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PACIFIC SALMON AQUACULTURE PROGRAM

Incubation and Cultivation Phases

Sea Grant Final Report

Principal Investigator: John M. Lindbergh

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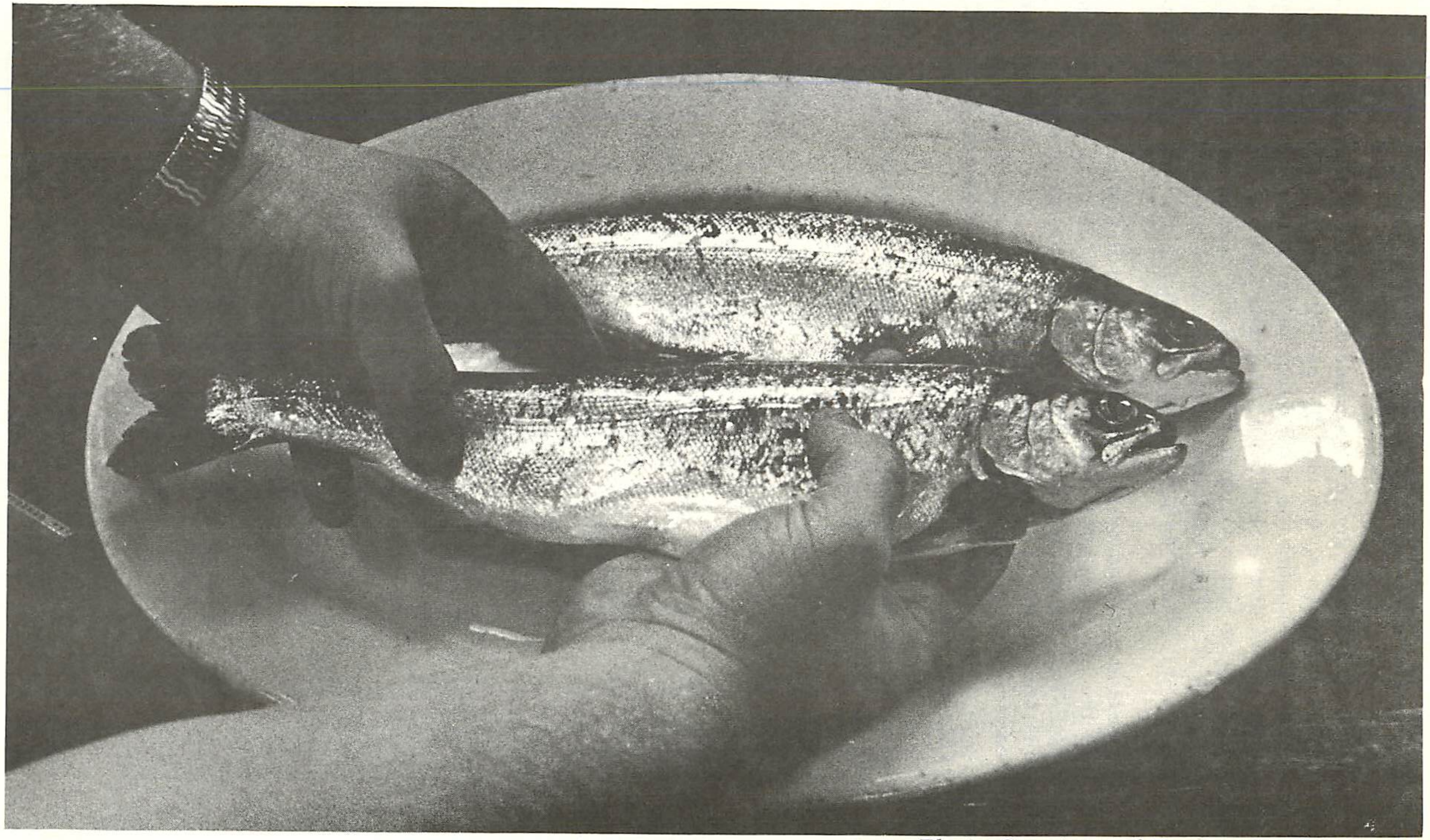


Photo Courtesy of Bremerton Sun

PAN-SIZE SALMON

PREFACE

The U. S. Department of Commerce awarded Sea Grant No. 208-1043-71(G) to Ocean Systems, Inc. for the period April 1, 1971 to December 31, 1971 to partially support the work described in this report. Subsequent to the termination of the Sea Grant, Domsea Farms, Inc. was formed as a subsidiary of Union Carbide to engage in salmon aquaculture as a business project. The total aquaculture activity formerly with Ocean Systems, Inc., was purchased by Domsea Farms and continued.

The period covered by this report through December 31, 1971, describes the program while under the supervision of Ocean Systems, Inc. The period after December 31, 1971 describes the program while under the supervision of Domsea Farms, Inc. In order to avoid confusion to the reader, the name of Ocean Systems, Inc. is used throughout the report to represent both the contributions of Ocean Systems as well as Domsea Farms, Inc.

The principal Investigator for the program throughout its entirety was Mr. Jon M. Lindbergh

C. D. Zerby
President
Domsea Farms, Inc.

SUMMARY

This is the final report of a Sea Grant project to demonstrate the feasibility of raising marketable pan-size salmon on a commercial scale in Puget Sound, Washington.

A total of 211,000 salmon were successfully raised from eggs to an average marketable 12-inch size (approximately 340 grams) in fourteen months using floating net pens. The following phases of the operation are described in this report:

1. Incubation of eggs
2. Freshwater cultivation in ponds
3. Saltwater cultivation in net pens
4. Stimulation of public awareness
5. Environmental monitoring

The program was carried out under a cooperative agreement between Ocean Systems, Inc. and the National Marine Fisheries Service (NMFS).

1.0 INTRODUCTION

In the Pacific Northwest, the salmon is the most highly prized of all food fish. Pacific salmon resources have been depleted by man-made alterations of rivers and estuaries and by the effects of fishing. To offset the depletion of salmon stocks, an elaborate system of hatcheries has been established. Although these are highly refined systems, they deal only with the early stages of the life cycle of the salmon. In an intensive system of salmon culture, the fish would be reared through their entire life cycle. It would then be possible to apply a full range of methods of husbandry and selective breeding to the development of stocks best fitted to the demands of the market.

The availability of fresh salmon is seasonal. A culture system that would permit control of the quantity, quality, and time of harvest of stocks would have market advantages. In addition, the early harvest of the salmon would permit the introduction of a pan-size salmon of approximately 12-ounce (340 grams) size. A small portion-sized salmon is in demand by the market.

This report describes such a project to raise salmon on a commercial scale. The program is based on experiments carried out by the National Marine Fisheries Service Biological Laboratory, the Washington State Department of Fisheries, Dr. Lauren R. Donaldson of the University of Washington, and others.

2.0 GENERAL DESCRIPTION OF THE PROJECT

This project demonstrated the feasibility of a commercial-sized pilot operation to raise pan-size salmon from egg to market size in enclosures in Puget Sound, Washington.

Ocean Systems, Inc. provided management for the direction and completion of the program. In cooperation with the firm, the National Marine Fisheries Service Biological Laboratory, Seattle, provided technical advisory services and facilities. The project was conducted in cooperation with the National Marine Fisheries Service, the Washington State Department of Fisheries, and the University of Washington. The site was leased by NMFS from the Washington State Department of Natural Resources and was made accessible through land owned by the U. S. Navy and the Environmental Protection Agency. A permit to install the pens was obtained from the U. S. Army Corps of Engineers. Six months after the project started, matching support for the saltwater cultivation phase was received from the National Sea Grant Program.

2.1 Background

Washington State's first salmon hatchery was built in 1895 on the Kalama River and was able to release 1,000,000 fry each year. Since then, the hatchery system has changed into a combined hatching-rearing program capable of releasing 100,000,000 fry and migratory-sized smolts into the wild environment.

Fifteen hatcheries are located on Puget Sound tributary waters, Willapa and Grays Harbor waters, and eight are located on the Columbia River tributaries.

Salmon have several advantages for culture over other fish. They are highly prized as food, they are fast growing, and their hatchery technology is the most highly developed of any marine fish. The fact that five species of Pacific salmon and numerous races exist makes the possibility of genetic selection promising. [1]

The Puget Sound area is blessed with an abundance of marine resources which are now used in only a limited way. Intensive fish culture would utilize the large supply of clean flowing salt water to produce a supply of high-quality food fish beyond that which is now available through traditional fisheries. This would not only provide a non-polluting industry and jobs for the area, but would also compete with imported fish products, and support auxiliary businesses such as fish food manufacturing, fish processing, and distribution operations.

[1] Lauren R. Donaldson, "Selective Breeding of Salmonoid Fishes," Contribution #135, Conference on Game Agriculture, Oregon State University, Marine Science Center, Newport, Oregon, May 23-24, 1968.

2.2 Objective

The overall objective of the program was to stimulate aquaculture development by demonstrating the feasibility of commercial-scale production of pan-size salmon.

2.3 General Technical Approach

The program described in this report consisted of six phases:

1. Incubation of salmon eggs
2. Cultivation of fingerling salmon in freshwater ponds
3. Cultivation of salmon to a marketable size in floating pens in salt water
4. Harvesting and test marketing
5. Stimulation of public awareness of the aquaculture potential in the Puget Sound area
6. Environmental monitoring

The description of the first two phases contains little new information about salmon cultivation. Techniques which were employed are considered standard and the information about these phases is included for completeness.

3.0 DESCRIPTION OF PROGRAM

The salmon culturing program consisted of five major phases, involving incubation of eggs, freshwater cultivation, saltwater cultivation, marketing and stimulation of public awareness. The following sections will describe the objectives, procedures, and results of each phase.

3.1 Incubation Phase

The artificial spawning of salmon eggs, their subsequent incubation and hatching, are accomplished routinely by many state and federal hatcheries in the Pacific Northwest. Although specific techniques and facilities vary, the procedures are well established and constitute no new problems.

The objective of this first phase of the pilot operation was to provide sufficient salmon fry for subsequent cultivation. The hatchery techniques were similar to those described elsewhere. Events included egg and sperm collection, incubation, sorting, and hatching. Of 700,000 coho eggs purchased, 420,000 (60%) were hatched. In addition to the coho, approximately 400,000 chinook fry were later included in the project. The chinook eggs were incubated and hatched at the University of Washington.

3.1.1 Facilities Description

The coho egg incubation phase took place at Beaver Creek, a small freshwater stream flowing into Clam Bay at Manchester, Washington. (Figure 1). Authorization was given by the U. S. Navy to convert a small surplus building (Bldg. 67) next to Beaver Creek into a temporary hatchery (Figures 2 to 4). Nine 16-tray Heath Techna vertical flow incubators (Model #369) were installed according to the plan shown in Figure 5. All plumbing was of PVC, exposed wood was coated with polyester resin, and steel was coated with asphaltum varnish. Four 2,000 kilowatt glass heaters were installed in the downstream side of the header box. With straight-through flow, temperature in the incubators held at about 1.5°C above creek temperature. A recycling system and filter were installed and placed in operation on 25 November. Filter and bypass valves were adjusted to provide for approximately 80% recycled water, which allowed temperature to be maintained at 5°C above creek temperature. Two thermostats, each controlling two heaters, were set to allow a maximum temperature of 11°C. Due to construction delays, water flowed through the system for only two days prior to introduction of the eggs. Each incubator received approximately 3 to 5 gallons per minute flow. The results of water analyses at Beaver Creek during this period are shown in Table I.

3.1.2 Operations

A permit was received from the Washington State Department of Fisheries to purchase 700,000 coho salmon eggs from surplus Skykomish Hatchery stock. This hatchery is located on May Creek, about four miles

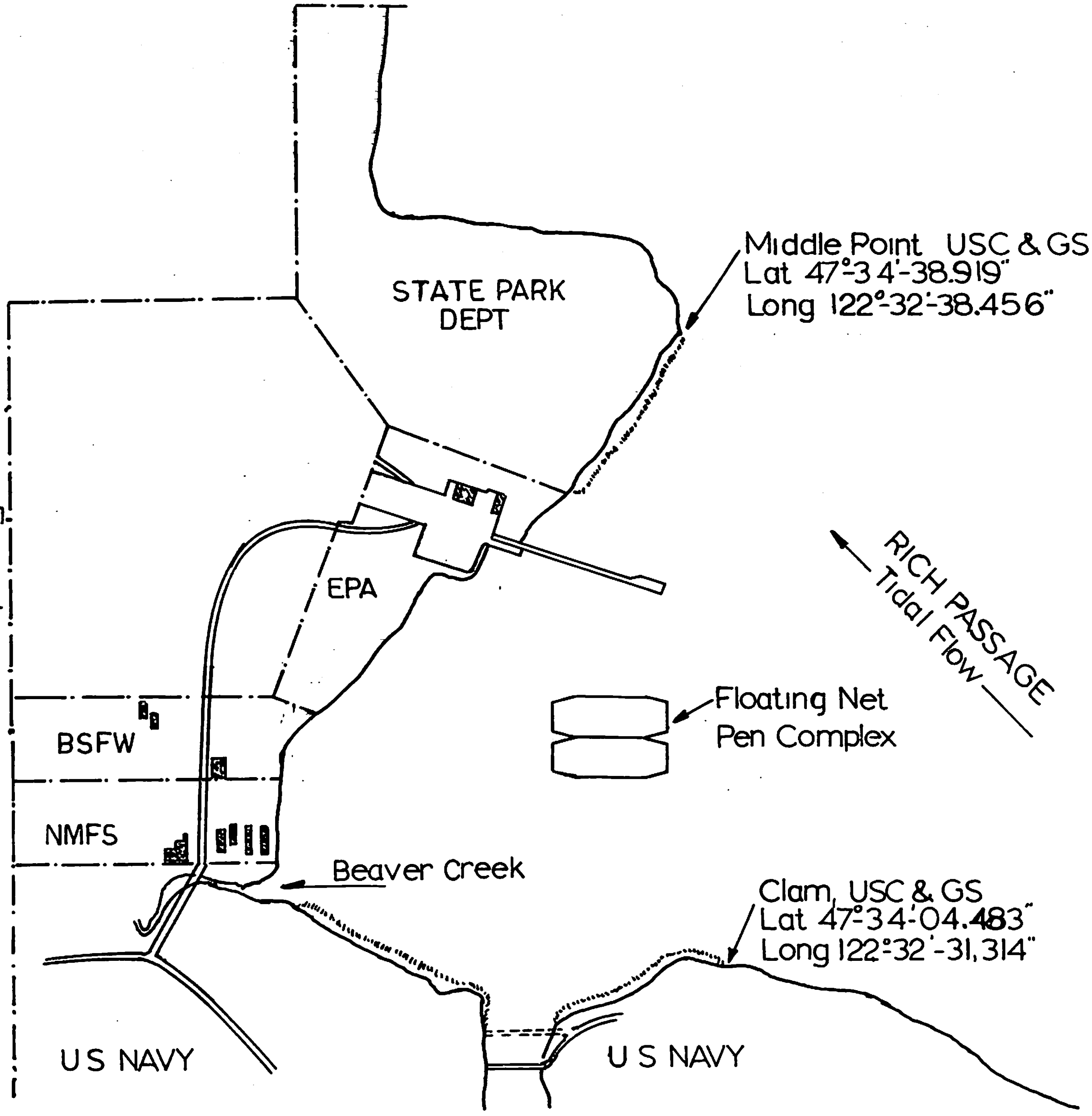

STATE PARK DEPT
Middle Point USC & GS
Lat 47°-34'-38.919"
Long 122°-32'-38.456"
EPA
RICH PASSAGE
Tidal Flow
Floating Net Pen Complex
BSFW
NMFS
Beaver Creek
Clam, USC & GS
Lat 47°-34'-04.483"
Long 122°-32'-31,314"
U S NAVY
U S NAVY

Figure 1

FIGURE 2

The incubator facility at Beaver Creek. The small building to the left is the pump house. The header box is mounted on the roof. Incubator stacks are mounted inside the building.

FIGURE 3

Inside the incubator facility. Incubator stacks are at the right standing on the drainage tables. Laboratory equipment is assembled on the left. Windows were covered with opaque plastic to prevent light shocking of eggs.

