.

In 1974 Maine Salmon Farms (MSF) obtained Sea Grant aid to investigate the feasibility of commercially rearing pan-size coho salmon utilizing the heated effluent of a fossil-fuel power plant. Specific areas of investigation were:

1. Effects of heated water
2. Freshwater growth and seawater entry
3. Nutrition
4. Disease
5. Engineering
6. Marketing
7. Management practices
   - Farm practices
   - Finances
   - Conclusion

An investigation into effects of intensive fish culture on benthic organisms was terminated after eight months when we found that numbers of species and individuals were determined by an environmental problem unrelated to fish culture (Adams and Towle, 1974.)

Co-principal investigator and company biologist Evelyn S. (Adams) Sawyer will report on items 1 through 4. Frederick G. Towlé, co-principal investigator and MSF President will report on items 5 through 7.

Part 1: Effects of Heated Water:

Site description:

Central Maine Power Company's Mason Station is a 150,000 kw fossil fuel plant discharging a total of 500 m^3/min of cooling water heated 11° C above ambient into the Sheepscot River estuary. Ambient temperatures measured one meter below mean low water near the intake screens range from 1.0° C to 19° C; salinity range is 19 ppt to 28 ppt. Monthly averages are shown in Fig. 1. Maine Salmon Farms has twelve fish pens made of nylon nets hung from styrofoam and wood walkways 30 to 45 m from the warm water discharge pipe. The nets are 3.0 to 5.0 m in depth and include 4.5 m square pens, a 4.5 x 7.0 m rectangular pen, and a hexagonal pen 6.0 m in diameter. These net pens are moored in 10 to 12 m of water at low tide. A log boom with a baffle 2.0 m deep deflects heated water toward the pen area in winter and away in summer (Fig. 2.). Tidal range is about 3.0 m and surface currents average 0.2 m/sec reversing direction with the tide, so there is continuous flushing action and oxygen remains near saturation. There is little or no pollution in the area. Ferrous sulfate, used to coat internal surfaces of the condenser tubing, is the only chemical added to the discharge water. Analysis of water samples by atomic absorption spectroscopy showed 0.5 ppm iron 16 m from the discharge pipe. We encountered no problems from supersaturation of gasses in heated water.

Methods:

Beginning in March, 1974, 6,000 yearling coho smolts averaging 6.0 g were placed in a 4.0 x 4.0 m net pen 3.0 m in depth and 30 m from the warm water discharge. A control group of 6,000 weighing 6.0 g was placed in a similar pen 250 m from the discharge. Both groups were fed the same amounts of a commercial salmon pellet and ground herring and shrimp. The same management procedures such as routine diving and net cleaning were done with both groups. Weight counts were taken every two weeks and water temperatures recored by a *Peabody-Ryan* automatic temperature recorder. Disease outbreaks caused by *Vibrio anguillarum* occurred in experimental and control fish, and both groups were fed Terramycin for 10 days on three separate occasions. Overall mortality from disease was 34% in control fish and 22% in experimental fish. The experiment was terminated in December, and then repeated from June to May 1975 with two new groups of fish averaging 11 g at the start.

Temperature differences between control and experimental areas fluctuated with tide, wind and current, and ranged from 0.5° C to 4.0° C. Figure 3. is a tracing of temperature recording tapes from experimental and control pens during a four day period in February 1974. It shows typical fluctuations and temperature differences in the two sites. On several occasions the plant went off line and the heated discharge water was suddenly cut off at times when ambient temperatures were at their lowest (1.0° C). The fish were not harmed.

Results and Discussion:

There were no significant differences in weight of control and experimental fish in either trial. In the first trial (March to December 1974) both groups grew from 6 g to 86 g; in the second trial (January to May 1975) control fish went from 11 g to 28 g and experimental fish from 11 g to 29 g. We saw no difference in feeding or behavior in the two groups. Although sudden (4° C) temperature drops did not kill fish, feeding slowed for several days. The high mortalities from disease in both groups during the March through December trial casts some uncertainty on these results, as we later found that disease outbreaks affected growth in surviving fish (Part 4).

Theoretically fish metabolism increases 10% for each 1° C rise in temperature (Halver, 1972). However, the proportion of metabolism committed to growth decreases as fish increase in size. It seems probable that when coho are large enough for transfer to saltwater, they are too large to show benefits in growth from the small and fluctuating temperature rise obtained from the heated discharge. Since the heated discharge water prevents severe icing in winter, we continue to divert it toward the pens for this purpose.

Conclusions and Current Use of Heated Water:

The use of heated discharge water from a power plant resulting in a 1° to 4° C rise in water temperature did not increase growth measurably in coho salmon smolts.

Our current and most promising use of heated water from the power plant is in our freshwater hatchery where fish are small enough to respond with accelerated growth to the 10° C temperatures obtained during the winter (Part 2).

Part 2: Freshwater Growth and Saltwater Entry

Introduction:

For normal growth and survival coho salmon must enter saltwater during a photoperiod that extends from early spring through July (Novotny and Mahnken, 1972). The fish's physiological readiness for saltwater (smolting) is dependent on size (Baggerman, 1960); therefore they must be large enough during their first spring to undergo smolting or spend another year in freshwater. Maine Salmon Farms has found it necessary to transfer salmon to saltwater by mid-June of their first year as the extra year in fresh water is prohibitively expensive; also, our fresh water supply (like most surface water in southern Maine) becomes too warm (20-25^{o} C) for salmon by late June. The problem has been to grow fish large enough for saltwater entry their first spring; for example, in Puget Sound where average monthly salinities are 28-30 ppt, coho must be 15 g or larger. However, small fish may survive and grow well at lower salinities (Kepshire and McNeil, 1972). Growers like MSF with an estuarine location in the Northeast have the advantage of lower salinities, especially during spring run-off (Fig. 1.), that allow salmon to enter saltwater at a smaller size. Conte et al (1966) and Otto (1971) investigated coho size vs. salinity at entry for small numbers of fish in the laboratory. Using their findings as guidelines, we sought to determine the minimum size for coho at each salinity that would insure not only maximum survival, but good growth for the following 6 to 18 months. This information was needed in deciding first, how soon fish could go to the saltwater pens, and later as we built our own hatchery, how much saltwater could be added how soon to our shoreside rearing pools to supplement a limited freshwater supply and acclimitize fish to high salinities without stress.

We have been fortunate in receiving early eggs (hatching by January 1) through the help of National Marine Fisheries Service. Without early eggs, saltwater entry the first year would be almost impossible.

Methods and Results:

We have tried four different approaches to getting our fish in saltwater their first spring:

1. Transferring fish of various sizes directly from a freshwater hatchery to saltwater
2. Transferring them from the hatchery to a low salinity area - then to saltwater.
3. Raising fish in heated freshwater and pumping saltwater to increase salinity in rearing pools - then to saltwater.
4. Raising fish in floating cages in a small pond that warms early in the spring - then to saltwater.

1. Hatchery to saltwater:

During our first year of commercial operations (1973) we rented limited facilities at a freshwater hatchery. Fish were held in groundwater at 7.0° C from January through March and then in the outlet of a pond where temperatures rose to 17° C by June. We fed *Ewos* in this and all succeeding freshwater operations as its high cost was less significant for the relatively small amounts used for young fish. Lots of 10,000 or more fish of various sizes were moved directly to saltwater at a time dictated more by financial necessity and the hatchery owners' convenience than by their biological readiness.

Most of these fish were too small in June (4.0 g) for transfer to a salinity of 22 ppt and losses were high. Our experience was similar to that of Novotny (1972); in those fish that survived, growth was subnormal and disease problems were severe (Part 4). In late July we moved 10,000 5.0 to 6.0 g fish to a salinity of 24 ppt; survival was good but growth poor.

The experience showed us first, the need for our own freshwater facilities, and second, the futility of attempting saltwater entry the first spring unless we could use warmer water to obtain faster growth, or a lower salinity entry site could be found.

2. Hatchery to low salinity:

A second approach in 1973 was to move 1.5 g fish early in May from the hatchery to floating pens at a site up-river from MSF where salinity was 5 to 9 ppt, temperatures 9.0 to 16° C through May and June, and natural food was abundant. Salmon were held at a density of 500 fish/m^3. Twice weekly plankton tows averaged 200,000 organisms/m^3, mostly copepod and barnacle nauplii and polychaete larvae---a concentration roughly 200 times that of the open sea. We fed the fish (*Ewos*) only once a day because of the time and expense of transporting a boat and motor 50 km round trip from MSF at Mason Station.

At a density of 500 fish/m^3 the salmon grew from 1.5 g to 6.5 g in 6 weeks and were successfully transferred to the higher salinities (22 ppt) at MSF Mason Station.

In 1974, lack of suitable mooring space for more cages in this area forced us to hold fish at a higher more practical density (3,000 fish/m^3). Temperatures, salinity and food were similar to 1973, but at the higher density salmon grew from 1.5 g to only 2.5 g in six weeks---too small for saltwater (22 ppt) entry. The low salinity, natural food technique that produced excellent results at low densities was not practical on a commercial scale.