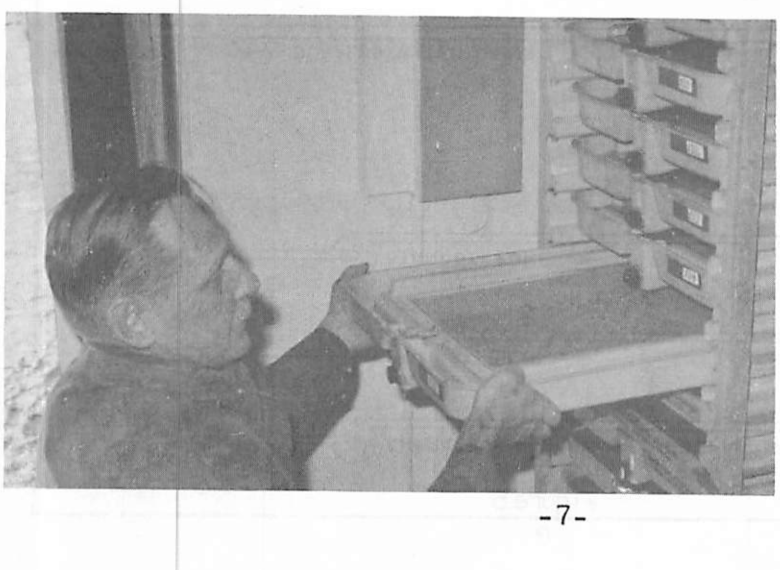


FIGURE 4

A typical try of eggs in Heath incubator. Fiber-glass trays are supported in aluminum stand and water cascades through the trays.

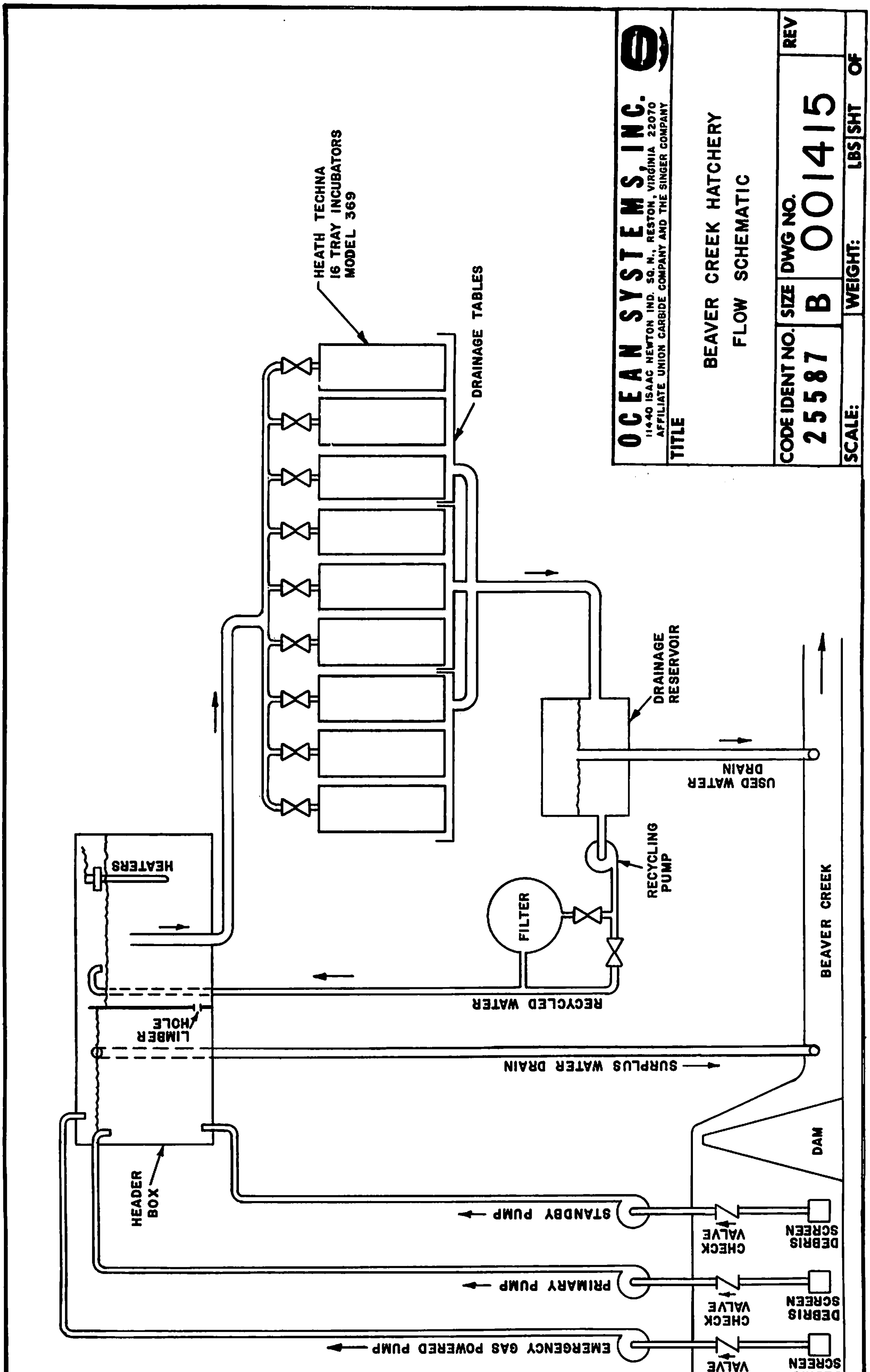

OCEAN SYSTEMS, INC.
11440 ISAAC NEWTON IND. SQ. N., RESTON, VIRGINIA 22070
AFFILIATE UNION CARBIDE COMPANY AND THE SINGER COMPANY
TITLE
BEAVER CREEK HATCHERY
FLOW SCHEMATIC
CODE IDENT NO.
25587
SIZE
B
DWG NO.
001415
REV
SCALE:
WEIGHT:
LBS
SHT
OF
HEATH TECHNA
16 TRAY INCUBATORS
MODEL 369
DRAINAGE TABLES
DRAINAGE RESERVOIR
USED WATER DRAIN
RECYCLING PUMP
FILTER
HEATERS
RECYCLED WATER
LIMBER HOLE
SURPLUS WATER DRAIN
BEAVER CREEK
DAM
HEADER BOX
STANDBY PUMP
PRIMARY PUMP
EMERGENCY GAS POWERED PUMP
CHECK VALVE
CHECK VALVE
CHECK VALVE
DEBRIS SCREEN
DEBRIS SCREEN
DEBRIS SCREEN

Figure 5

WATER ANALYSES

TABLE I INCUBATORS	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Temp. °C Mean	7.9	8.2	8.7	9.4						
Range	10.0-4.4	10.1-5.1	10.5-4.0	10.6-1.1						
Dissolved Oxygen ppm	-	11.7	12.5	11.2-11.6						
pH	7.5	7.2	7.2	6.5-6.6						
Total Hardness, ppm	-	50	38	35-40						
Total Alkalinity ppm	-	39	34	30-35						

TABLE II COHO POND	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Temp. °C Mean				6.8	6.8	9.6	10.2	10.5	11.8	12.6
Range				10.6-1.1	10.0-3.9	9.9-6.1	11.0-8.1	11.9-9.1	13.7-10.2	13.9-11.2
Dissolved Oxygen ppm				8.2+	9.0	9.9	8.3	6.6	6.3	6.3
pH				6.5	6.6	6.6	7.1	7.1	6.7	6.8
Total Hardness ppm				35	35	39	50	51	50	52
Total Alkalinity ppm				40	39	46	46	56	55	53

TABLE III CHINOOK POND	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Temp. °C Mean				6.8	6.8	9.7	10.4			
Range				10.6-1.1	10.0-3.9	10.3-7.5	11.8-8.4			
Dissolved Oxygen ppm				8.2+	8.15	7.5	6.2			
pH				6.5	6.5	6.7	6.7			
Total Hardness ppm				35	35	40	40			
Total Alkalinity ppm				40	40	43	43			

east of Sultan and 40 miles northeast of Seattle. On November 6, 1970, the hatchery, gave notification that ripe coho salmon had arrived at the weir. Project personnel, supervised by Anthony Novotny of NMFS subsequently took eggs on November 9 and 19 (Figures 6 to 14).

Skykomish Hatchery employees ran a seine net around several hundred fish and crowded them against the bank. Small numbers of fish were dip netted, males segregated from females, and the largest and fittest of each selected.

Eggs and sperm were packed in ice and transported to a hatchery at Beaver Creek near Manchester. Each gallon of eggs was poured into a clean five-gallon plastic bucket and one cup of sperm added. The eggs and sperm were allowed to sit for one minute, then they were washed, drained, and split into two incubator trays.

Dead eggs were picked from trays during the period from 18 December through 21 December. Mortality was considerably higher than anticipated. Eight trays were particularly bad, having mortality rates of 90% or more. In all cases these trays were paired, indicating a problem with sperm or fertilization.

On 22 December the eggs were weighed and the trays balanced so each tray would contain approximately the same number of eggs. Residual eggs from trays with severe mortality were kept together. Four one-hundred ml samples of eggs were counted from three separate trays and weighed to provide a weight count. Extrapolating this count to the total weight of eggs gave an estimate of 469,000 eggs surviving from the original 700,000 for a mortality of 33%.

Extensive hatching took place on January 12-14, and by January 15 over 95% of the eggs were hatched. On January 31, the estimated number of live coho salmon was 445,000 or 63.5% of the original number of eggs.

The major problems found in the incubation phase were low water temperatures, silt deposition and saprolegnia. The first two of these can be corrected by proper engineering design and choice of water supply. Supplemental heating adds significant costs to the operation, while adequate filtration is relatively inexpensive. The saprolegnia problem can be minimized by treatment with a fungicide before extensive mortalities occur.

Chinook incubation and hatching was conducted at the University of Washington.

3.2 Freshwater Cultivation

The freshwater phase of the salmon culture program spanned about six months, from the time of hatching until the fingerlings were large enough to adapt to salt water. The goal for this period, production of

FIGURE 6

Seining of wild spawning stock at the Skykomish hatchery in Washington State. These fish were returning to the hatchery where they were spawned and reared 3 or 4 years ago.

FIGURE 7

Selection of the prime coho specimens. The fish were selected for size, shape and free from disease or defects.

FIGURE 8

After selection, the fish were killed and bled to facilitate contamination of the sperm by blood. The fish would normally die soon after natural spawning.

FIGURE 9

Collection of eggs from female coho salmon. The abdominal wall was slit and the ripe eggs spill into the collection pail. At this point it is important that slime or blood is kept away from the eggs as contamination will reduce fertilization.

FIGURE 10

After the eggs of several fish are collected, they were decanted into 1-gallon jugs and iced for the journey to the incubator.

Fertilization took place at the incubator facility.

FIGURE 11

Stripping of sperm from male coho salmon. Sperm was "milked" from the salmon by massaging the abdominal wall. The sperm was collected in small cups for transport to the incubator at Beaver Creek.

FIGURE 12

After delivery to the incubator, the sperm and eggs were mixed and placed into incubator trays. The eggs were left undisturbed until after they had eyed out. At that point the dead and infertile eggs were removed.

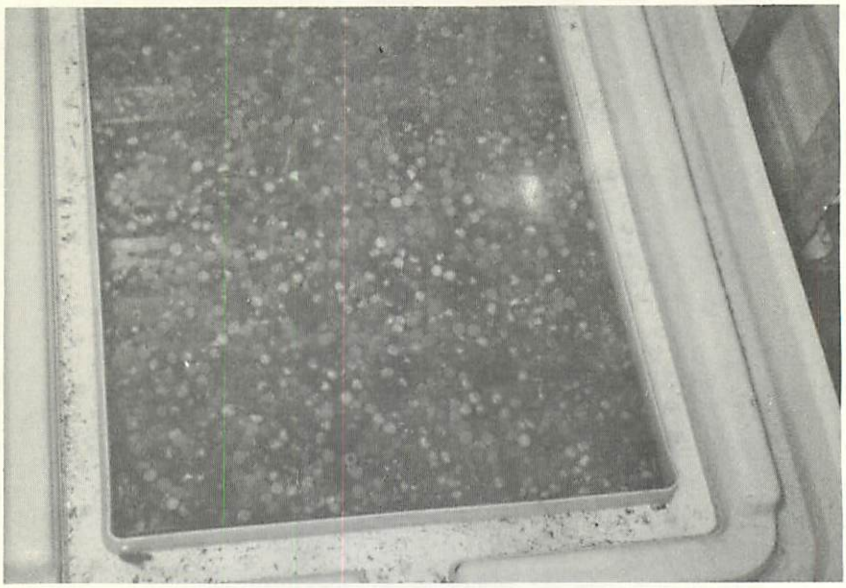


FIGURE 13

A typical tray after the eyed out stage. The white eggs are dead or unfertilized. Black eggs are also dead and have become covered with saprolegnia (a fungus).

FIGURE 14

Picking of the egg trays. Each defective egg was removed with tweezers and transferred to a graduated measure. The healthy eggs were washed and returned to the incubator until they hatched.

700,000 chinook and coho fingerlings, was met during the summer months. Major tasks for the period included feeding, cleaning, predator control, temperature and oxygen adjustments and inventory estimations.

3.2.1 Facilities

The freshwater cultivation took place at two freshwater ponds (Glud's) near Brownsville, Washington. These ponds total about one acre of area, with an average depth of 10 feet, and are fed consecutively from a single creek with an estimated minimum flow of 500 gpm (Figure 15). The inlets and outlets can be controlled to fill or drain the ponds. Each has a mud bottom and dirt banks covered with a veneer of sand. Temperatures and water analyses taken during this period are shown in Tables II and III. To increase the low water temperatures, the oil-fired heater from the hatchery was installed at the upper pond and delivered 20 gpm of heated water to the pond with a 15°C differential. Pond temperature was raised approximately 1°C. The fish, however, tended to stay in the vicinity of the discharge, which was significantly higher. Heating continued until mid April when temperatures rose to over 10°C.

3.2.2 Operations

Approximately 420,000 coho fry were transferred from the incubators at Manchester to Glud's upper pond on February 6 and 7. This was accomplished by truck, with an insulated fish transfer box and oxygen, so that very few fish were lost in the process. The fry were placed in 4' x 8' x 6' net enclosures, designed to crowd the small fish to help them start feeding. However, during the first night the small fish moved to the bottom of the net which bagged and caused them to pile up. The fry on the inside of the pile began to suffocate. As soon as this was noticed, the fish were released to the pond. The survivors immediately schooled and appeared to be feeding adequately. An estimated 300,000 coho survived the transfer and abortive crowding attempt.

Subsequent to this incident discussions were held with Dr. L. R. Donaldson, of the University of Washington. Dr. Donaldson agreed to donate 463,000 surplus chinook fry for inclusion in the experiment, in order to provide some comparative data about the two species. These fish were produced at the University by genetically selected spawners from a strain that has been developed by Dr. Donaldson for nearly 20 years. They were selected for maximum growth and disease resistance as well as other factors. A permit was received from the Washington State Department of Fisheries to authorize the transfer and the inclusion of chinook salmon in the experiment.

These chinook fry were transferred to the lower pond in seven loads on February 9-12. Net crowding enclosures were not used, and the chinook started feeding immediately. A total of 463,000 fry with a total weight of 668 pounds were thus stocked with very few mortalities.

FIGURE 15

Glud's Pond near Brownsville, Washington. The two ponds had been developed for freshwater cultivation of trout and had been used by Washington State Department of Fisheries for salmon cultivation.

FIGURE 16

Preparation for transfer to freshwater cultivation. The transfer box is mounted on the truck parked outside the incubator facility. A standard insulated box with oxygen bubbler system was utilized.

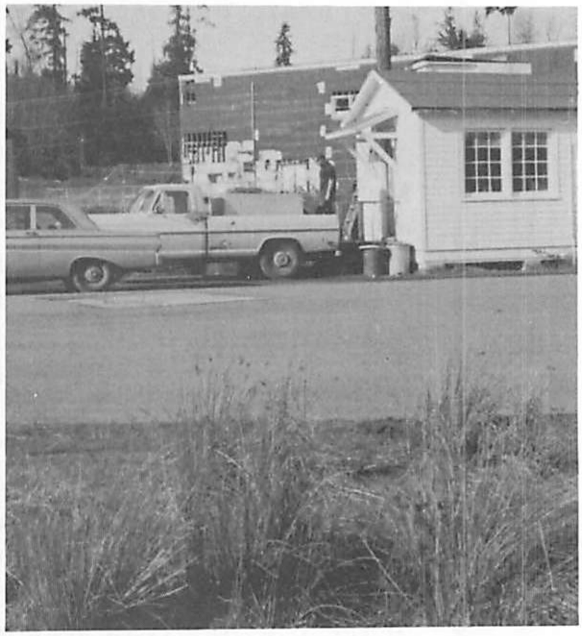


FIGURE 17

Transfer of the fry from the trays to the transfer box. Once the fry had absorbed their yold sacs, it was necessary to transfer them from the tray to the pond.

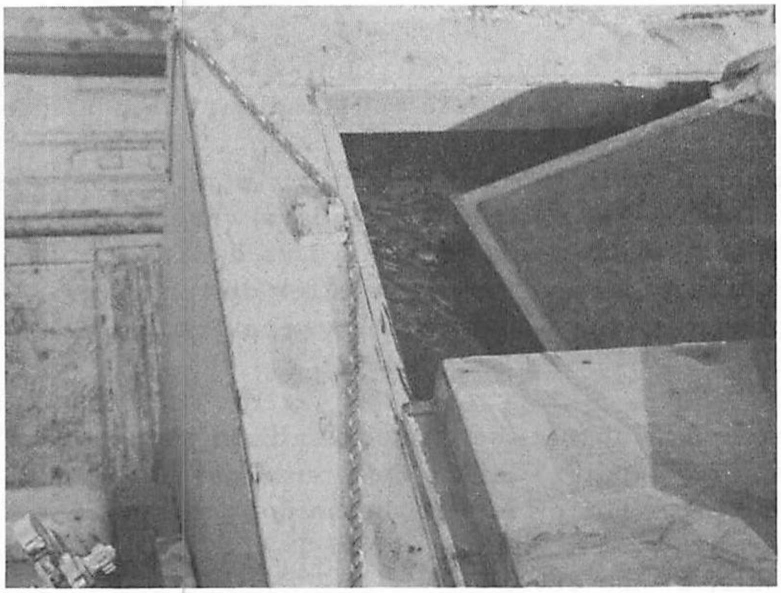
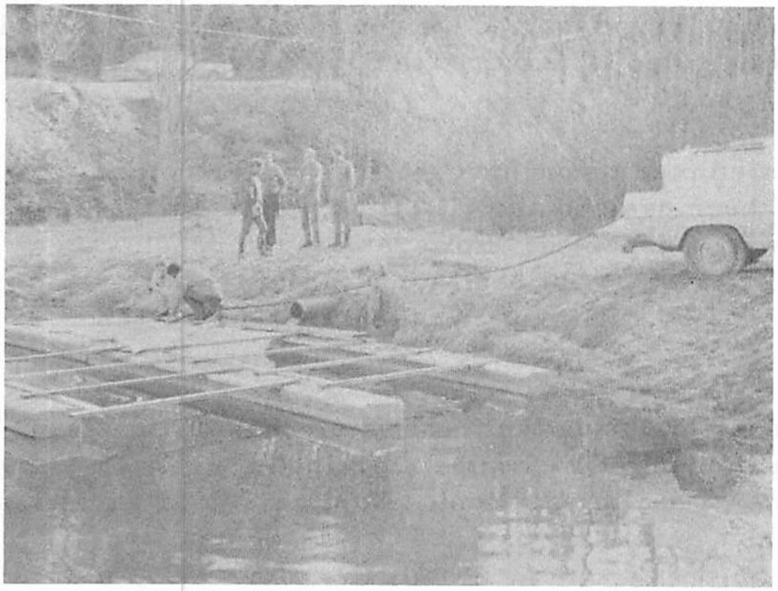


FIGURE 18

Each tray was carried to the truck and the inner container was lowered into the transfer box. The screen was removed and the fry poured into the box

FIGURE 19

Temporary crowding facilities at Glud's Ponds. The 4' x 8' nets were intended to serve as low-cost hatchery trashs in which the swim-up fry would start feeding. The crowding facility was not successful.



Clark's "New Age" salmon feed, a dry formulation, was chosen to begin feeding both the chinook and coho fry. Economic and handling considerations lead to a dry rather than a moist pellet. Feeding was begun at 6% of total fish weight per day. Of this a possible 10% was lost to the pond bottom and sides which requires hand raking. Four automatic feeders were installed during March, feeding at 15-minute intervals from dawn to dusk. Supplemental hand feeding was required once each hour to better distribute food to the larger chinook pond. As the fish grew they were gradually shifted to coarser grade pellets.

In mid-March it became apparent that the chinook salmon were not growing well. Their diet was changed to Clark's Oregon Moist Pellet II, and they resumed normal feeding. The effects of the chinook diet change can be seen clearly on the growth chart, Figure 21 and Table V. The coho continued to feed normally on the dry diet.

By mid-April the density of fish had increased to the point that supplemental aeration was required. A small air compressor was installed, an additional 12-inch pipe was installed between the ponds and the entire creek flow directed through the ponds.

In May, rising temperatures and dry weather required installation of additional aerators and several recirculation pumps. Water flow in the creek dropped to 550 gpm and dissolved oxygen in the lower pond fell below 6.0 ppm at one point. On May 19, the transfer of chinook to salt water started, so the oxygen demand in the lower pond was reduced immediately. In June and July, low dissolved oxygen in the ponds required a reduction in the coho feeding rate. Their growth during the project is shown in Table IV and Figure 20 .

Predator control was attempted throughout the freshwater cultivation phase. Since the ponds had been drained and cleaned prior to stocking the salmon fry, no native fish were suspected. However, at the conclusion of the freshwater phase a total of 66 very fat healthy cutthroat trout were removed during the coho inventory. These accounted for a loss of an estimated 33,000 small coho.

Disease was never a problem during the freshwater phase. James W. Wood of the Washington Department of Fisheries examined the fish on April 12 and found their general health excellent. No diseases or parasites were found in many subsequent examinations.

3.3 Saltwater Cultivation

The unique aspects of this aquaculture project concern the saltwater cultivation phase. Introduction to seawater occurred at a size of approximately 5 grams for chinook and 15 grams for coho.

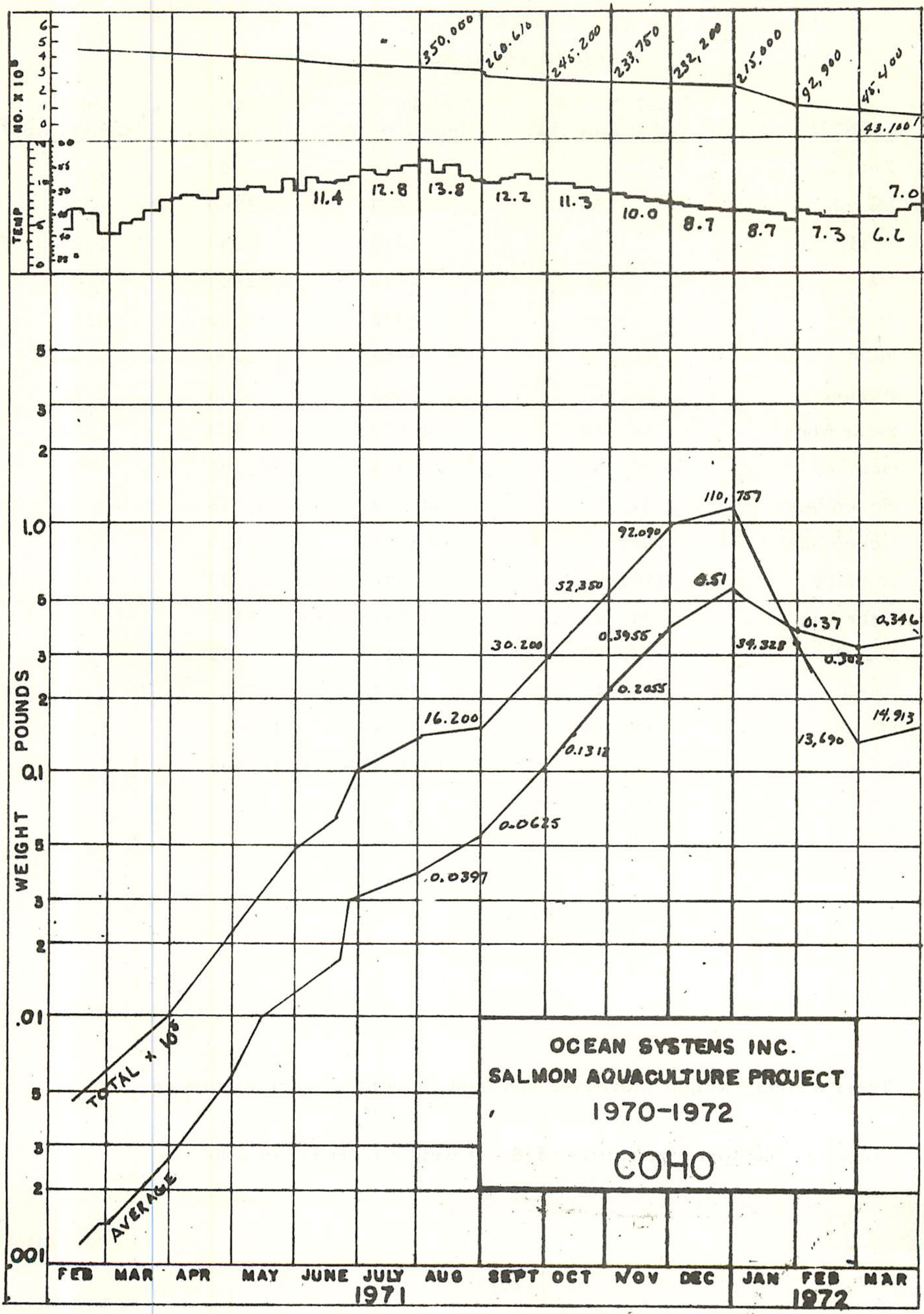

NO. x 10⁶
TEMP
350,000
260,610
245,200
233,750
232,200
215,000
92,900
45,400
43,100
11.4
12.8
13.8
12.2
11.3
10.0
8.7
8.7
7.3
6.6
7.0
WEIGHT POUNDS
1.0
0.1
.01
.001
110,757
92,090
52,350
30,200
16,200
0.51
0.3956
0.2055
0.1312
0.0625
0.0397
34,328
0.37
0.346
0.302
13,690
14,913
TOTAL x 10⁵
AVERAGE
OCEAN SYSTEMS INC.
SALMON AQUACULTURE PROJECT
1970-1972
COHO
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
1971
1972

FIGURE 20

TABLE IV

COHO FEEDING

MONTH	Total Weight 1st of mo. lbs.	Weight Increase lbs.	Food Fed lbs.	Food Conversion[1]
February	420	130	300	2.30
March	550	460	1260	2.74
April	1020	1250	2240	1.79
May	2270	2790	2800	1.00
June	5060	5090	4350	0.90
July	10,150	3750	5090	1.36
August	13,900	2300	6200	2.70
September	16,200	14,000	14,050	1.00
October	30,200	26,490	26,290	0.99
November	57,390	44,200	33,075	0.75
December	101,590	8535	21,125	2.30
January	110,125	75,797 (loss)	12,600	-
February	34,328	20,639 (loss)	5196	-
March	13,689	1224	6255	5.11
April	14,913	3072	7621	2.48
May	17,985	5685	12,630	1.98
June	23,670	13,617 (loss)	10,700	-
July	10,053			

[1] Total Weight, weight increase, and food conversions are estimated.

[2] Food conversion = weight feed fed/net weight increase of fish

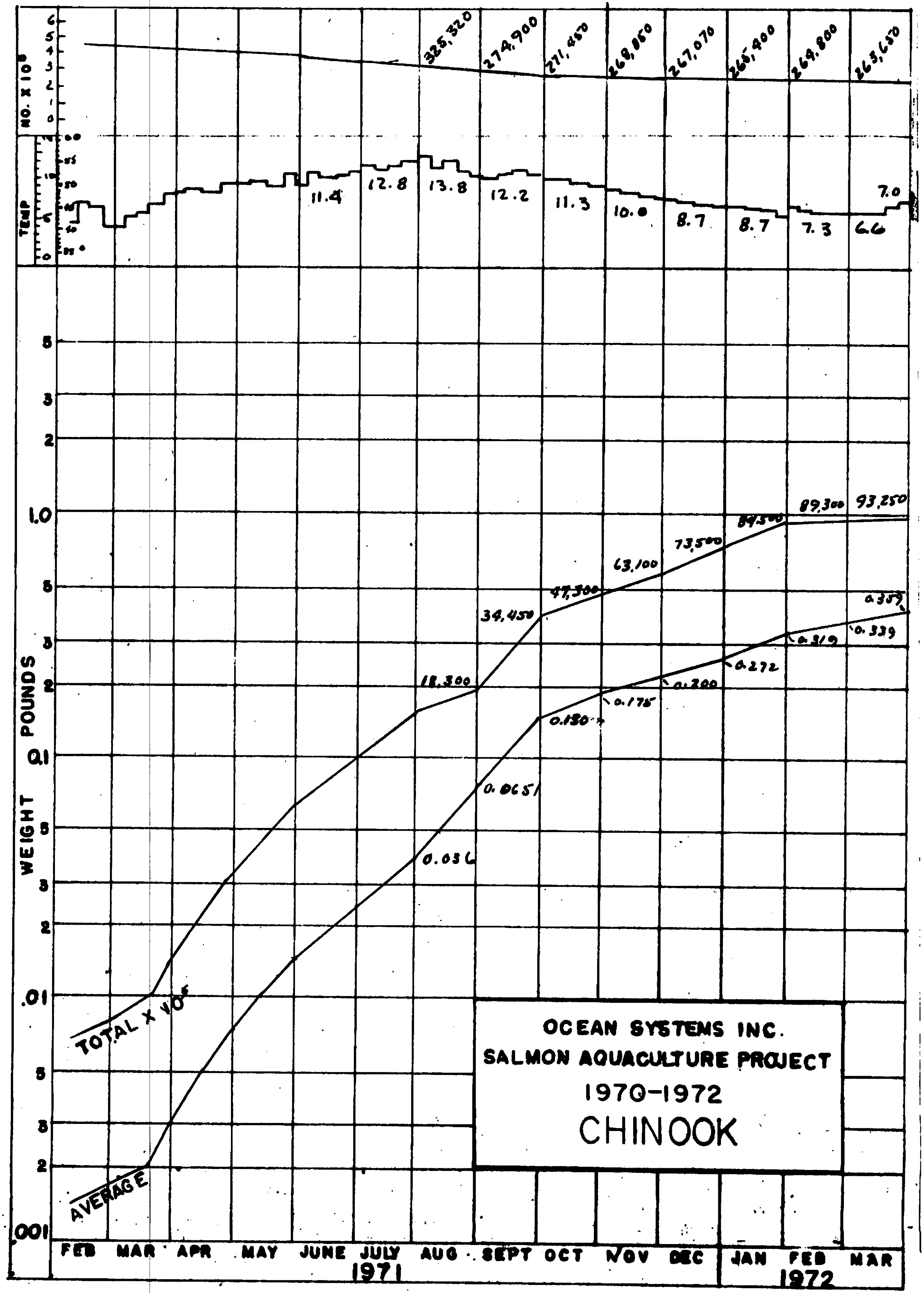

NO. X 10⁵
TEMP
325,320
274,900
271,460
268,860
267,070
265,400
269,800
263,650
11.4
12.8
13.8
12.2
11.3
10.0
8.7
8.7
7.3
6.6
7.0
WEIGHT POUNDS
1.0
0.1
.01
.001
89,300
93,250
84,500
73,500
63,100
47,300
34,450
18,300
0.359
0.339
0.319
0.272
0.200
0.175
0.130
0.0651
0.036
TOTAL X 10⁵
AVERAGE
OCEAN SYSTEMS INC.
SALMON AQUACULTURE PROJECT
1970-1972
CHINOOK
FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR
1971
1972

FIGURE 21

TABLE V

CHINOOK FEEDING

MONTH	Total Weight 1st month lbs.	Weight Increase lbs.	Food Fed - lbs.	Food Conversion[1]
February	668	87	500	5.75
March	755	570	1700	2.98
April	1325	1955	3400	1.74
May	3280	3200	3950	1.23
June	6000	3160	5940	1.88
July	9160	3400	7150	2.10
August	12,560	5340	11,265	2.11
September	17,900	17,550	19,155	1.10
October	35,450	11,850	29,520	2.49
November	47,300	6970	30,820	4.42
December	54,270	19,241	25,500	1.33
January	73,511	10,971	23,550	2.15
February	84,485	4848	30,950	6.38
March	89,330	3920	21,300	5.44
April	93,250	8520	20,956	2.46
May	101,770	78,131 (loss)	13,150	-
June	23,639	15,946 (loss)	6500	-
July	7693			

[1] Total Weight, weight increase, and food conversions are estimated.