3. Heated fresh water and increasing salinity:

In 1975 we contracted with the Sea Grant hatchery at UNH under the direction of Dr. R. G. Strout to hatch 200,000 eggs for MSF and rear them to approximately 0.8 g. Meanwhile we built holding facilities, plastic swimming pools 8.0 m in diameter, on the shore at the Mason Station, and obtained agreement with the power company to use 76 liters/min of their freshwater. They pumped this water from a nearby pond and then treated it by sand filtration, alum precipitation, and adjusted the pH to 7.2 for use in their boilers. The time required for treatment inside the power plant warmed the water to approximately 10° C in April and 15° C by June. We used this water alone or in combination with UV treated saltwater to rear 120,000 coho from 0.8 g to an average of 6.6 g as shown in Table 1. Amounts of saltwater that could be added safely as the fish grew were determined mostly by trial and error. Using the data of Hoffman et al (1974) we built our own UV system, a plywood box 1.4 m x 2.8 m, 0.15 m in height with 6 G30T8 30-watt lamps designed to deliver 16,000 MWS (microwatt seconds/cm^2) at a flow of 150 liters/min. Dilution plate counts indicated that numbers of bacteria were reduced at least 100 fold. To maintain sufficiently low salinities, we were forced to use untreated water direct from the pond during the last two weeks before saltwater entry. Fish were fed *Ewos* 6 to 8 times daily at first and 3 times daily as they approached saltwater entry.

The treated freshwater from the power plant proved to be excellent for coho rearing. Fish grew well at densities up to 2.4 kg/liter/min with no disease problems; growth was depressed above this level, even with aeration, probably due to the build-up of ammonia and other metabolites (Table 1). During May and early June we transferred groups of 500 fish at sizes of 4.0 g, 5.5 g, 6.0 g and 6.5 g to the saltwater pens (22-24 ppt salinity); all survived but growth was poor (Fig. 4). Approximately one half of our fish in the rearing pools reached a size of 7.5 g in late June and were transferred to saltwater (24 ppt) with less than 1% mortality. These fish continued to grow normally. Figure 4. summarizes our experience with different sizes of O-age coho at different salinities.

If our freshwater supply had been sufficient, and growth had not been suppressed by overloading, it seems probable that all fish would have been large enough for saltwater entry at that time. Table 1. shows actual growth and loading rates in 1975, and probable growth with sufficient water and no overloading.

4. Pond rearing:

We held several thousand 2.0 g coho in floating pens at the power station's small freshwater pond at a density of 1200 fish/m^3. This pond warms early in the spring, and we hoped the warmer water would produce sufficient growth for saltwater entry in June. The salmon were moved to the pond in late April when water temperatures were 7.0° C. As temperature climbed, growth in the pond fish was similar to that of fish in the rearing pools.

When water temperature reached 20° C in early June growth slowed and columnaris broke out. Although the fish were not quite large enough (6.0 g) for the prevailing salinity (24 ppt), we chose to transfer them to saltwater to control the disease. The saltwater was effective against columnaris, but this group of fish has since grown poorly and been especially prone to other diseases.

Conclusions:

Attempts to rear coho to large enough size for saltwater entry their first spring were unsuccessful using ambient freshwater temperatures in Maine---even in an ideal early-warming pond. Although the pond almost produced large enough fish, disease problems and uncertainties of weather and temperature made it difficult to grow salmon to a critical size at a critical time.

Transfer of small fish from a hatchery to a low salinity site was not a practical approach because the site was too far away from the normal grow-out area. This location, like most low salinity sites in Maine, became too warm for salmon early in summer so a second move was necessary. Transportation costs and labor costs to feed fish adequately at a distant location made this approach unprofitable.

The more controlled environment of shoreside rearing pools, use of heated freshwater from the power plant, and UV treated saltwater added in increasing amounts appeared to be the approach best suited to this area.

Part 3: Diet

Introduction:

A diet for commercially reared salmon must give maximum growth, even during the winter, at minimum cost, and produce a high quality product. Unlike state and federal salmon hatcheries, we are not concerned with fish health and survival beyond 300 grams, but we must consider market factors such as taste, texture, and color.

Methods:

In freshwater stages we fed *Ewos* as a starter and later used some *Rangen* Salmon Feed in amounts roughly those recommended by commercial feed tables. Feeding was done manually except for brief testing of automatic feeders.

In saltwater, amounts of food consumed varied considerably with tide and weather, therefore fish were fed manually. Feeding was done three times a day except in winter, and then once or twice daily. Each feeding continued until fish no longer rose to the surface.

Conversions (dry weight of food/weight weight of fish) were determined for periods of time in spring and fall when bacterial disease losses were low (less than 5 fish/1000 fish/week) and water temperatures were between 8° and 15° C. Similar pens containing approximately the same numbers of fish were used for all tests. Mortalities and symptoms generally associated with poor nutrition, such as scoliosis, loss of equilibrium, pale livers or renal casts were recorded.

The dry pellets used included commercial feeds and our own diet; the formula for the MSF pellet is given in Table 2. All dry feed contained $<$ 10% water. Our wet diet consisted of 50% waste whole shrimp which had been cooked in brine (4.2% NaCl retained in shrimp) and 50% whole raw alewives and herring waste from a nearby sardine plant. This mixture was ground and frozen into 5.0 kg food balls containing 65-75% water. These frozen food balls floated, and acted as automatic feeders as they thawed.

Results and Discussion:

Table 3 summarizes the diets we have tried and our results.

We began by feeding two commercial trout pellets, *Strike* and *Silver Cup*. These pellets are designed for trout held in 10° to 15° C fresh water, and are relatively low in protein (37%). For coho salmon in saltwater at temperatures of 1° to 18° C they produced unsatisfactory growth and conversions. Fish would not feed on trout pellets when water temperatures fell below 4° C. A Swedish salmon pellet, *Ewos*, gave good results. We still use it as a starter feed (up to #3 crumble) and would use it on larger fish if the price were not prohibitive.

Rangen's commercial salmon food has also been satisfactory, but price is high; their lower priced mixed protein pellet (FPSS) has given good results for larger fish in limited tests. Since herring meal, herring oil and shrimp meal is processed nearby, we hoped to save considerable transportation costs by having our own formula made locally. In theory, we could produce the lowest cost high quality pellet this way, but in practice, several problems arose. Chicken feed mills would not run special formulas; dairy feed mills were cooperative, but their pellet size was too large (#5 or larger), and they were reluctant to make less than 5 ton lots. Local manufacturing ended when the residue of herring meal from our formula ruined several tons of dairy feed. We now have a commercial fish food manufacturer in Pennsylvania make our formula.

The wet diet represents a more natural food, and may provide some growth factors not present in the pellets. Fish fed actively on this mixture even at lowest (1^{o} C) water temperatures. Growth was 17% better in fish fed the wet diet exclusively during January through March than in pellet-fed fish. Other reasons for feeding the wet diet are color, taste, and texture of the product. Six to eight weeks of 50% wet diet gives a pink color to the fish flesh and appears to improve taste and texture (Part 6).

The wet diet has several disadvantages when fed exclusively. When raw herring or alewives are fed for several months, salmon develop thiamine deficiency symptoms (Saunders and Henderson, 1974). Although growth was better in fish fed the wet diet, mortality and incidence of nutritional disease was significantly higher than in pellet-fed fish. Cost of alewives ($0.08/kg) and shrimp waste ($0.13/kg) is low, but labor, transportation, processing and storage bring the total cost to $0.20/kg. Considering that two thirds of this product is water, cost in dry weight is high - 0.60/kg. The wet diet also carries a risk of disease transmission and contributes to net fouling in summer.

Conclusions:

Dry pellets provide balanced nutrition at low cost; the wet diet gives better growth in winter (when pellet acceptability is poor), and provides good taste and color characteristics to the product. Our best results in saltwater have been from feeding dry pellets in the morning and wet diet in the afternoon.

Part 4: Disease

Introduction:

Disease has been the greatest single production problem for Maine Salmon Farms. Losses of approximately 40% occurred the first two years of operation almost entirely from bacteria; parasites and fungal disease have caused little or no mortality. Neither have virus diseases been a problem. (Coho eggs must be certified virus free before importation to Maine.)

Three factors in particular have contributed to these losses. First, our initial inexperience in handling large numbers of fish precipitated several outbreaks. Second, as a commercial fish rearing company, we must, for economic reasons, hold fish at densities far above those of state or federal hatcheries, thereby increasing the likelihood of disease. Finally, once fish are in the saltwater net pens, external treatment for disease is almost impossible.

Freshwater disease:

Freshwater bacterial diseases that we have encountered include kidney disease (*Corynebacterium sp.*), furunculosis (*Aeromonas salmonicida*), columnaris (*Flexibacter columnaris*), and *Pseudomonas sp.* Of these, by far the most damaging has been kidney disease. The causative organism appears to be ubiquitous in freshwater; also Maine waters are very soft (less than 15 ppm bicarbonate alkalinity) a factor that seems to increase the incidence of kidney disease (Warren, 1963). Whenever we used untreated (no filtration or UV treatment) surface water or groundwater in earthen raceways, the result was kidney disease. The pattern of mortalities usually was similar to that described by Wood (1968), the loss of a constant percentage of fish each week continuing for months. Our mortalities from kidney disease persisted and sometimes increased after saltwater entry indicating transmission - probably through healthy fish eating dead or dying fish. Sulfamerazine fed at 20 g/100 kg of fish each day was ineffective and the taste of erythromycin (10 g/100 kg/day) caused fish to stop feeding.

A. salmonicida and *Pseudomonas sp.* were other bacterial problems originating in untreated freshwater and persisting through summer saltwater entry and into fall and winter. Limited control was achieved with furazolidone, (*Furox 50*) 12 g/100 kg/day for 10 days.