[2] Food conversion = weight feed fed/net weight increase of fish

3.3.1 Site Description

Puget Sound is a narrow estuary lying entirely within the contiguous waters of the State of Washington and is connected to the North Pacific Ocean via the Straits of Juan de Fuca. The exchange of water in narrow constricted inland seas such as Puget Sound is generally typified by two circulation patterns. The first, characteristic of areas where evaporation exceeds precipitation, exhibits seaward flow of dense, highly saline water at depth. The Mediterranean Sea is one such example. The second, typical of areas where precipitation exceeds evaporation, exhibits seaward flow of less dense low salinity water at the surface. The latter case typifies Puget Sound where dense nutrient rich waters enter the basin via Admiralty Inlet in the north, creating eutrophic conditions similar to the Baltic Sea. Primary productivity measurements in Puget Sound between Admiralty Inlet and the Narrows range from 0.8-8.0 gm carbon fixed/m^2/day with an average annual production of 450 gm/m^2. Certain embayments, due to their shallow nature, heavy stratification and turbidity, probably do not exceed production for the main body of the Sound on an annual basis or in carbon fixed/m^2/day but may exceed production in carbon fixed/m^3/day.

Clam Bay, a portion of Puget Sound near Manchester, Washington, possesses an ideal temperature range, good tidal flow, protection from most storms, a sandy silt bottom, and very little pollution. The floating pens for this project were moored on the south side of the Bay, in 30-40 feet of water. The average tidal range is about 10 feet with currents of up to 2 knots. Water analyses taken at this site throughout the period are summarized in Table VI.

Support facilities used during the saltwater phase, such as laboratory and personnel space, garages, storage space, and loading platforms, were provided by the National Marine Fisheries Services (including the RV BROWN BEAR), the Environmental Protection Agency, and the U. S. Navy. Other facilities used was a workshop, large capacity freezer, fork-lift truck, air compressor, and various boats.

3.3.2 Facilities Description

The concept of the floating net pen is the key to the viability of this pilot project for salmon cultivation. Floating net pens were developed to utilize the following advantages:

a) Free-flowing tidal water currents are used to bring dissolved oxygen into the pens and to flush out metabolic wastes. Unlike pond cultivation, wastes are thoroughly removed and no pumping power is required.

TABLE VI

WATER ANALYSES - SALT WATER

		June	July	August	September	October	November	December
Surface Temperature, °C,	mean	11.4	12.76	13.8	12.2	11.3	10.0	8.7
	range	9.8-12.3	11.0-15.0	12.0-15.9	11.6-13.0	10.3-12.2	9.4-10.5	7.5-9.5
Dissolved Oxygen	mean	9.5	9.0	8.7	10.4	7.5	8.8	8.6
	range	10.1-8.9	5.3-10.43	8.4-10.8	10.3-10.4	7.1-7.2	8.4-9.6	6.8-8.9
Salinity	mean	28.5	28.4	28.5	29.2	29.7	29.0	30.0
	range	27.6-29.0	27.2-29.8	27.4-29.6	26.0-30.0	29.5-30.0	26.0-30.0	29.2-31.5

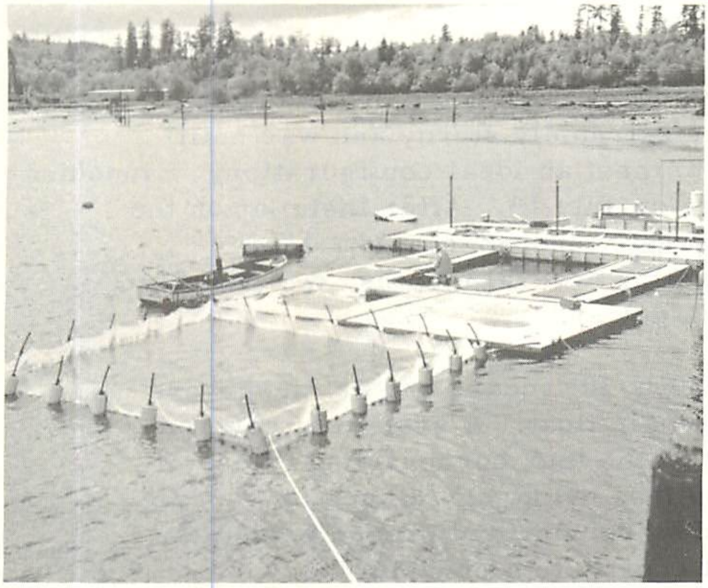
FIGURE 22

The R/V BROWN BEAR tied up at Manchester. The vessel serves as the laboratory and operating base for the NMFS Biological Laboratory. Pens are tied up next to the BROWN BEAR.

FIGURE 23

Experimental hexagonal pen developed by NMFS for early release experiments for the sports fishery. This pen has the capability of being submerged for bottom cultivation.

Experimental net pens are shown in the foreground. These are typically used for laboratory scale experiments.



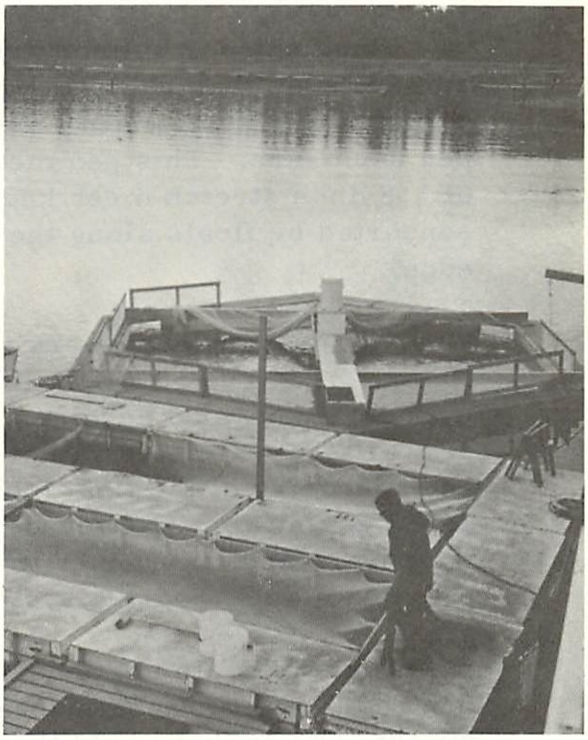


FIGURE 24

The first prototype floating net pen. The unit was 30' x 30' x 15' deep. When this picture was taken it contained almost 350,000 chinook smolts.

b) The net pen is resilient and yields with high current forces. At the time of maximum current the pen is partially collapsed while absorbing the pressure. Although volume at maximum current may be considerably reduced, water flow and hence dissolved oxygen in the pen is high so the fish do well despite crowded conditions.

c) The net pen is a relatively low capital investment facility when compared to alternatives such as fixed structures and diked ponds.

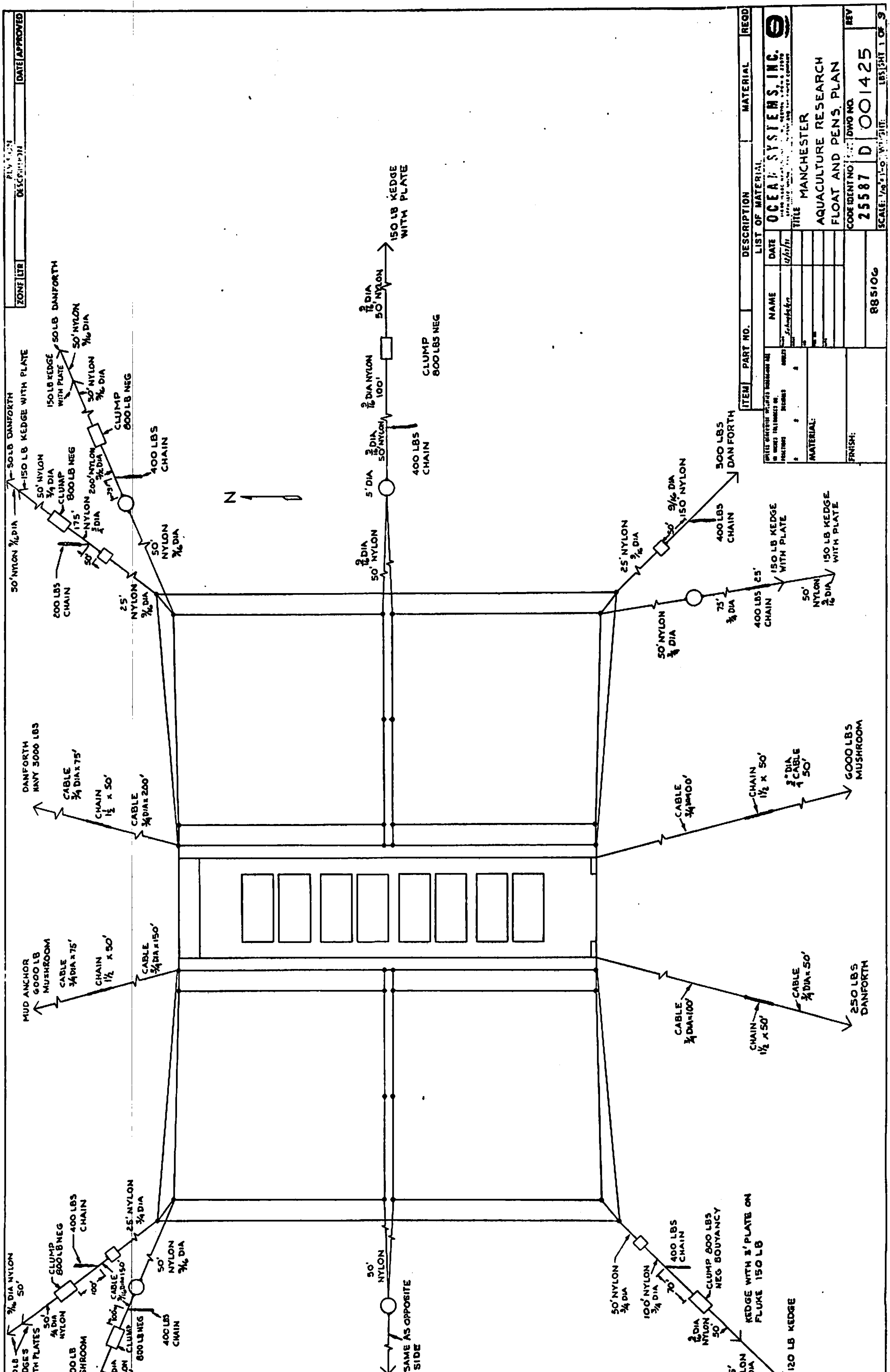
d) The large thermal mass of Puget Sound is utilized to buffer the temperatures in the pen. Unlike pond cultivation, temperatures throughout the year were relatively stable and constant in the net pen enclosures.

e) The net pens have a low environmental profile because they do not require permanent changes in the ecology and can be moved if necessary.

Since chinook salmon are capable of adapting to salt water at a much smaller size than coho, their transfer began earlier. Preparations for the transfer were started in April with the construction of an intermediate net pen enclosure. This pen measures 30' x 30' x 15' deep and is fabricated of 3/8-inch stretch mesh knotless nylon of 126 denier strength. It is supported by floats along the top edge and weighted along the bottom edge.

The growing pens were secured to a moored raft as shown in Figure 25. The 100' x 24' platform was constructed of welded steel cylinders and wood decking. It was extremely sturdy and was built of available materials rather than to meet an ideal configuration. Launching and anchoring of the float took place on July 15. After installation the anchoring system was found to be greatly underdesigned. Much temporary and emergency work, lasting several months, was required before a stable mooring system was devised.

The four main net pens, each 50' x 50' square and 25' deep were moored to the two long sides of the main float. A system of counter weights and anchors held them taut at the four corners regardless of tidal fluctuations. The netting, knotless nylon of 7/8-inch mesh (126 denier strength), could be repaired by serving and proved extremely rugged. Fouling with algae did not constitute a problem below 2 or 3 feet. Heavy mussel sets to approximately 10' became a serious problem at the onset of the spring of 1972.



OCEAN SYSTEMS, INC.
MANCHESTER
AQUACULTURE RESEARCH
FLOAT AND PENS PLAN
25587
D
001425
N
150 LB KEDGE WITH PLATE
CLUMP 800 LBS NEG
400 LBS CHAIN
6000 LBS MUSHROOM
250 LBS DANFORTH
300 LBS DANFORTH
MUD ANCHOR 6000 LB MUSHROOM
DANFORTH NAVY 3000 LBS
SAME AS OPPOSITE SIDE
120 LB KEDGE