A severe outbreak of columnaris occurred in fish held in the pond at Mason Station when water temperatures rose to 19° C. Laboratory drug sensitivity tests showed tetracyclines were active against the organism. Control was achieved by feeding Terramycin (*TM 50*) 12 g/100 kg/day for ten days, and transferring fish to saltwater.

Saltwater disease:

Vibrio anguillarum was our major problem in saltwater the first two years of operation, occurring shortly after temperatures rose to 15° C in July and continuing until temperatures dropped below 15° C in September. We isolated the organism, a strain antigenically similar to a *Vibrio* from Puget Sound #775 (Harrell et al, 1975), and Dr. Richard G. Strout at the University of New Hampshire produced a vaccine that was injected in a group of 10,000 yearling smolts before saltwater entry in 1974. Estimated cost of the vaccine, including labor, was $.005/fish. Mortalities in these fish and comparable groups of untreated fish and fish receiving medication (Terramycin) are shown in Table 4. The vaccine was successful in preventing mortality from vibriosis, and by October, it became apparent that vaccinated fish were growing faster than other groups. By January 1, 1975, 25% of the vaccinated fish were 200 g (minimum marketable size) or larger, compared with 12% of medicated fish and 6% of untreated fish (Figure 5.).

During spring 1975 Dr. Strout prepared an oral vibriosis vaccine and fed it to a group of 10,000 fish which were later transferred to saltwater at MSF. Water temperatures were higher in summer 1975 than in 1974, but vibriosis was not a problem; therefore the effectiveness of the vaccine could not be assessed.

In summer 1975 we took extensive (30%) mortalities from a saltwater myxobacterium (*Flexibacter sp.*). The organism produced fin rot and eroded jaw in affected fish. We tried oral medication with Terramycin, furazolidone, (*Furox 50*) and sulfamerazine without success. By the time fish showed symptoms, copper sulfate dips (1:2000 for 2 minutes) were ineffective. It was impractical to dip all two hundred thousand fish from the net pens and unwise to handle them at high water temperatures; therefore, we could only wait out the disease. Fish improved dramatically as water temperatures fell below 15° C. Comparative mortalities for the 1974 *Vibrio* and 1975 *Flexibacter* outbreaks and the relationship of these diseases to temperature are shown in Fig. 6.

Presumptive evidence points to marine species of *Cytophaga*, *Sporocytophaga*, and *Achromobacter* as the cause of higher than normal mortalities especially in winter.

Discussion and conclusions:

MSF encountered freshwater diseases from untreated surface waters or earthen raceways. These diseases continued to be a problem long after saltwater entry. Our current use of filtered, UV treated water (Part 2) appears to be the answer.

The saltwater diseases presented greater problems and uncertainties. *Vibrio anguillarum* was controlled partly by drugs and more completely by an injected vaccine. Better growth in vaccinated fish six months after the outbreak indicated that infection with *V. anguillarum* exerts a long term stunting effect on surviving fish. We did not find an effective treatment for *Flexibacter sp.*

Our experience indicates that these are by no means the only marine fish pathogens in this area. Until recently, time and cost would not permit us to determine more than general description and drug sensitivity for bacteria isolated during periods of low or moderate mortality. It is probable that these organisms, given proper environmental conditions, could produce epizootics. Although vibriosis appears to be the single major bacterial problem for West Coast salmon growers, our wider range of salinity and temperature in the Northeast may favor a variety of fish pathogens as yet unidentified.

Part 5: Engineering
(Engineering written with William B. O'Brien)

In open marine culture the design, engineering and construction of the fish holding facility is of prime importance. The pens must be designed to produce good fish growth and control. The pens must be engineered, with simplicity, to withstand maximum sea and storm conditions for the area. And the pens must be constructed to provide strength and durability at a reasonable cost.

We have found that fish growth is greatly affected by pen size. Without exception, the salmon have responded better as the size of the pen has been increased. (The larger pens allow the fish to swim in a uniform circular pattern whereas the smaller pens produce a random mixing.) Our initial pen size was 10' x 10' x 12' deep (Footnote). In steps we have increased the size to the present 20' x 14' x 12' (Figure 7). Beyond this point, management and fish control is reduced. The poor results achieved in many of our early efforts may be traced to the small size of the original holding pens.

Our pens are rectangular, with 2' wide walkways. Each of the four walkways is separately hinged, allowing it to work independently during storm conditions. Construction is of rough-cut spruce, which increases strength and reduced cost. Flotation is provided by the standard styrofoam blocks.

It is our experience that octagonal pens are less stable and seaworthy due to increased stress at the walkway joints. Also, the circular nets suspended inside this type raft are more expensive.

The nets are knotless nylon of medium weight and vary from 3/4" to 1-1/8" stretch mesh. In the water they are weighted at the bottom corners to maintain their shape.

The dacron mooring lines are counterweighted to provide a constant tension, enabling the pens to hold their positions during the ebb and flow of the 10' tide.

<u>Footnote</u> All measurements in sections 5, 6 and 7 will be expressed in ounces, pounds, feet and fahrenheit.

Part 6: Marketing

Prior to Maine Salmon Farms' first commercial harvest in May, 1974, we conducted a market evaluation of the existing "pan size" trout and salmon products. The results of that evaluation were as follows: (1) Frozen West coast individual-sized salmon were encountering some resistance and price weakness in conventional market outlets; (2) Japanese frozen trout imports were a low price inferior product; (3) Idaho white-meated trout were of good quality but lacked the texture of a saltwater reared salmonid, and suffered from the age-old taste problems of a hatchery-diet reared fish. We concluded that a saltwater reared salmon of this size was a specialty sea food and that a substantial market potential did exist for a fresh, premium product at a premium price. A number of Maine seafood restaurants were contacted and they were also convinced of the potential of a pink meated 1/2 to 3/4 pound salmon, available weekly throughout the year.

Our first harvest received extensive press coverage (Figure 8) and the introduction of the fish in those restaurants was a success. (The conventional salmon fishing industry disappeared from Maine waters in the fifties.) To the present, Maine Salmon Farms has marketed 24,000 pounds of "yearling" salmon in a total of 22 restaurants and specialty fish stores from Maine to New York City. We have received an average price of $2.30 a pound. Our largest single customer is the famous Anthony's Pier 4 of Boston. Other well known restaurants include the Cheechako, Damariscotta, Maine; the Ritz-Carlton, Boston; and the Grant Central Oyster Bar, New York. Under the direction of Richard C. Gower, Maine Salmon Farms Vice President, the city of Providence, Rhode Island was selected for trial marketing to smaller individual restaurants on a when-available basis. We found this approach to be successful also, and in some cases enhanced the appeal.

In the past, aquaculture products have suffered from the lack of aggressive marketing. There are real market advantages to a saltwater farmed fish, and the buyer should be made aware of those advantages (Figure 9). Specifically, a marine farmed product can arrive at the market place fresher than a fish that may have been in the hold of a boat for some time; the sea farmer can execute quality control measures over his product, and a marine culture company can provide the market place continuity of supply, and avoid the irregular and seasonal aspects of the fishing industry. It was on this basis that we entered the market place. We did so directly, developed our own processing, and by-passed conventional marketing channels. From that time to the present, the major problem has been meeting the demand. In the early months of production, it was occasionally necessary to supplement our market supplies by flying in fresh fish from the West coast.

The potential market that exists from Boston to Washington for this type premium fish product is extensive. How extensive has been the subject of a number of institutional marketing studies--most of them incomplete. With Maine's proximity to the major national market, and with natural supplies diminishing, over-production is not and will not be a point of concern for Northeast marine culture companies producing a quality product.

Part 7: Management Practices

Farm Practices

(Farm Practices written with Michael Hennessey)

Feeding:

Feeding is the most important of the daily practices. If fed correctly, salmonids in saltwater will respond well. However, if the feeder is disinterested and haphazard in his approach to his work, food conversions and food costs will skyrocket. Feeding at Maine Salmon Farms is done on a demand basis during the spring and fall when maximum growth occurs, three times a day in the summer and twice a day in the winter. We introduce the wet diet (ground shrimp and herring) when fish are approximately 6 to the pound and it is increased as a percentage of the diet, as the salmon approach harvestable size.

Grading:

The natural variation in individual fish growth provides the company with a year round inventory of marketable size fish. This difference in individual growth rate also makes periodic grading necessary. We grade just prior to saltwater entry to insure that the young salmon are large enough (60 to the pound) to adapt to the change in environment. We also grade at least once during the grow out phase and at harvest time. It is essential to keep fish of the same size together. A large variation in size in a pen results in stunted growth in the smaller salmon.

The grading operation is accomplished by a "Go-no go" adjustable floating box (2½' x 4½') with parallel rods on the bottom. The design is based on the standard small Neilson grader, and adapted for our use and constructed by Maine Salmon Farms personnel. Using this method the fish are graded in the water and rough handling and stress are kept to a minimum.

Inventory control:

Continuing records must be kept on estimated numbers of fish in each size group. Retaining large numbers of marketable size fish in inventory is expensive and can result in growing fish, in sizeable numbers, over the standard market size of 1/2 to 3/4 pound dressed weights. It is necessary therefore to maintain marketing flexibility. At present our weekly harvests vary from 500 to 1200 fish. The size of each harvest depends on the inventory, present demand and estimated future needs.