Figure25

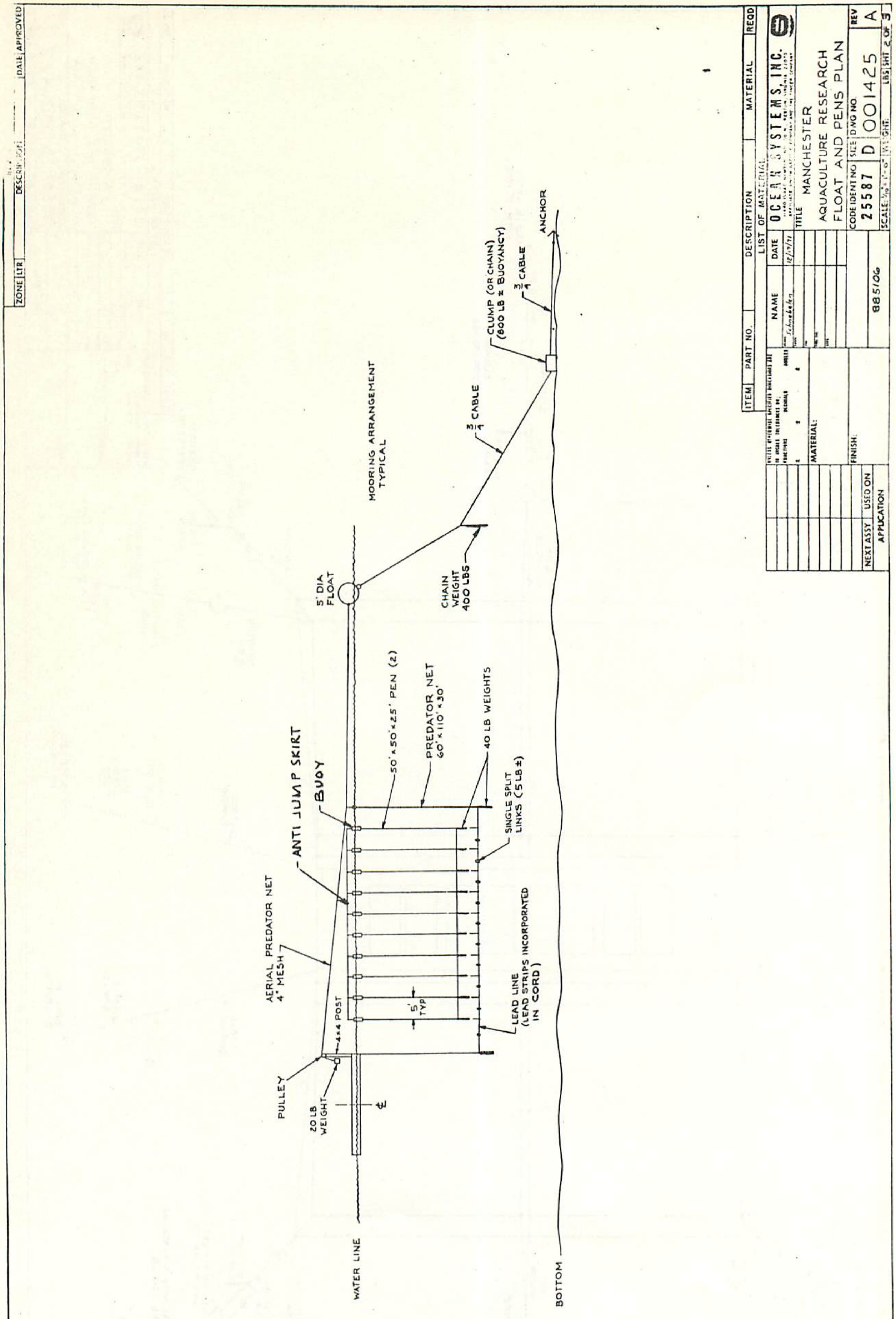
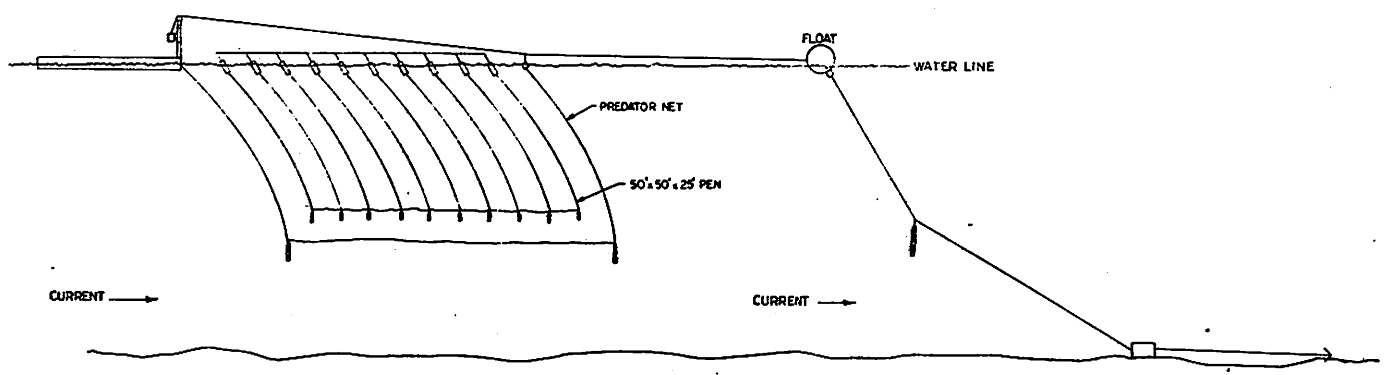

MOORING ARRANGEMENT TYPICAL
AERIAL PREDATOR NET 4" MESH
ANTI JUMP SKIRT
BUOY
50'x50'x25' PEN (2)
PREDATOR NET 60'x110'x30'
40 LB WEIGHTS
SINGLE SPLIT LINKS (5 LB ±)
LEAD LINE (LEAD STRIPS INCORPORATED IN CORD)
5' TYP
4x4 POST
PULLEY
20 LB WEIGHT
WATER LINE
BOTTOM
5' DIA FLOAT
CHAIN WEIGHT 400 LBS
3/4 CABLE
CLUMP (OR CHAIN) (800 LB ± BUOYANCY)
3/4 CABLE
ANCHOR
ITEM
PART NO.
DESCRIPTION
MATERIAL
REQD
LIST OF MATERIAL
NAME
DATE
12/17/71
OCEAN SYSTEMS, INC.
TITLE
MANCHESTER
AQUACULTURE RESEARCH
FLOAT AND PENS PLAN
CODE IDENT NO
25587
SIZE
D
DWG NO
001425
REV
A
MATERIAL:
FINISH:
NEXT ASSY
USED ON
APPLICATION
885106

Figure 26

EFFECTS OF STRONG CURRENTS ON PEN



NOTE:
1. COMPLETE MOORING SYSTEM NOT SHOWN

ITEM	PART NO.	DESCRIPTION	MATERIAL	REQD
		LIST OF MATERIAL		

NAME	SLT
DATE	1-5-73
	OCEAN SYSTEMS, INC.
TITLE	MANCHESTER AQUACULTURE RESEARCH FLOAT AND PENS PLAN
CODE IDENT NO.	25587
SIZE	D
DWG NO.	001425
SHT	3 OF 3

MATERIAL:

FINISH:

NEXT ASSY | USED ON

APPLICATION

Figure 27

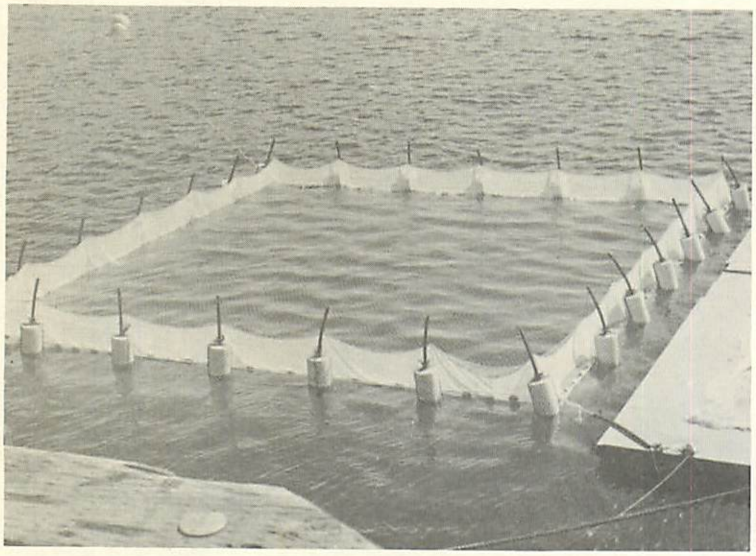
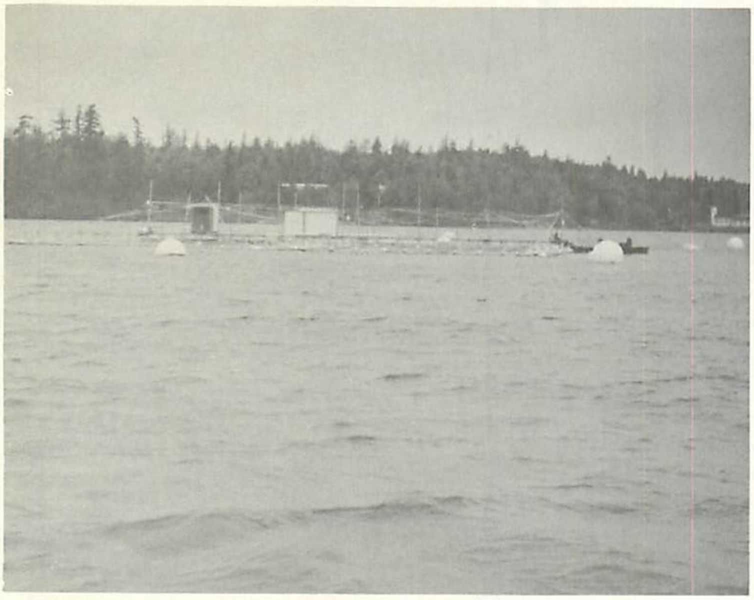


FIGURE 28
The prototype floating net pen. A predator net covers the top of the pen to thwart fish-eating birds.

FIGURE 29
The raft assembly moored in Clam Bay. The small buildings provide storage and shelter. The large round buoys held taut by counter weights maintain a constant tension on the pens.



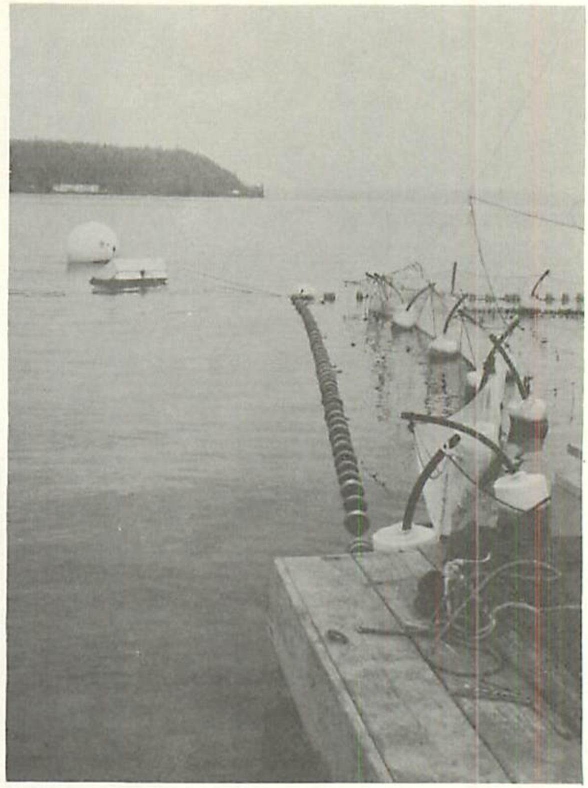


FIGURE 30
Details of the pen installation on the main raft. The small floats support the aerial predator net that was installed to keep dogfish from chewing into the main cultivation pens. The inner pen is similar to the prototype but measures 50' x 50' x 25' deep. The square float in the background supports a counter weight that tensions the pen.

During the project the maximum current experienced was approximately 3 knots. Maximum wave heights were 2 to 2 1/2 feet. Maximum winds, coming out of the SW, were 40 to 50 knots. Debris was a problem and logs, branches, and macro algae were frequently fouled in the nets and rigging.

The system of anchors and counterweights was inadequate throughout the project and continuous maintenance was required. The system did not provide a taut net system during extreme tidal fluctuation.

In August, dogfish (Squalus acanthias) caused serious damage to the pens shortly after salmon were introduced. Dogfish attacked mortalities laying on the bottoms of nets and three or four feet up the sides. With their extremely sharp and abrasive teeth, the dogfish tore dozens of holes up to two feet in diameter while trying to eat mortalities. Several dogfish were found inside the pens and an unknown number of salmon escaped.

Dogfish attacks were prevented by installing an outside net completely enclosing the 50' x 50' x 25' nets at a distance of 5 feet. This predator net was 60' x 110' x 30' deep in dimensions and fabricated of 5-inch stretch mesh gill netting. The concept was highly successful. Dogfish only attempt to bite directly at food and do not have sufficient intelligence to try to open up an entry. The net is damaged incidentally to biting and even a small gap appears sufficient. No attacks were experienced even though the two nets were touching during strong currents.

Gill netting does not appear to be the best material for predator nets. It is not sufficiently strong, and it may entangle desirable wild fish as well as dogfish.

The aerial predator net was designed to keep fish-eating birds from attacking the salmon, but caused chronic problems. The geometry of the main nets became distorted by strong currents and allowed the aerial nets to dip close or into the water. Salmon became entangled and killed, sometimes as many as 10 or 20 per day. When aerial nets were allowed in the water for only a short time, algae became attached and the nets were heavy and difficult to relift. Rips in the net were frequent and extensive.

Seven foot high masts were installed on the main float and the aerial nets were attached to the tops with counterweights to keep the netting taut. This method, while an improvement, was not adequate. The birds were limited in their access as long as the nets were reasonably intact.

The net pens were supported by canister floats which worked well for the early months but deteriorated before the end of the project. The floats (with plastic pipe risers) abraded and ripped holes in the aerial nets and had a tendency to pull free from the headlines. In several cases they ripped netting as they broke free. Under the weight of bay mussels in the spring of 1972, the floats began to sink. Eventually the canister floats were

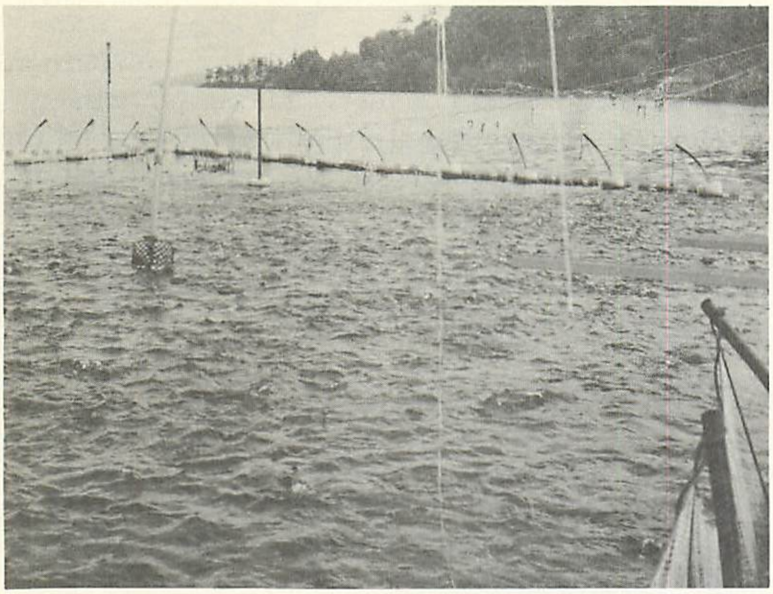


FIGURE 31

Interior details of the cultivating pen. The extended planks facilitate access by divers.

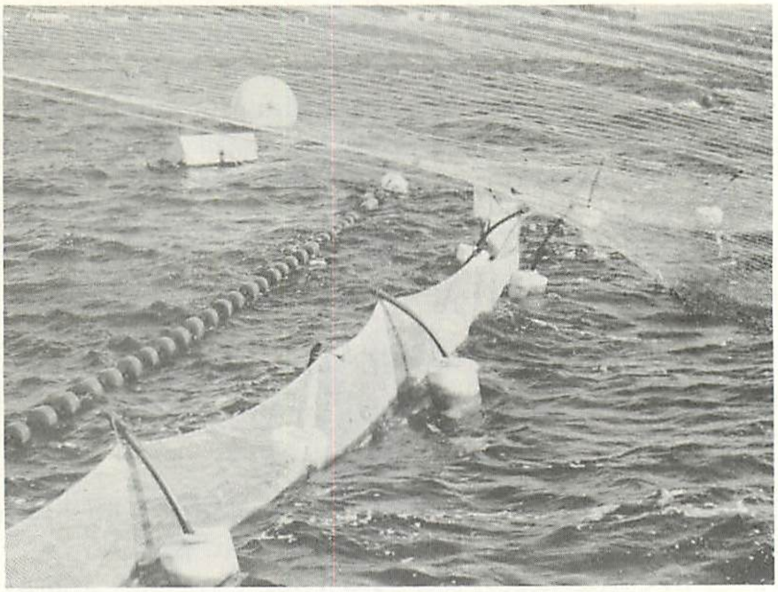


FIGURE 32

Net pen in strong wind and current.

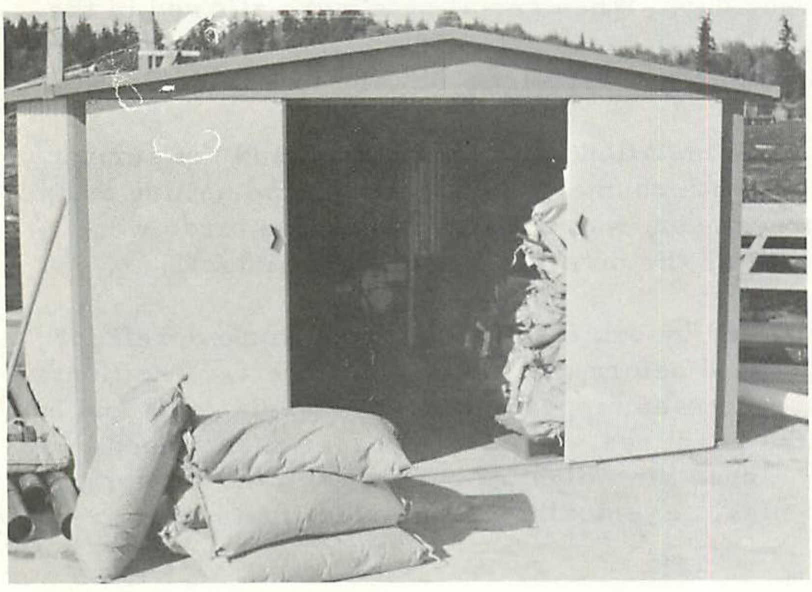


FIGURE 33

Pneumatic feed blower house on the main raft assembly. A gasoline powered blower was used to disperse the feed into each pen.

replaced by eight-foot long styrofoam billets that were sewn continuously around the skirt perimeter.