Fish density:

In commercial fish farming it is necessary to achieve the highest density possible without slowing fish growth. The maximum density (pounds per cubic foot of water) depends on the size of the fish, the size of the pen, and the water temperature. In saltwater, one pound per cubic foot has been the standard rule. However, we have found that fish over 8 to the pound can exceed this density in pens over 15' square. Smaller fish, that have recently entered the saltwater, require a much lighter density. We have also found it desirable to disperse fish as much as possible during July and August when our water temperatures rise slightly above 60°.

Diving:

In addition to removing dead fish and inspecting nets and underwater equipment, periodic diving in the pens is necessary for the observation of the salmon in their environment. A trained diver can spot potential disease outbreaks, percentage of marketable fish, and overfeeding. Our diver, William O'Brien, goes into the pens once a week in the warmer weather, and every two weeks in the winter.

Net fouling:

One of our most persistent problems has been net fouling. A fouled net restricts water exchange, increases the potential for disease, and becomes heavy and unworkable. After trying various means of maintaining the nets free from marine fouling, we found that the simplest method was the periodic replacement of the net. With the assistance of a diver, the new net is brought up from below and fastened into position around the outside of the fouled one. The old net is then pulled to the surface and the fish are simply dumped into the new enclosure. This procedure is possible with pens up to 25' x 15' in size but is not recommended for larger enclosures.

We plan to test a copper-nickel mesh cage developed by Dr. John Huguenin of the University of Massachusetts Aquaculture Engineering Laboratory. If successful, it could solve the problem of fouling altogether.

Predator Protection:

One of the most frequently asked questions, from site visitors, involves predators. At Maine Salmon Farms predators have not been a serious problem. We use light weight nets over the top of the pens to protect against diving birds. Human predators have been a problem at other sites. The security provided by the power plant eliminates this completely. We have not used the surrounding underwater predator net which is in use at most West coast salmon farms. We consider it cumbersome, expensive, and unnecessary.

Finances

In the past, East coast aquaculture has been unable to attract substantial private investment because of its inability to be productive. It had become a vehicle for institutional "grant getting" and the result was "aquarium aquaculture."

In 1973, Maine Salmon Farms raised the initial capital by the sale of stock to five individuals (Frederick G. Towle, Evelyn S. Sawyer, Richard C. Gower, William B. O'Brien, and Michael Hennessey). Each person also actively contributed their time and abilities to the organization. The officers of the company received no pay. In 1974 the Company received the first of two federal Sea Grants. With funds from these sources available, our objective was to make Maine Salmon Farms commercially productive as quickly as possible at a minimum cost. Debt financing was avoided. In 1975 with proven production and marketing, Maine Salmon Farms did receive private financing which enabled the Company to further expand its facilities.

Recently on the Maine coast a number of other seafarming companies have come into existence. They soon will be producing oysters, mussels, trout and salmon for market. Marine culture is capital intensive and is justified commercially only by the volume production of high priced products. Farming of any kind on a small scale is inefficient farming. Aquaculture does not lend itself to the cottage industries approach. Our financial projections demonstrate how the total cost per pound of salmon produced is reduced as volume is increased:

Pounds produced	Cost per pound
25,000	$3.04
75,000	1.85
150,000	1.66
225,000	1.33

It is important that Maine marine farming companies consolidate in an effort to reduce costs, to increase production, and to attract substantial private capital investment.

Aquaculture in many other countries is totally government subsidized. The research conducted has made a contribution; however, marine farming in these countries has demonstrated an inability to make the transition to the commercial. The future of seafarming on this coast and in this country will depend on its ability to make this transition to productivity and profitability with private capital.

Conclusion

Central Maine Power Company and Maine Salmon Farms:

Our experiments showed little difference between fish growth in and outside of the power plant warm water discharge. This may have been because the discharge was difficult to control and intermittent. However, other benefits have developed from our association with the power plant. The ice-free saltwater pen area, and the availability of 52° freshwater for the fry have proved beneficial. In addition, it is my opinion that the immediate saltwater area surrounding the Mason Station has been enriched by the years of discharging warm water and provides some natural food for the salmon.

In the larger context, what has developed of importance at the Central Maine Power Mason Station is the union of commercial energy production and commercial food production through cooperation.

Maine Salmon Farms, Inc. today:

Maine Salmon Farms has 12 fish pens in the saltwater and we are scheduling the addition of pens at other sites in the spring. Presently the pens contain approximately 150,000 coho salmon in different size and age groups. Fifty larger fish, some over three pounds, have been separated in the hope that eggs from our own stock can be taken next fall. Our adjacent shoreside facility (Figure 10) is hatching 200,000 eggs and an additional 150,000 are being hatched at the University of New Hampshire hatchery. We estimate a production of 40,000 pounds for 1976. Last December we marketed our first "0-age" fish. If we can continue to achieve this in increasing numbers, our production for the coming year could exceed 50,000 pounds.

Maine Salmon Farms is working closely with Xodar Corp. of Providence, Rhode Island. This company designs and manufactures freshwater conditioning equipment. We have installed their equipment in order to make maximum use of the available supply of freshwater.

Demonstration facility:

A secondary duty, in connection with the grant, was to serve as a marine culture demonstration facility. We have been encouraged by increasing numbers of site visitors and their interest in the work. In the past two years, we have been host to representatives of the Japanese, French, and Canadian governments, Kellogg Foundation, National Sea Grants Committee, various groups from private industry, and science classes from colleges, secondary, and grade schools.

Areas of needed work and potential:

After four years of salmon farming on the Maine coast, specific areas of needed work and potential have become apparent:

First is the need for marine fish disease research directed at our particular Northeast coast problems. We estimate mortalities from all causes at 40% from egg to market. To this point, our actual losses have run slightly higher. With improved procedures and techniques this rate can be reduced to some degree, and, on a limited basis, successful commercial salmon farming will be possible as the majority of losses are incurred when the fish are young and represent a relatively small investment. However, if East coast seafarming is to grow and to become a profitable industry, it will be necessary to substantially reduce losses from disease.

Second is the potential that exists in many fishing industry by-products as a source of inexpensive and natural food for marine fish culture. In cooperation with the National Marine Fisheries Service, we are presently testing red crab by-products as a food and coloring agent for the salmon.

In nature, the salmon goes to sea at an ounce and in 2 to 3 years returns at 15 to 40 pounds. This growth can be attributed to the fish's saltwater diet. If sea farmers are to approach this rate of growth it will be achieved with something close to the salmon's natural diet presented to the fish in a ground wet form.

Third is the need to locate a freshwater site in New England for the volume production of salmon and trout smolts to supply the future demands of the marine culture industry on this coast. Southern Rhode Island appears to be the most promising area because of its excellent year round supply of 50° groundwater.

Finally is the need for a cooperative and aggressive marketing effort on the part of Northeast aquaculture companies.

Aquaculture training program:

A report on saltwater fish farming would not be complete without recognition of the "men on the rafts." At Maine Salmon Farms they are Mike Davis and Chuck Meserve. These men came to us through the Maine C.E.P. Aquaculture Training Program and are now employees of the company. Seafarming is hard work and they do it well.

We thank the National Sea Grant Program for the assistance provided Maine Salmon Farms. We express confidence in the work that has been done and in the report submitted.

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Table 1

Actual fish growth at various loading rates and salinities and projected growth at ideal loading rates and salinities (Temperature 10° - 15° C).

Date	1975: Average fish size (grams)	1975: Loading rate with aeration (kg/liter/min)	1975: Salinity (ppt)	Projected (loading rate=2.4 kg/liter/min): Average fish size (grams)	Projected: Salinity (ppt)
April 1	0.8 (Transfer from UNH Hatchery)	1.8	0	0.8	0
8	0.9	2.4	0	0.9	0
15	1.7	2.4	7	1.7	7
22	2.4	2.4	10	2.4	5-10
29	2.9	2.6	10	2.9	5-10
May 6	3.3	2.8	10	3.3	5-10
13	3.6	3.1	10	3.9	5-10
20	3.9	2.6	12	4.5	12
27	4.5	2.6	12	5.0	15
June 3	5.0	2.4	15	5.6	15
10	6.0	2.6	17	6.4	15-20
17	6.3	3.0	20	7.5 All fish ready for saltwater (24 ppt) entry	15-20
24	6.6 ½ were 7.5 g and ready for saltwater (24 ppt) entry	3.0	20		

Table 2.

Maine Salmon Farms Pellet

Herring meal (65% protein)	35%
Herring oil (stabilized with BHT)	4%
Wheat middlings	28%
Soybean meal	25%
Shrimp meal	4%
Calcium carbonate	1%
Vitamin pre-mix	1%
Binder (usually whey)	2%

Vitamin pre-mix (mg/kg)

Thiamine	40
Riboflavin	20
Pyridoxine	60
Niacine	150
Folic acid	10
Ascorbic acid (coated)	500
Pantothenic acid	60
Biotin	0.25
Choline	1000
B_{12}	0.02
A	2000
E	50
K (Hetrazeen)	5
D_3	1000

Table 3

Diet	Cost ($/kg)	Conversion (Dry Wt./wet wt. of fish)	Growth	Acceptability	Nutritional mortalities or disease	Quality of fish produced
Strike Silver Cup	$.33	3:1	poor to fair	fair in summer poor in winter	few mortalities but high incidence of mottled, pale livers, stomach edema and scoliosis	fair; no color to fish
Ewos	$.92	0.8:1 in fresh-water stages 1.6:1 in salt-water	excellent	good	few mortalities or signs of nutritional disease	good; but little color to fish
Rangen Salmon Feed	$.55	1.6:1	fair in fresh-water stages; good in saltwater	good	few mortalities or signs of nutritional disease	good; but no color to fish
Rangen FPSS	$.35	1.4:1	not tested in small fish; good in larger fish (100-250 g)	good	few mortalites or signs of nutritional disease in limited testing	fair to good; no color
MSF Pellet	$.31	1.4:1	not tested in small fish; good in larger fish	good	few mortalities or signs of nutritional disease	good; but no color
Wet diet Shrimp and Herring	$.60	2.0:1	excellent	excellent	high mortalities and incidence of nutritional disease when fed exclusively; scoliosis, cloudy lens, loss of balance, renal casts, mottled, pale or shrunken livers	excellent

Table 4

Weekly mortalities (per thousand) of coho salmon during an outbreak of *Vibrio sp.* July-September 1974

Date	Temperature (°C)	Untreated fish	Vaccinated fish	Medicated fish
July 22	15	1.8	2.7	3.2
29	15	5.3	5.1	6.3
Aug. 5	15	18.0	3.2	7.6
12	16	14.6	1.4	10.7
19	17	58.0	1.8	12.3
26	16	66.7	6.3	9.8
Sept. 2	15	43.5	7.1	11.3
9	14	16.8	6.3	3.6
16	14	9.2	1.6	1.5
23	13	2.5	1.3	0.8
Totals (%)		23.6	2.9	6.7

Fig. 1. Average water temperature and salinity for 1975 Maine Salmon Farms, Wiscasset, Maine.

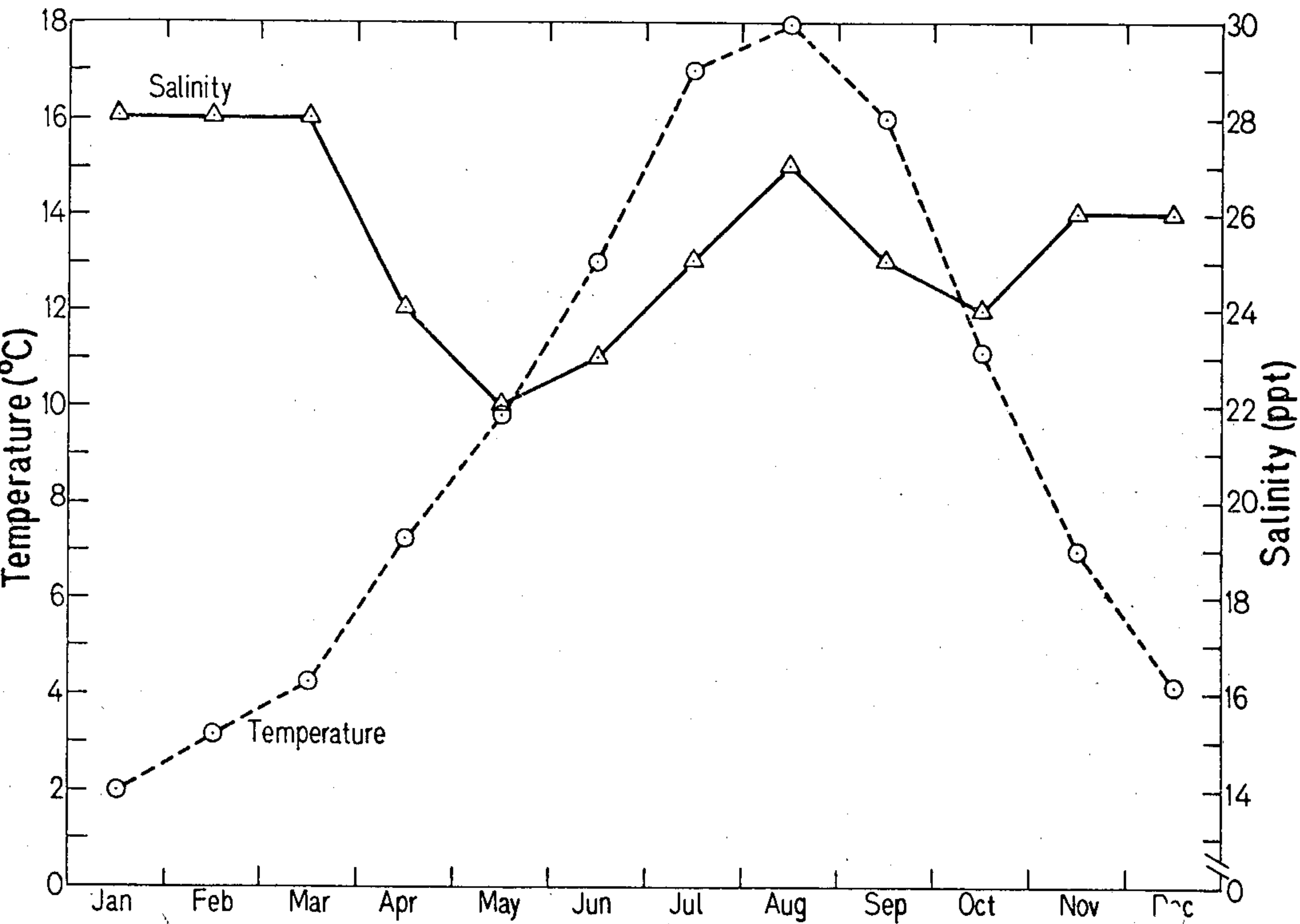
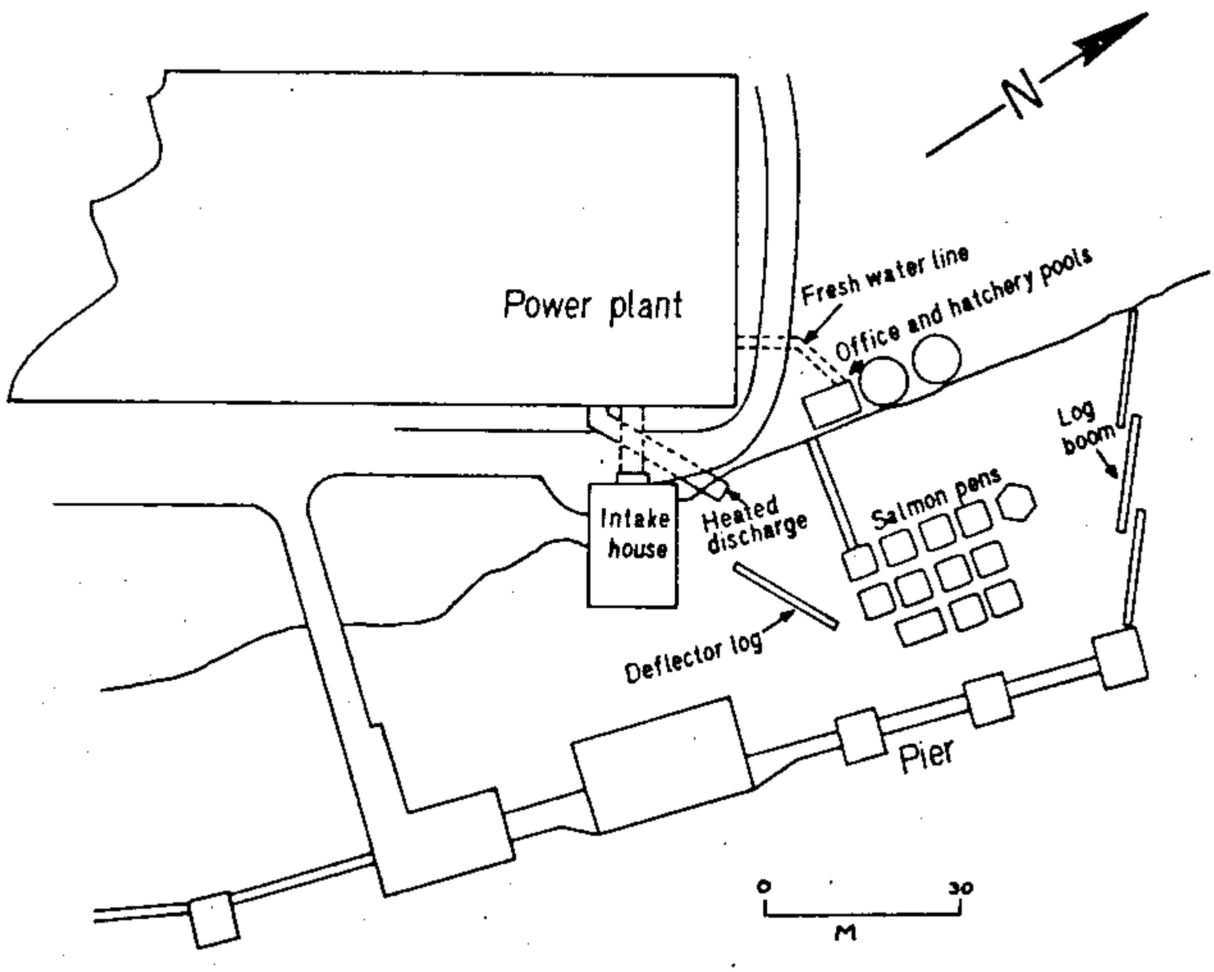
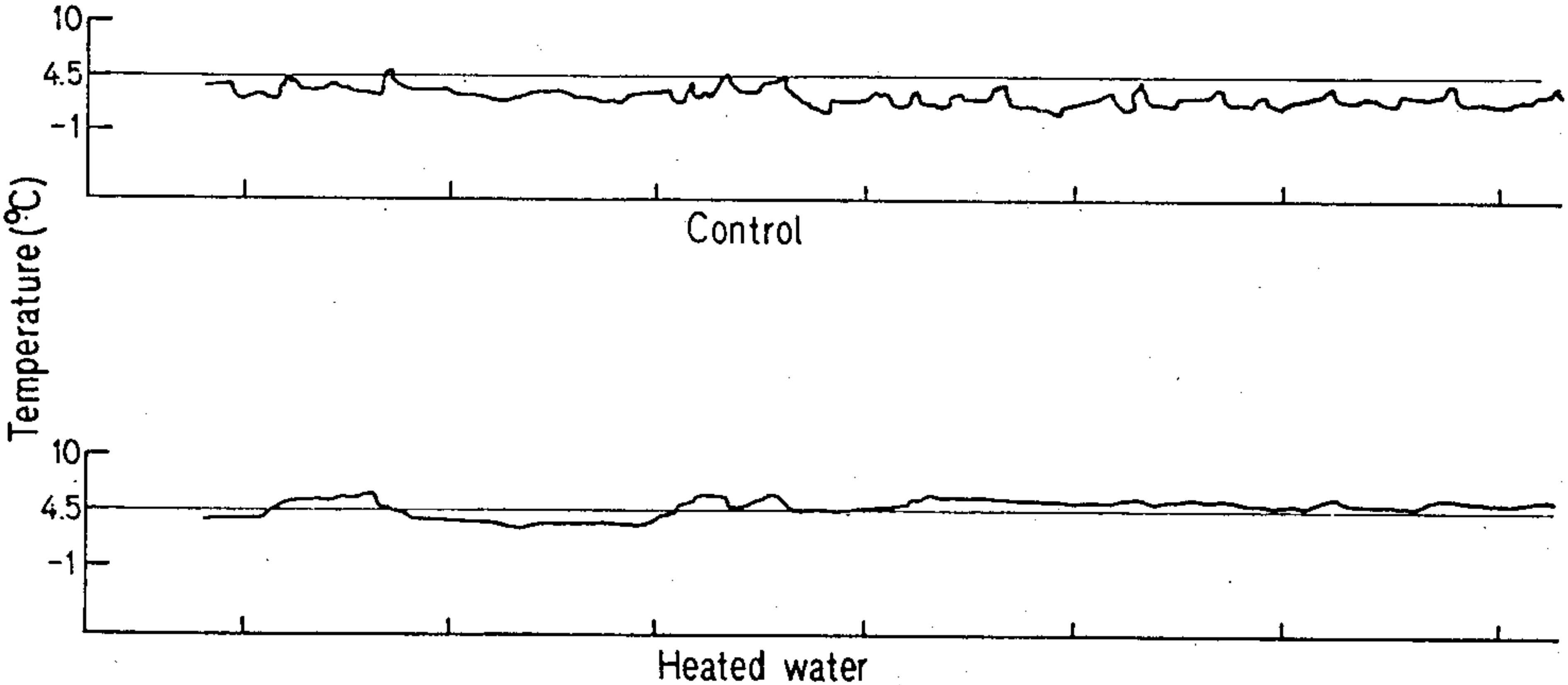