Some difficulties were experienced when the chain weights beneath the growing pen became tangled in the underwater predator net. The problem was solved by retensioning the predator net, but future installations should have all weights attached outside the outermost net.

In the saltwater phase, the rapid growth of the fish (Figures 20 and 21 required ever increasing quantities of food, and this in itself created new logistic problems. An amphibious truck, DUKW, was acquired for hauling feed to the main float. It has a capacity of 5,000 pounds of feed, and permits shore loading from a forklift truck (Figure 32). A freezer capable of handling 20,000 pounds of moist feed was installed. Feed was at first dispersed by hand, but in October an air blower was installed on the main float in an attempt to increase efficiency.

3.3.3 Operations

The first chinook smolts were transferred to salt water on May 19, 1971. No prophylaxis treatment against disease was attempted. Smolts were seined and hauled by truck to Manchester, where they were briefly adapted to the salinity and temperature difference. Salt water was introduced into the tank over a 30-minute period before the fish were drained through a 2" hose 100' long into the net enclosure.

A total of 394,000 (6,000 lbs.) of chinook were moved to the 30' x 30' pen in 35 trips. About 7,000 fish were released in compliance with the State permit that allowed Ocean Systems to receive these fish from Dr. Lauren R. Donaldson. Another 1,000 fish were flushed into the creek when the pond was drained. Only about 900 chinook (0.25% were lost in transportation to Manchester.

In early June the first evidence of an epidemic of Vibrio angularans[2] occurred. Mortalities increased dramatically on each succeeding day. The presence of Vibrio was confirmed by culture analysis. Vibrio is a bacterial infection endemic in salt water. It usually affects fish more severely in high temperatures or when they are in a weakened state, such as after handling.

On June 9, the chinook were treated with food fortified with Terramycin (TM-50), which was continued for five days. On June 12, the mortality was reversed and by June 19 the attack appeared controlled. Total mortality resulting from the epidemic was about 19,500.

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[2] Subsequent references to _Vibrio_ describe Vibrio angularans, not Vibrio parahemoliticus.

FIGURE 34
Piping from the feed blower house to each pen. Also shown are experimental pens suspended below the main raft.

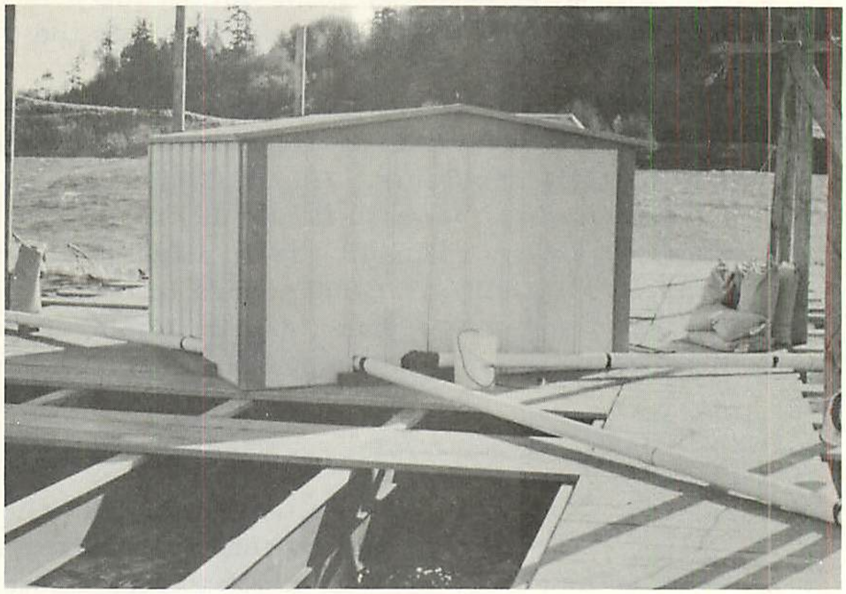
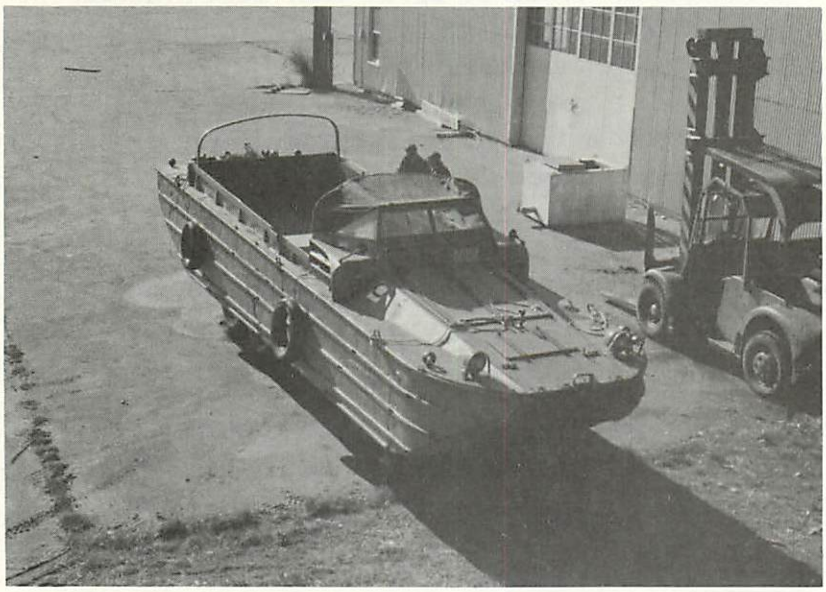


FIGURE 35

An amphibious DUKW that was used to transfer feed from the storage site to the main raft assembly. The vehicle is capable of 5,000 pounds payload per trip.



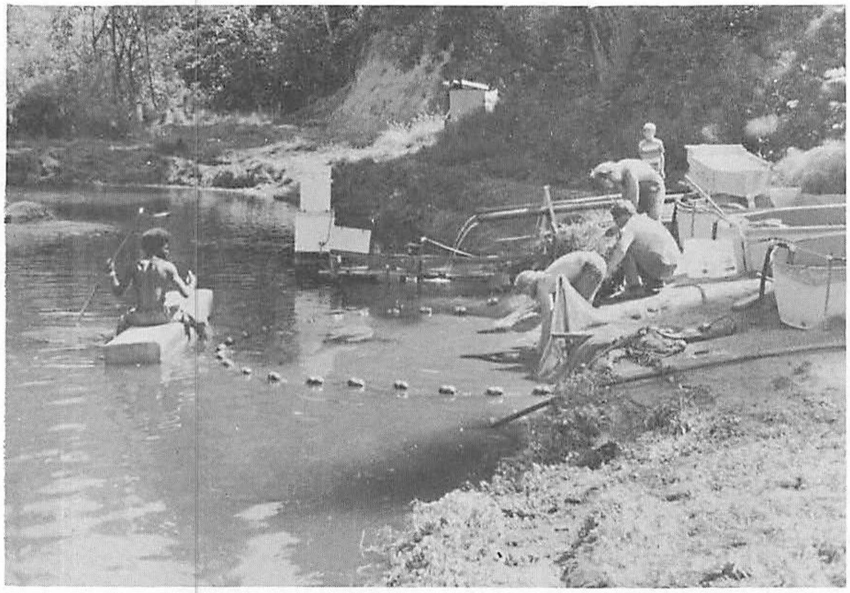


FIGURE 36

Seining of the fish at Glud's Ponds. After the fish were crowded they were brailed into buckets and run through a Nielson grader. Various holding pens and pools are shown which were used to prepare batches for the truck.

FIGURE 37

The Nielsen grader in operation. Each fish slides down between slightly divergent bars and falls through into one of three chutes. The smallest were returned to the pond; the other two groups were transferred to the floating pens at Manchester.

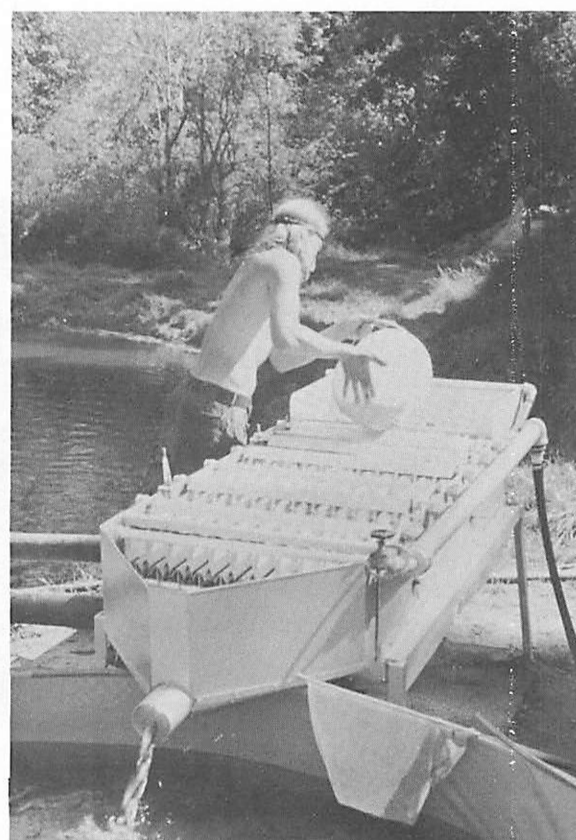
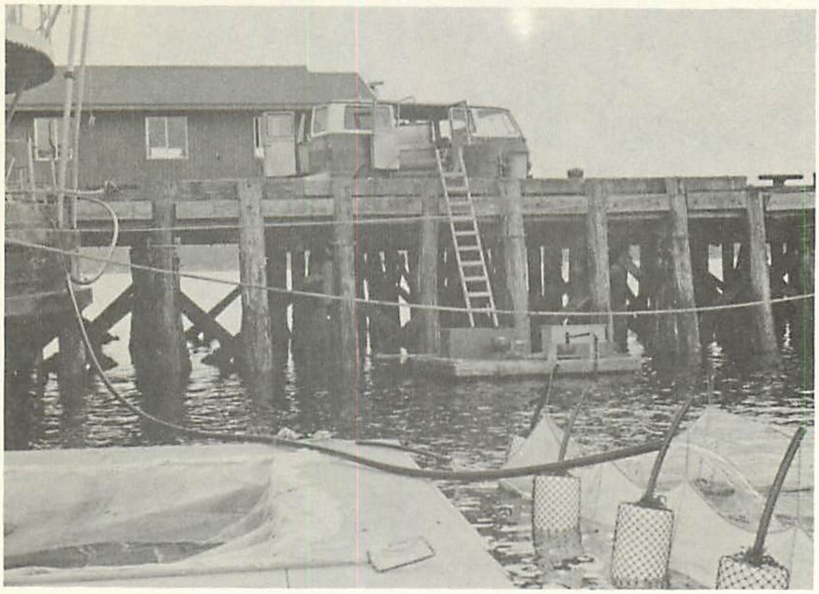
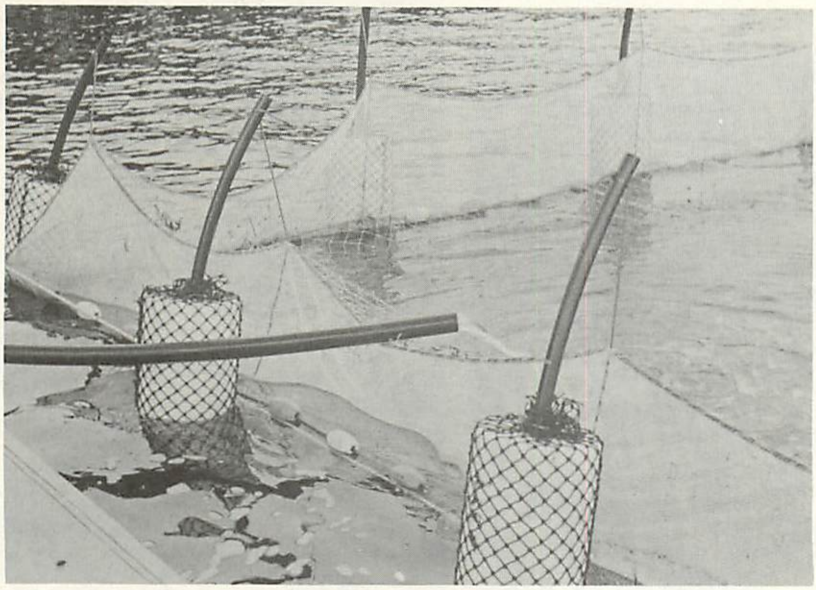


FIGURE 38



Transfer to the floating net pen. A truck with smolts is located on the pier. A pump on the small raft pumps salt water to the box for a controlled temperature and salinity transition. Thereafter, the fish are drained down the long black pipe into the pen. Shown below is the discharge with a small chinook smolt about to enter Puget Sound.



On June 29, however, a second outbreak occurred. It was treated the same as the first and was controlled by July 8. The mortality from the second outbreak was 25,800 giving a total of 44,300 from Vibrio in a month. Experience in this project and elsewhere indicates that prophylaxis treatment for Vibrio should be undertaken at transfer to salt water and other situations of unusual stress to the fish.

Between July 23 and August 12, the chinook were weighed and then sorted with a Neilson automatic fish grader. They were transferred to the two 50' pens on the west side of the main float after Terramycin treatment. Very little disease was encountered, but scale loss due to handling, aggravated by high water temperatures, (above 14°C) contributed to 33,632 chinook mortalities.

Between July 7 and August 31, the coho salmon were graded, transported, introduced to salt water, and stocked in the two 50' pens on the east side of the float. Only coho larger than 15 grams each were chosen. A total of 261,000 coho were successfully transferred with a mortality of 1.1% during the process. These coho were treated with Terramycin prior to the move and no Vibrio outbreak occurred.

The coho salmon remained on the Nelson "Silver Cup" dry feed. For test purposes, half the chinook salmon were continued on Oregon Moist Pellett II while the other half were changed to Silver Cup dry feed in August. The salmon diet figures are summarized in Tables IV and V. The conversion rates shown, while important to the economics of the project, can be misleading since they include mortalities, losses and at times questionable inventory statistics. Their optimization depends on an accurate estimate of the total number and weight of fish fed. Since inventories during the project varied in their accuracy, feeding rates were not always optimal.

Natural food brought to the nets by currents may have contributed some small portion to the conversion rates. Preliminary small-scale experiments conducted with underwater lights by NMFS indicate that this contribution could be no more than 10%. Because of the large number of salmon held in the floating pens, the actual contribution must have been considerably less.

Disease losses during the saltwater phase constituted about 33% of the chinook and 11% of the coho. Disease monitoring was performed regularly by Anthony Novotny of NMFS, particularly for Vibrio, furunculosis and kidney disease. No external parasites caused epidemics, although an occasional Argulus was found. In order to assess disease effects as well as to adjust the inventory, mortalities were removed twice weekly by divers. A pro-rated mortality count greater than 1% per month was considered suspicious.