Temperature (°C)
Salinity (ppt)
Salinity
Temperature
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
0
2
4
6
8
10
12
14
16
18
14
16
18
20
22
24
26
28
30

Fig. 2. Site plan of Maine Salmon Farms at Central Maine Power Company's Mason Station, Wiscasset, Maine.



N
Power plant
Fresh water line
Office and hatchery pools
Log boom
Intake house
Heated discharge
Salmon pens
Deflector log
Pier
0
30
M

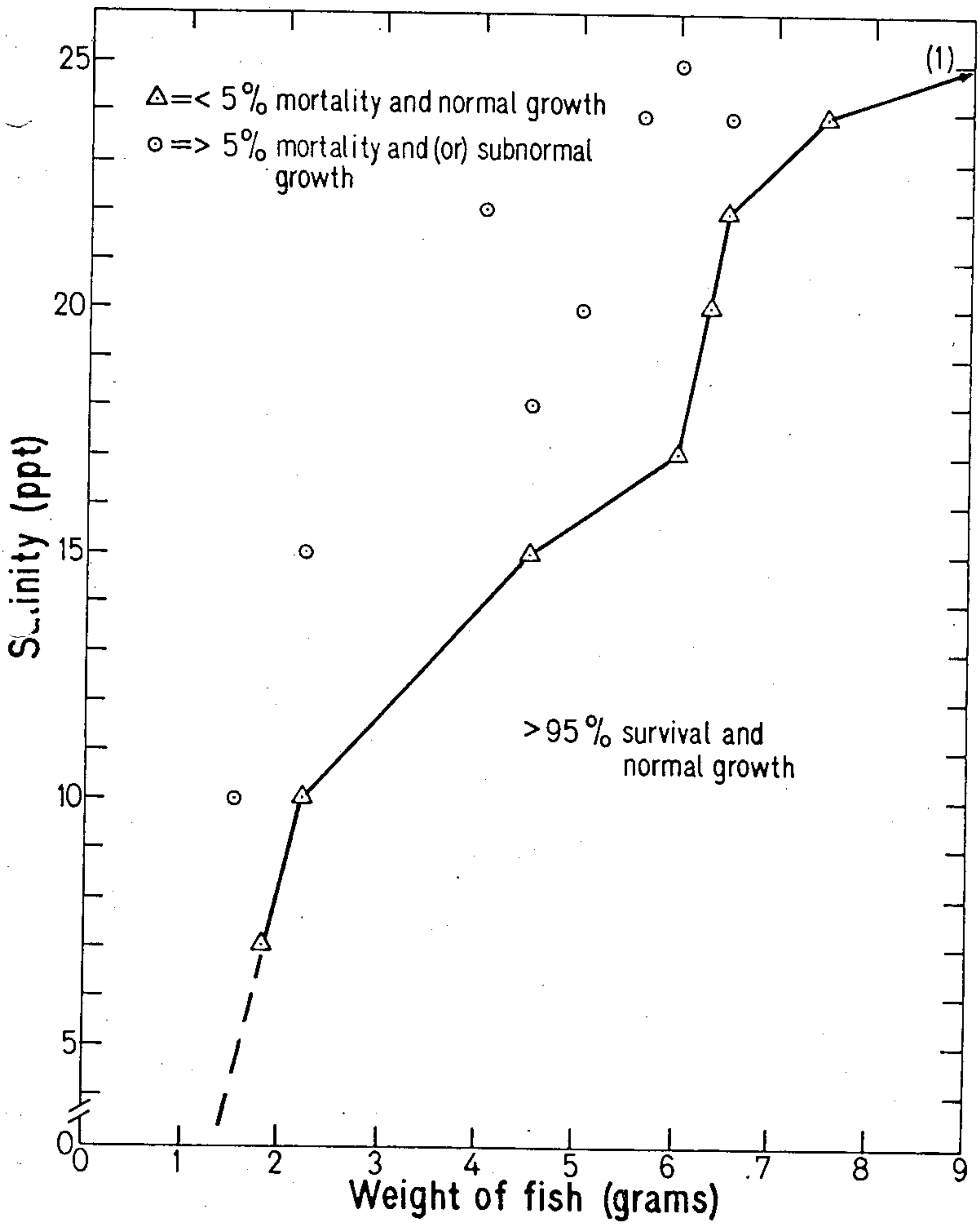
Fig. 3. Water temperatures (at 1.0 m depth) in control and heated water pens during February 13 through 18, 1974.



Temperature (°C)
10
4.5
-1
Control
10
4.5
-1
Heated water

Fig. 4. Survival in relation to salinity vs. size for 0-age coho salmon given gradual acclimation to saltwater during April through June, 1975. Temperature 10°-15° C.

(1) 15 g at 29 ppt. Novotny and Mahnken, 1972.



Δ =< 5 % mortality and normal growth
⊙ => 5 % mortality and (or) subnormal growth
> 95 % survival and normal growth
(1)
S.inity (ppt)
Weight of fish (grams)
0
5
10
15
20
25
0
1
2
3
4
5
6
.7
8
9

Fig. 5. Growth in a given percentage of three groups of yearling coho salmon following an outbreak of vibriosis in 1974.

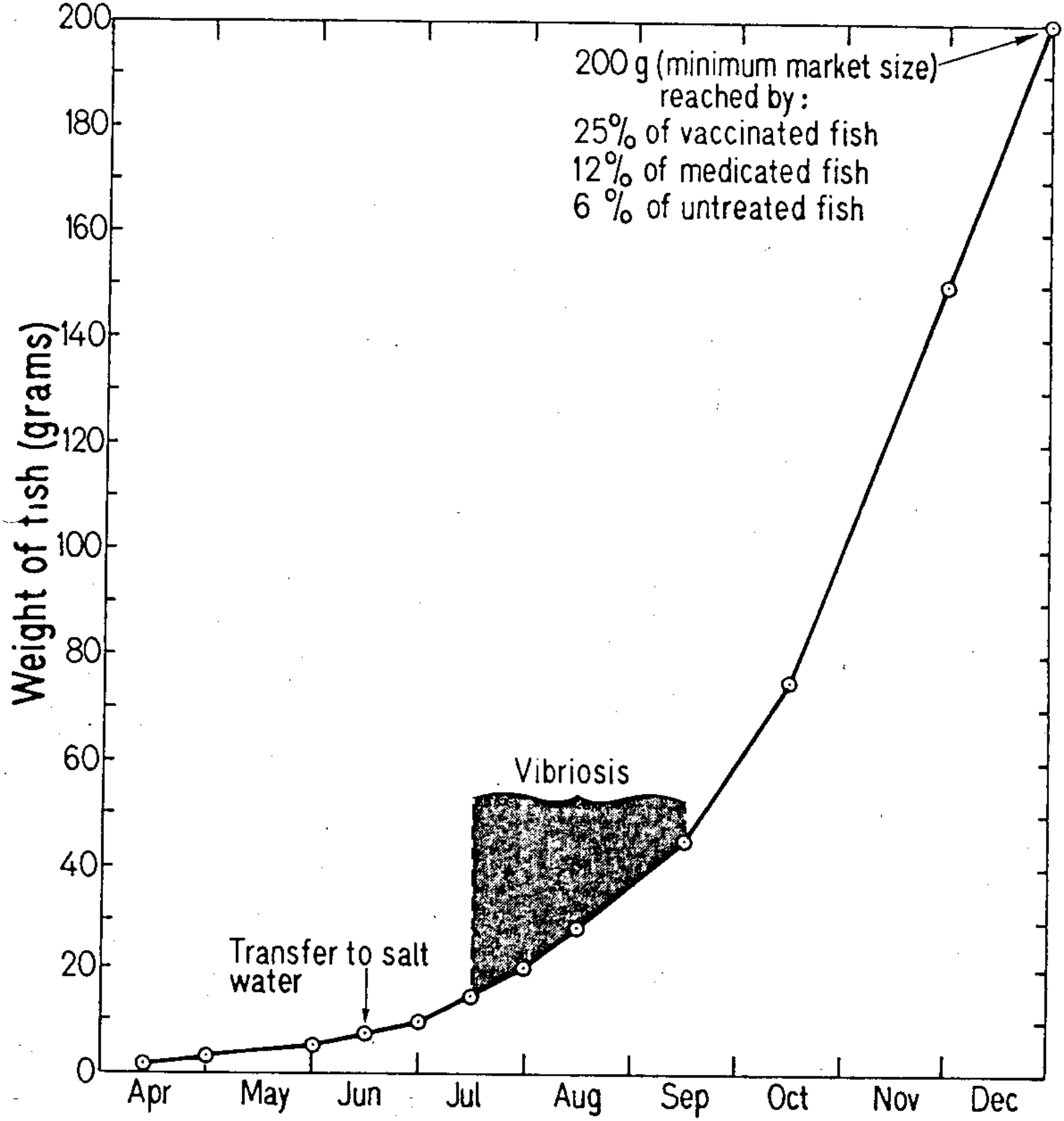

Weight of fish (grams)
200
180
160
140
120
100
80
60
40
20
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
200 g (minimum market size) reached by:
25% of vaccinated fish
12% of medicated fish
6 % of untreated fish
Vibriosis
Transfer to salt water

Fig. 6. Weekly mortality in 0-age coho salmon during 1974 *(Vibrio anguillarum)* and 1975 *(Flexibacter sp.)*. Temperatures were above 15° C from mid-July until early September.

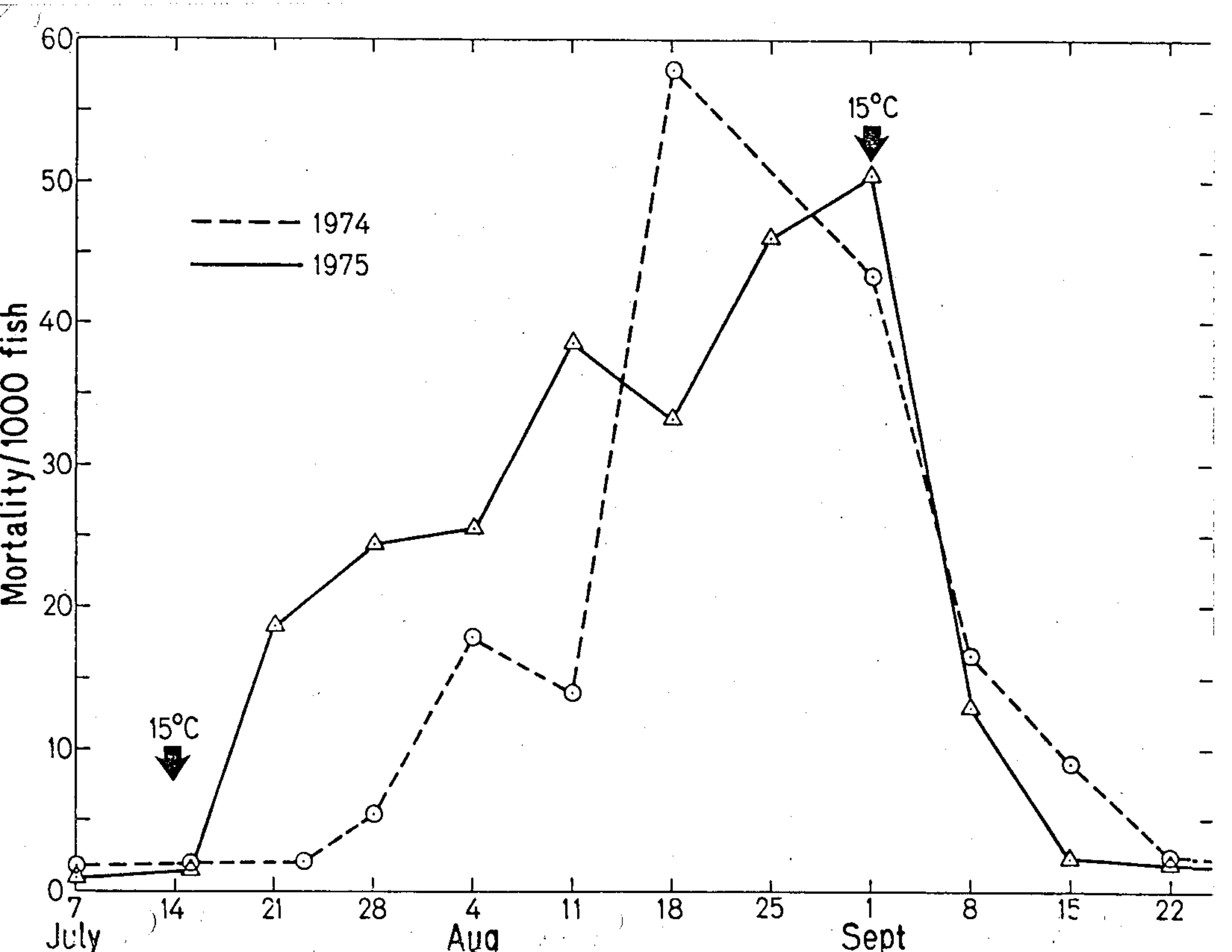

Mortality/1000 fish
0
10
20
30
40
50
60
1974
1975
15°C
15°C
7
14
21
28
4
11
18
25
1
8
15
22
July
Aug
Sept

Fig. 7. Photograph showing 20' x 14' x 12' (deep) saltwater salmon holding pen and other adjacent pens at Maine Salmon Farms, Wiscasset, Maine.

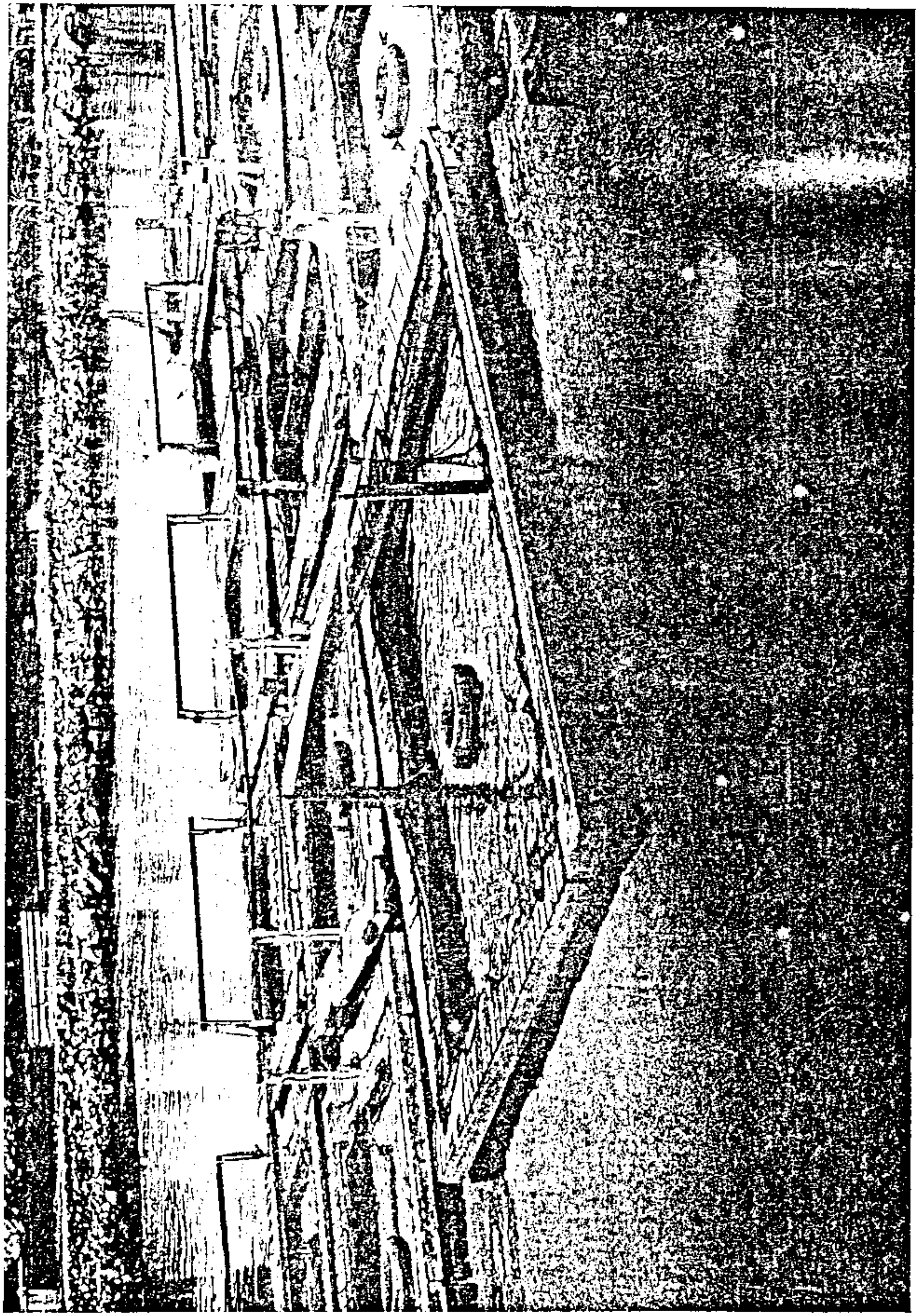
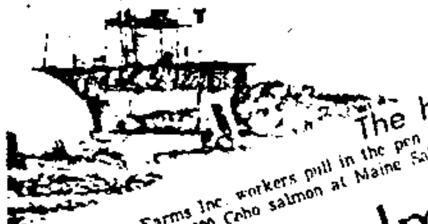