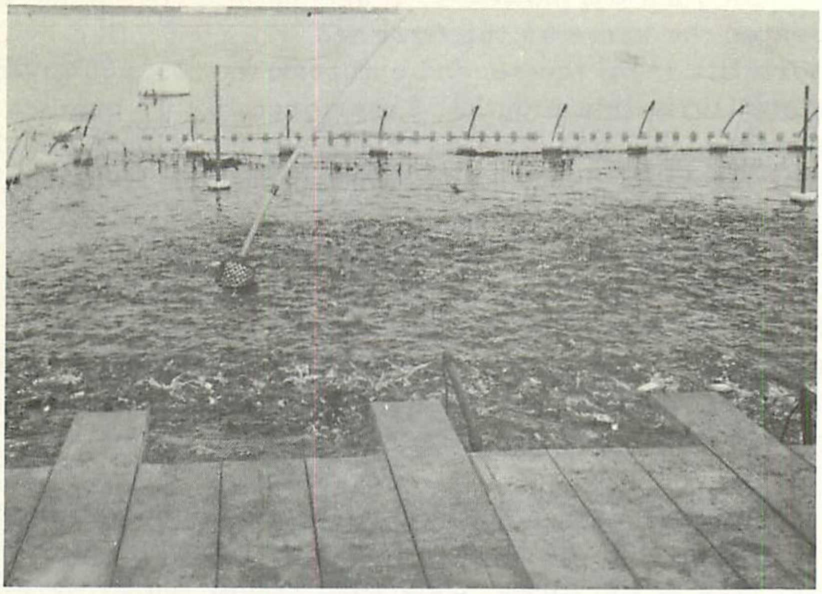
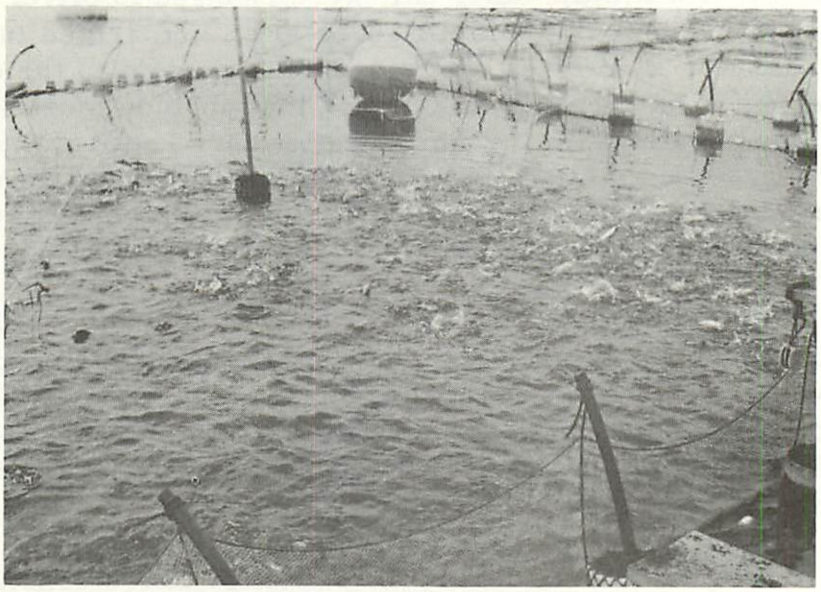


FIGURE 39

Feeding time on the main raft. These photos show the problems associated with the aerial predator nets. Various devices from poles to beachballs were used to keep the nets out of the water.



Growth was very good during September as the 12.2°C temperature was close to optimum for both species. Both groups doubled in size with excellent feed conversions. Disease losses were normal in September, with only Vibrio being of any consequence. The chinook indicated a Vibrio mortality rise in mid-September, but were successfully treated with Terramycin.

During September, the second group of coho were graded into two groups and 12,250 fish were transferred to NMFS for a feeding experiment. Very little scale loss was encountered when handling the coho in salt water and mortality was minimal (as opposed to chinook which exhibited very loose scales in salt water and suffered high losses).

During October temperatures dropped and began to affect all fish. The coho continued their growth, although rations were cut slightly to compensate for the lower metabolism at the colder temperatures. Feed conversions remained constant for the coho and there was no disease.

Both pens of chinook once again contracted Vibrio and were shifted to medicated feed. The fish were, however, reluctant to eat it. On October 25, at the termination of treatment, the second pen of chinook was shifted to Nelson dry food. Both groups of chinook had been growing and converting about equally, and dry food is cheaper and easier to handle. At the end of October, however, sub samples of chinook in both pens showed sharp declines in growth and conversion. This was attributed to disease and unpalatable medication.

Difficulty became apparent in obtaining reliable sample weights. Dip nets and towed nets up to four feet in diameter allowed the larger fish to avoid capture more easily than smaller fish. Obviously, such samples are biased and all resultant plans and statistics are unreliable. It was found necessary to use a large seine which would sweep a big area of the pen.

During November saltwater temperatures decreased to a low of 9.4°C. Chinook growth rates and feed conversions continued poor. The coho continued feeding well and both growth and conversions were excellent. Disease presented no major problems for either species this month.

During December the water temperatures dropped below 8°C consistently and both coho and chinook began feeding poorly. To attempt to stimulate feeding, the chinook in the southwest pen were switched back to Oregon Moist Pellets but little difference was noted between the moist and dry feed. A surprising, but not serious, mortality was sustained in the first pen of coho approaching market size. It is suspected that the increased density in this pen, approximately 1.6 lbs/ft^3, and resultant low dissolved oxygen were major factors.

Harvest operations began during mid-December and are described in a later section. The largest fish were retained for brood stock purposes. During the last week of December, a rip occurred in the corner of the southeast coho pen and an estimated 70,000 market-size coho escaped. Many of the fish remained in the vicinity of the pilot project raft and some 2,000 were recovered. The bulk of the escapees were classified as an involuntary release for the Washington State sportsmen.

During January, water temperatures dipped to 5.5°C and rations for both species were cut to 1% of body weight per day. No significant growth occurred. Growth and conversion data for the coho during January became confused as the population was reduced and fish were stressed. Disease was not a problem in January.

Temperatures began to increase during February and consistently hovered between 6.5°C and 7.0°C. Rainfall and turbidity were unseasonably high and feeding behavior was correspondingly poor on several days. Feed rations were increased in an attempt to stimulate growth on the rising temperatures, but no increase was noticeable. Once again disease was not a problem and no medicated feeds were required. Harvest of the market-size coho was completed and a sub market-size group was left for further growth. Feed conversion for the coho during February is not meaningful due to the stress of harvesting and transfers.

Warmer air temperatures and gusty southwest winds predominated in March and water temperatures climbed to 7.9°C. The chinook continued to feed and convert poorly and both species were treated with TM-50 due to the rising incidence of Vibrio. No meaningful samples of the largest coho kept for brood stock were taken, but there was evidence that they grew significantly all winter.

Water temperatures responded to generally fair and warm weather in April. Water temperatures increased to 8.6°C and the increased photo period stimulated all fish to feed vigorously. Growth rates and feed conversions increased. The brood stock coho reached an average weight of 2.5 pounds by the end of April. The chinook finally reached market size at approximately 3/4 pounds and harvesting began on April 25.

Both dry and moist diets evidenced marked improvement in feed conversions and acceptability this month with increased temperature. Neither feed appears to be of appreciable growth value below 7°C and dry feed was poor below 7.5°C

Approximately 3,000 small fish were turned over to the NMFS researchers for feed and ration studies. The intent of this work is to investigate feed conversions and growth rates resulting from various rations at increasing temperatures and photo periods.

3.4 Harvest and Marketing

The purpose of the project was to demonstrate the feasibility of commercial scale production of pan-size salmon. In addition to cultivating salmon, it was necessary to harvest, process, and sell the product. Several approaches were investigated and test marketing was conducted prior to actual harvesting.

3.4.1 Description of Equipment and Process

In October 1971, a trial batch of pan-size salmon was processed by an established salmon packer in the Seattle area. The results and time studies indicated that the facilities and personnel used to dress large salmon could not process the pan-size fish economically. A processing system was designed specifically for the pan-size salmon. Available commercial facilities and equipment were reviewed and a material balance was conducted on the system in order to minimize handling. Materials and equipment were ordered for mid-December delivery.

3.4.2 Harvesting

Fish were crowded within the pens with a 30' x 60' seine. Once crowded they were pumped with a six-inch fish pump from the seine across a dewatering device and spilled into an adjustable bar grader where they were separated into three sizes (submarket, market, and brood stock). The market size fish were discharged into holding nets where they were held until a full-day's processing run had been accumulated.

Slaughtering by chill killing was selected because it minimizes handling, provides the freshest product, and eliminates struggling prior to death. Electric shock and suffocation were also investigated but were rejected as inferior methods. The fish were pumped from the holding net across a dewatering device, and discharged directly into a converted dairy cream storage tank containing -1.5°C concentrated brine. They were instantly killed and within minutes their body temperature was lowered to 0.0°C. The chilled fish were loaded into 100-pound tote boxes and trucked to the processing plant.

3.4.3 Processing

Butchering and packaging operations were standard and manual, although special care was exercised to maintain the high quality of the product. Butchering operations were physically separated from the inspection, weighing and packaging stations. Most of the fish were marketed "dressed heads on", with only the entrails, gills, and kidney tissue removed. Weight loss in processing was about 20%. A vacuum eviscerator was used to remove the kidney tissues without scraping or damaging the bones and membranes of the belly cavity.

After inspection, the fish were held in chilled brine until they were packaged. All fish were graded into 6-8, 8-10, 10-12 and 12-14 ounce categories. Each fish was placed into a polyethelene pouch and heat sealed. The pouched fish were placed into five-pound waxed cardboard cartons which were overwrapped with polypropylene film.

The fish were frozen at -40°C in a conventional blast freezer, and then packaged into thirty pound corrugated cardboard master cartons prior to being transferred to the warehouse. A coding system was developed to identify each lot and the day of processing. Samples from each day's pack were sent to an independent laboratory and bacteriological analyses were made to count total bacteria, coliforum bacteria and staphylococci.

3.4.4 Description of Operations

Harvesting and processing equipment was assembled throughout November and early December to conduct a trial run in mid December. Permission to begin harvesting the crop was received by the Washington State Department of Fisheries and a wholesale fish dealer's license was obtained. The Department of Fisheries also ruled that the State privilege tax of 2% of the primary market value of all sales was applicable to farm-raised salmon.

During December several trial runs were held in order to perfect the harvesting process. In general, all worked well, although the mechanical grader caused considerable bruising and scale loss to larger fish. In addition, very active smaller fish often bypassed the grading slots instead of dropping through. For these reasons, hand grading was substituted and a crew of harvest workers replaced the mechanical grading system. Weather conditions during winter months were sometimes severe and efficiency dropped. Proper clothing under such conditions is vital and as much shelter as possible is important.

The harvest continued whenever fish reached market size until the termination of the Pilot Project on June 30, 1972. In addition to the fish which were harvested, others were released for the sports fishery, escaped, were released because they would not reach market size prior to the end of the Pilot Project, or were turned over to NMFS for research projects. In addition, approximately 5,200 were retained as brood stock for future selective breeding purposes. Unknown, but probably significant, numbers of slow growing fish were lost to cannibalism. Frequently, small salmon were found in the stomachs of larger fish being processed.

The following table summarized the harvest:

	Coho		Chinook	
	Number	Weight	Number	Weight
December 1971	14,472	9,806		
January 1972	45,326	32,889		
February 1972	15,218	11,486		
March 1972	4,431	2,847		
April 1972	745	458	15,361	9,167
May 1972			78,131	50,462
June 1972			37,292	17,963
Total	80,192	57,486	130,784	77,592
Grand Total			210,976	135,078

Processing proceeded in a routine fashion as described earlier. These operations are shown in Figures 40 through 45. Late in June, a small batch of 10-12-ounce salmon were boned in order to test customer reaction to the boned product.

3.4.5 Marketing

In order to evaluate the market appeal of pan-size salmon, the Division of Marketing Services of the National Marine Fisheries Service conducted a small-scale market survey during the spring of 1971. Samples of the fish were sent to 27 selected brokers and buyers throughout the nation. The response was generally favorable. A copy of the inquiry letter is provided in Appendix C.

After January 3, 1972, pan-size salmon were introduced to the institutional seafood market by established seafood brokers. Five marketing objectives were given to the brokers:

a) Establish the pan-size salmon as a new high quality, gourmet item worthy of a premium price;
b) Concentrate on the prestige restaurant trade and establish a repeat order business in a major city;
c) Establish an export market;
d) Test the retail market;
e) Introduce the fish selectively throughout the United States in order to begin the development of a brood market base.

FIGURE 40

Butchering Operations. Fish are inspected and washed; the bellies slit and gills cut. Butchered fish are then placed on a slide for transfer to the eviserating station.

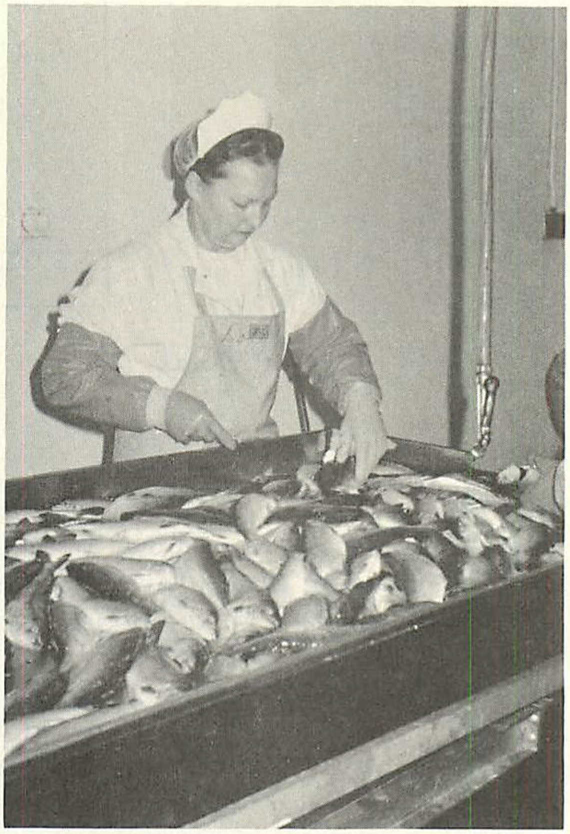


FIGURE 41

Eviscerating. Viscera and gills are removed and placed in containers to be recycled into fish food. Eviscerated fish are washed, trimmed and inspected before passed to the vacuum eviscerator to remove kidneys.

FIGURE 42

Kidney Removal. The kidney is sucked from the backbone without scraping with the use of a vacuum eviscerator. This approach serves to keep the belly cavity and rib cage intact while thoroughly removing the blood and kidney material.

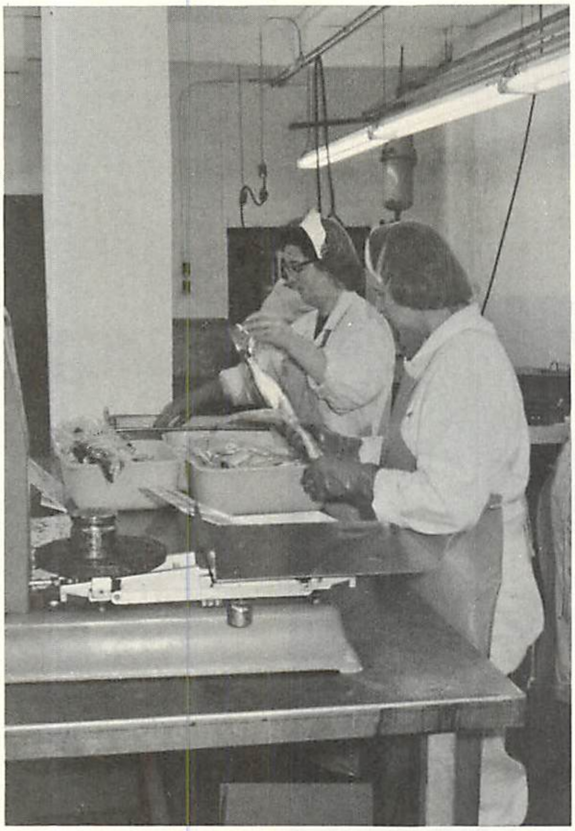


FIGURE 43

Inspection and Grading. Each fish is weighed and separated into size categories. Graded fish are stored in chilled containers until each group is to be packed.