Fig. 8. Various newspaper articles announcing Maine Salmon Farms' first commercial harvest and the introduction of fresh "pan-size" salmon to New England Restaurants.

PAGE EIGHTEEN THURSDAY, MAY 30, 1974

First Salmon Netted At C.M.P. Plant



The harvest

Maine Salmon Farms Inc. workers pull in the pen nets Wednesday to harvest 1,000 Coho salmon at Maine Salmon Farms rearing site in the thermal discharge of the Central Maine Power Co. Mason plant at Wiscasset. (Maher)

First Coho salmon harvest is in

(Continued from Page 1)

jaters) of heated water that surges into the pen area every minute. The water level is ... a boom, and ... the ...

larger fish are retained for brood stock, but Towle expects to import another 200,000 Coho eggs this fall. He hopes to begin in late June with regular harvests of 1,000 fish every two weeks. ... most difficult part of ... process was ... find the ...

with algae cultures, shellfish, and Atlantic salmon to determine how they react to the warm water environment. Apparently the Atlantic are not responding to the warmer environment the same way as the Coho ... Afte... biol...

stimulate ... contended they ...

Salmon Make News

Salmon made ... Maine this week ...

Coho Salmon Harvested At Wiscasset

WISCASSET, Maine (AP) — One thousand pan size Coho salmon have been harvested in the shadow of an electric generating plant. The salmon, weighing between a half pound and a pound, were ... their pen ... the first ...

... will begin a twice-a-month harvest of the salmon in June and estimates a potential annual yield of ...

Coho Salmon

... harvesting of Coho salmon ... the first marine venture of its ... ast. The Cohos are native to th...

Commercial salmon hauled from site near power plant

WISCASSET — A first in the developing ... weeks. "This way we'll be able to keep the

26 MANCHESTER (N. H.) UNION LEADER — Thursday, February 28, 1974

Being Raised in Warm Water

The Coho Salmon: A New Gourmet Treat

(ED. NOTE: The following is reprinted from the November (1973) edition of Down East, The Magazine of Maine, published monthly at Camden, Maine.)

FOR years the Atlantic ... salmon, the silver scaled ... ... recent ... to Maine and is being ... as a gourmet delicacy.

An experimental ... called Maine Salmon Farms Inc. is raising coho in the warm water discharge ... Centr...

... and Portland ... was ... to an outdoor job with financial promise. An article in Sports ... Adams and Baron ...

Coho Salmon Are Harvested At CMP Plant

WISCASSET (AP) — One thousand pan-size Coho salmon have been harvested in the shadow of an electric generating plant.

The salmon, weighing between a half pound and a pound, were ... from their pen Wednesday to become the first commercial marine harvest of Cohos on the East Coast.

A delicacy generally associated with the Pacific Northwest, the Maine-grown Cohos are being shipped to restaurants between here and New York. *23 May 74*

They were raised by Maine Salmon Farms, Inc., in the Sheepscot River near the warm water discharge from the Central Maine Power Co. generating station.

The fish pens are anchored near the plant's 70 degree water discharge, which keeps the average water temperature in the pens around 50 degrees, suitable for the Cohos to flourish.

Fed a diet of natural shrimp bits, the salmon harvested Wednesday were nurtured for 16 months. Maine Salmon Farms President Frederick G. Towle said that with further experiments, he hopes to reduce the growth period to a year.

Towle said his salmon eggs were purchased from federal and state hatcheries in the Northwest. Regular harvests of 1,000 fish every two weeks are scheduled to begin late next month, he said.

Cultured Salmon Harvested From Sheepscot

The first commercial harvesting of Coho salmon in Maine was accomplished recently by a small, new company based in Wiscasset — Maine Salmon Farms Inc. The pioneering company maintains salmon pens on the Damariscotta River and on the Sheepscot River in the warm water discharge of the Central Maine Power Company's Mason Station. Not long ago Dave Littleton-Taylor talked with Frederick G. Towle, the articulate, enthusiastic ... of Maine Salmon Farms. The following is a portion ...

bay. We use by-products of the shrimp industry (small, unmarketable pieces of shrimp) which make up the natural diet of the salmon. This is organic fish farming I suppose — we're trying to give them ...

the Damariscotta River the ones that you hav... scot?

T: We put them up ... introdu...

Farming for salmon

The Boston Globe Thursday, September 26, 1974 By Gloria Hutch...

Gerry Towle Brings Coho Salmon to Maine

By Gail Pe... Globe Staff

WISCASSET, Me. — Frederick (Gerry) Towle is a tall, rugged 44-year-old who looks born to the Maine coast and to a uniform of dungarees, blue workshirt and sheathed hunting knife.

In reality, he was born in Providence, R.I., is a Brown University graduate in literature and worked 10 years as a Boston and Portland stock broker ... Brothers-type ... button-down ... he is just about the least likely candidate for a fish farmer ...

"But I never had intentions of writing poetry," Gerry says. "And I've always had an interest in the sea and an interest in farming."

So Gerry (pronounced Gary) Towle ... is just that. Fish farmer, to be ... salmon farmer, to be making ...

few yards from the Central Maine ... Co.'s huge brick plant. More are coming but it has ... easy.

"We were arrested in the ..." says Dr. Evelyn Adams, the biologist and a stock-holder.

Watchdogs of the Department of Marine Resources ... Towle with 800 market-size ... promptly turned them ... a time-honored law ... must be 14 inches long ... and line.

By the time ... capped and the law ... had been confiscated ... dren's home in Bath. Dr. Adams, meanwhile, were ... ruled.

Their salmon, she explains, were not "shorts" from the waters of Maine but specially harvested West Coast fish, flown in as eggs from Oregon. ... Towle eventually may grow his ... seven or even 10 pounds ... individual serving ... and restau...

First Salmon Harvested From Waters Near Generating Plant

WISCASSET — A first in the developing field of aquaculture took place Wednesday with one of the largest salmon hauls in ... Maine's newest crop, coho salmon, raised in the warm sea water near a nuclear electric power plant. ... Yorkers will be feasting on these fresh gourmet delicacies in first class restaurants from Damariscotta to New York City.

restaurants in Bosto... York City.

"I'd call it organic farming," Towle says ... natural shrimp diet helps produce a high ... tender pink meat."

Maine Salmon F... formed after more ... of experiments with salmon. Towle ...

Fig. 9. A promotion sheet describing Maine Salmon Farms' product.

Maine Salmon Farms, Inc.

WISCASSET, MAINE

TO OUR CUSTOMERS ABOUT OUR PRODUCT

Maine Salmon Farms is producing a new and superior fish product farmed from the sea.

What separates this product from others........?

- Our fish are a *true salmon* from Pacific Northwest stock.

- Our salmon are reared in the cold *salt water* of a Maine estuary. This natural environment produces a fish with firm flesh.

- Our salmon are fed a *natural diet* of whole ground shrimp and herring, a byproduct of the Maine fishing industry. The result is a salmon with *pink* meat and *delicate* flavor.

- Our salmon are sent to market *truly fresh,* harvested a matter of hours before delivery *direct* to select restaurants on the Northeast coast.

- Finally, each "pan-sized" salmon is inspected to meet standards of *quality* and *uniformity* before being packed and iced for delivery.

AVAILABLE 12 MONTHS A YEAR

Fig. 10. Photograph showing Maine Salmon Farms shoreside facilities on the grounds of a Central Maine Power Company power plant in Wiscasset. The dome is solar heated in the spring and contains the freshwater holding tanks for the salmon fry.