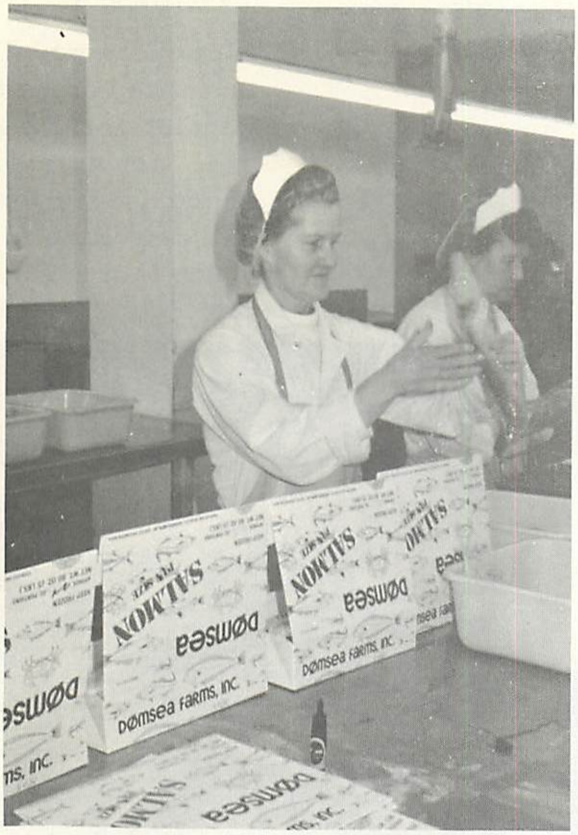


FIGURE 44

Packaging Operations. Each fish is placed into an individual polyethelene envelope. The fish are then packaged into five-pound institutional cartons.

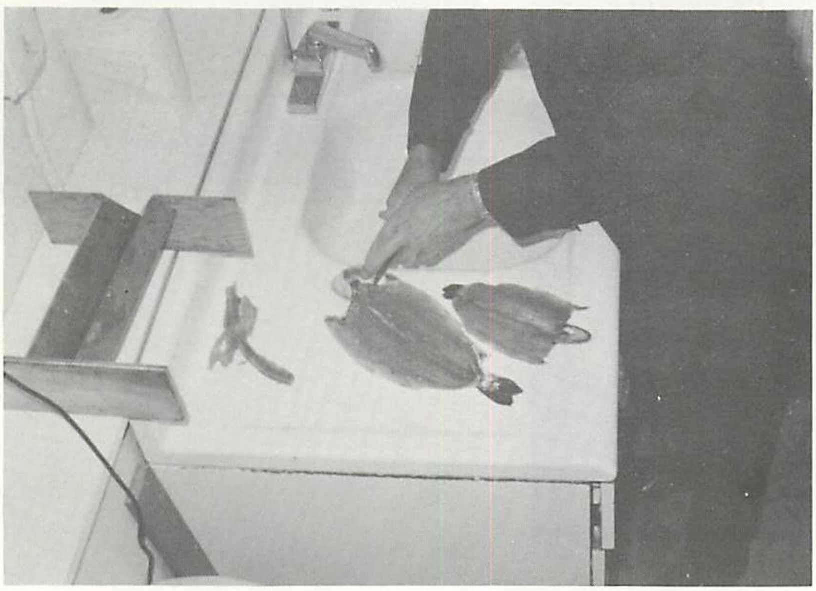


FIGURE 45

Boning. Small quantities of the fish were boned in order to conduct test marketing. The backbone was removed and rib bones stripped away from the flesh.

All objectives were achieved and the product has been sold by wholesale distributors to restaurants at approximately $1.75 per pound. The retail market was tested on a small scale, but due to the shortage of product and the high demand of the institutional market, the results were not conclusive.

3.5 Public Awareness

Since one of the primary goals of the Sea Grant Program was to disseminate information, an objective of this project was to increase public awareness of salmon aquaculture. Simultaneously an informal attempt was made to assess public acceptance of salmon aquaculture as an industry in the Puget Sound area.

A variety of semi-popular articles were published in trade magazines and newspapers. A partial list of these articles is included in Appendix A. In addition, a documentary film appeared on Seattle television in four installments during December 1971.

An extensive number of visitors toured the facility, including persons from Russia, Great Britain, Argentina, Nigeria, Norway, Japan, Israel, Canada, South Africa, France, U. S. Senators and Congressmen, representatives from U. S. Government agencies, and state and local agencies. Public addresses reached such groups as the Port Orchard Rotary Club, the U. S. Navy Technical Supervisors at Bangor, Washington, the County Planners Association held at Aberdeen, Washington, and various audiences through the country. A more complete listing is shown in Appendix B.

In conjunction with local sportsmen groups and the Washington State Department of Fisheries, 631 market-size coho were tagged and released in January 1972. This effort was part of the In-Sound Salmon Enhancement Program which appears to indicate that salmon which are cultivated in saltwater pens for a significant time prior to release are more likely to remain in Puget Sound rather than migrate to the open ocean. Releases of the tagged fish were made at Manchester and in Case Inlet in southern Puget Sound.

During January, the Department of Fisheries conducted hearings in Olympia to assist in the development of mariculture procedures. Washington State legislation previously authorized the Department of Fisheries to establish such procedures and authorize commercial salmon aquaculture. In general, public comment was favorable, and the Department of Fisheries decided to proceed with the licensing of commercial operations.

3.6 Environmental Monitoring Program

The presence of large numbers of animals in a restricted space makes the problem of waste materials inevitable. As in any feed lot operation, the salmon aquaculture project has the potential for contributing quantities of unused feed and fish waste material to the environment. In order to measure the direct effect of aquaculture in Clam Bay, we attempted to introduce a monitoring program in the fall of 1971. This program was not part of the original plan, but was felt worthwhile.

It was decided that direct changes in water quality would be slight and difficult to interpret due to the high tidal exchange. The approach was to measure changes in the degree and composition of sediment on the bottom in the vicinity of the pens. Changes in organic content and sedimentation rate were considered to be the best indicators of the fish waste influence. Four parameters were to be checked:

a) Sedimentation rate
b) Total organic carbon
c) Total organic nitrogen
d) Quantitative changes in benthic fauna

A twelve-point 400 x 500 ft. grid was established on the bottom by divers, with the net pens at its center. One additional point was located at a distance of about 500 ft. from the grid. Depths of these sampling sites range from 20 to 85 ft. at mean low water. A core sample was to be taken at each point, refrigerated, divided into sections, and analyzed for total organic nitrogen and total organic carbon. Ballinger and McKee (1971) have shown that the percentage of organic nitrogen and carbon give a good correlation with general pollutant loading and flow characteristics of overlying water bodies. The high organic content of fish wastes contrasts with the relatively low organic content of a sand and silt bottom.

When the cores were collected, dissolved oxygen readings were to be taken at the same location on the bottom and one meter above the bottom, both at strong ebb and at near slack water conditions.

Sedimentation was to be measured by installing cup-shaped containers at eight grid points. The collected material was to be collected and weighed.

3.6.1 Environmental Monitoring Operations

In practice, inclement weather as well as operational problems compromised the program to the point that little technical data was obtained. However, visual inspection in the vicinity of the floating net pens was conducted twice each week.

Sediment consisting primarily of fecal material but also of excess food did build up, particularly during the month before harvest. The depth of sediment varied at its peak from three or four centimeters directly under the pens to a trace 100 feet peripherally in the directions of maximum current flow. No sediment was observed beyond 100 feet from the pens.

Most benthic fauna and flora were destroyed in the 100 foot square area directly under the pens, probably due to high H_2S concentrations. In'a periphical zone approximately 30 feet surrounding the pens, benthic organisims were visibly affected. Beyond 30 feet from the pens, no visible deterioration was evident.

The National Marine Fisheries Services is conducting a detailed environmental study of the Pilot Project site beginning during the latter stages of fish rearing and continuing as the bottom reverts to normal. The results of these studies will be published at a later date.

4.0 CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

The basic objective of the Pacific Aquaculture Program was successful. Large numbers of coho salmon were cultivated at high concentrations in floating net pens in the salt waters of Puget Sound. Growth rates and conversion rates were good. The bulk of the fish reached market size at three-quarter pound after fourteen months from spawning. The fish were healthy and market acceptance seems good. We consider salmon aquaculture to be ready for full commercial development, albeit with substantial risks. Significant problems do remain to be solved.

1. Adequate inventory control was not accomplished. Without exception, there were considerably less fish than expected from projected write downs and mortality counts. The variability was not constant. On the other hand, Peterson estimates - a sample of fish counted, tagged, and released to be statistically analyzed on an immediate subsequent sample - gave quite low estimates.

   Loss of inventory control obviously means that business planning is difficult. It also means that control of feeding is lost. Feed cost and good conversions absolutely require accurate knowledge of the numbers and size of the group of fish to be fed.

   Beyond that, it is vital to learn about unexpected decreases of fish quickly in order to determine the causes and take timely action.

   To maintain inventory control it is necessary to determine how many fish are in a pen at a given time. Possible answers may be:

   a) Seine, grade, and weigh the fish more frequently. However, this is time consuming and stresses the fish.
   b) Better ways of conducting Peterson estimates.
   c) Develop an insitu counter, such as an ultra sound transponder system.
   d) Better control of the causes of losses and devising means of detecting the existence of losses.

Unaccounted for losses of fish appeared to come from several sources:

a) Nets developed holes and rips. Heavier and better designed nets, protection systems, and mooring systems must be developed.

b) Cannibalism occurs when the larger fish are more than three times heavier than the smaller fish. Sufficient grading will be necessary to prevent such a wide size discrepancy.
c) Predatory sea birds were a chronic problem. Adequate means to deter such birds must be developed.
d) Dogfish caused unknown escapes during the early part of the experiment. Concentric nets providing a separation were a successful solution.
e) Small fish disintegrate quickly and may have been missed by mortality counts.
f) Theft is an ever present concern as the fish reach market size. Thieves were chased off after being seen trying to fish in the pens. Two lures were found in the mouths of brood fish.

2. The chinook did not do well. It is our opinion that the species is not suitable for commercial aquaculture at the present state of the art.

a) They were considerably more subject to Vibrio at almost all saltwater stages of the project.
b) They did not adapt well to dry food in the freshwater stage. In salt water they did grow well with dry food in warmer water, but grew better in colder water with moist food.
c) The chinook sustained far more losses from handling and scale loss in salt water than coho.
d) Growth virtually stopped in October for the chinook, and they had to be carried through the winter.
e) The costs of raising a pound of chinook to market size were far higher than a pound of coho.

3. Significant numbers of the second group of coho, transferred to salt water in August, did not begin to grow until spring. There are strong indications that coho must be transferred early in the summer to be successful.

4. Underdesigned saltwater facilities caused serious maintenance and logistic problems. Anchors dragged, nets ripped, and cables and lines broke.

5. While present available foods are adequate, they are obviously not ideal. Further research is needed.

6. The fish raised in this experiment were spawned from wild parents which were evolved from the necessities of life in the sea. A fish best adapted for cultivation by man in the environment of a net pen could have marked advantages over a wild fish. Genetic selection of suitable strains for cultivation may well be the key to future aquaculture.

APPENDIX

A. List of published newspaper and magazine reports.

B. List of presentations.

C. Market Survey inquiry letter sent by the National Marine Fisheries Service, Division of Marketing Services.

APPENDIX A

LIST OF ARTICLES AND STORIES

Future
January issue - Sea Grant 70
January issue - Oceanology International
December issue - Fish Farming Industries

Fish Farming Industries, October 1971, Vol. 2 No. 4 p. 4 - Description of project and feature article to appear in December issue.

Agence France Presse, May 24, 1971

News Release, Office of Floyd V. Hicks and Julia Buther Hansen, July 20, 1971, describing serving of fish in Congressional dining rooms. Story was distributed to Seattle Post Intelligence, radio KCMC and KVI, KTAC, KTNT, Tacoma News Tribune, TV KING, KIMO, Bremerton Sun, Radio KBRO, Washington Post.

Tacoma News Tribune, Malcom MacNey, series of six articles on aquaculture in Puget Sound. Placed in Congressional Record on September 9, 1971 by Representative Floyd V. Hicks, pp E9348-9352.

Seattle Post Intelligence, Thursday, April 22, 1971. Feature article entitled "Salmon Farm under Experiment in Sound", by Judy Ismach.

The Seattle Times, January 20, 1971. Feature article by Hill Williams entitled "Sound Seen as Home of Salmon Farms".

The Seattle Times, October 17, 1971. Feature article by Hill Williams entitled "Puget Sound Site of Salmon Farm Tests".

Seattle Post Intelligencier (no date). Article by Dan Page entitled "Salmon Project Funded".

The Bremerton Sun, March 23, 1971. Article by Elling Simonsen entitled "Few Weeds Growing in Ocean Farming".

The Bremerton Sun, July 6, 1971. Article by Elling Simonsen entitled "Manchester Project Very Encouraging".

Tacoma News Tribune, July 21, 1971. Article by Malcom MacNey entitled "Aquacultured Fish on Varied Culinary Diet".

The Bremerton Sun, December 1, 1970. Feature article by Travis Baker entitled "Optimum Salmon - an Industrial $$$ Test at Manchester".

The Seattle Times, December 20, 1970. News story entitled "Underwater Farms could be big industry, says Bert Cole (Commissioner of National Resources)".

Parade Magazine, May 9, 1971. Feature story entitled "Can Fish Farms Solve the Food Problem?" By Sid Ross and Herbert Kupferberg, pp 12-13.

Commerce Today, June 14, 1971, p. 29. "Private Salmon Venture Boosted".

Tacoma News Tribune and Sunday Ledger. Article entitled "Fish Farmers Breed Super Salmon with Diet Control".

Port Orchard Independent, September 30, 1970. "Aquaculture Project may Lead to Industry of the Future for Kitsap County". Paper also featured an editorial supporting the project.

Bainbridge Review, January 2, 1971. "Raising Salmon in Pens".

Bremerton Sun (no date). "Power Plants and Fish Farms".

Bremerton Sun, March 22, 1971. Feature article by Elling Simonsen entitled "Fish Farming Prospects Look Good".

Bellingham Hearld (no date). "Sea Farming Experiment Appears to be a Success".

Tacoma News Tribune, June 20, 1971. Editorial entitled "Farming Puget Sound".

APPENDIX B

PRESENTATIONS

1. Meeting of Rural Development Subcommittee of the Overall Economic Development Committee appointed by the Board of Kitsap County Commissioners. October 8, 1970. As reported in the Overall Economic Development Plan (OEDP) for Kitsap County, Washington. November 1970.

2. Meeting of Natural Resources and Environment Subcommittee of the Overall Economic Development Committee appointed by the Board of Kitsap County Commissioners. October 19, 1970. As reported in the Overall Economic Development Plan (OEDP) for Kitsap County, Washington. November 1970.

3. Presentation of fish to the members of Congress by Representatives Floyd V. Hicks and Julia Butler Hansen.

APPENDIX C

National Marine Fisheries Service
Division of Marketing Services
2725 Montlake Boulevard East
March 15, 1971

SALTWATER-FARMED SALMON

Historically, salmon have been an important food resource in the Pacific Northwest. To supplement natural production, various governmental agencies operate 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 control over the entire life cycle of these fish, thereby enhancing the capability for breeding selectively for characteristics best suited to market demands. Research of this nature is currently being conducted at the National Marine Fisheries Service Aquacultural Experiment Station located at Manchester, Washington, in Puget Sound.

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.

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.

When transferred to the floating pens, the fish are fed with Oregon Moist Pellets, a wet, high-protein feed, originally compounded for salmon hatcheries. This feed is supplemented by the naturally-occurring plankton and other small forms of sea life that are carried in with the tidal currents. Growth under such ideal conditions is accelerated considerably over that normally achieved in the natural pattern of extended freshwater life. Salmon reared by this method are ready for marketing as trout-sized fish in 18 months or less.

Samples of these saltwater-reared salmon are being distributed by the National Marine Fisheries Service in an effort to obtain information from retailers, wholesalers and restaurant operators as to their interest in merchandising them. Information is needed as follows:

(1) Market form desired--dressed, head-on; dressed, head-off; or boned.
(2) Size or sizes preferred
(3) Acceptability of price
(4) Interest in merchandising these salmon

In January, 1972, a commercial enterprise which has recently entered this field, will have 400,000 saltwater-reared salmon available to market. The fish are being raised with technical assistance from the National Marine Fisheries Service and will be available fresh and frozen throughout the year.

If this initial sampling is successful, the company will raise approximately two million fish to be marketed starting January 1973. Since the eggs for these salmon must be hatched in August 1971, the information on market potential is needed prior to August.

Although it is difficult to predict at this time, it is expected that the wholesale price of the fish f. o. b. Seattle will be between \$. 90 and \$1. 15 a pound, depending upon size and market form.