EH

FISH COMMISSION

RESEARCH HEADQUARTERS

ROUTE 2, BOX 31A • • • CLACKAMAS, OREGON • • • 97015

AIR MAIL

January 3, 1972

Mr. E. J. Huizer, Deputy Commissioner
Alaska Department of Fish and Game
Subport Building
Juneau, Alaska 99801

Dear Ed:

Your letter to Gene concerning private chum hatcheries in Oregon was forwarded to me. I am rapidly becoming our "chum" man, through no particular effort on my part!

I have enclosed (1) a copy of Chapter 203, 1971 Oregon laws. This is the new law that allows private chum hatcheries in Oregon; (2) policies and procedures developed by our agency to handle applications; and (3) a copy of our application form.

We have received seven applications (each with $100 fee) to date and have issued one permit. The second application received will be reviewed next month and I expect a permit will be granted.

Also enclosed is a copy of the one permit we have issued. It gives you some idea of what is involved and how we responded.

I will be seeing you in Sacramento in January if you attend the PMFC meeting called by Dr. Harville. If you have any questions, we can talk them over at this time.

Sincerely,

Wallace F. Hublou
Director of Research

cc: Kruse

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the provisions of the contract shall be awarded to one of the parties, the prevailing party, whether he is the party specified in the contract or not, at trial or on appeal, shall be entitled to reasonable attorney fees in addition to costs and necessary disbursements.

(2) Attorney fees provided for in a contract described in subsection (1) of this section shall not be subject to waiver by the parties to any such contract which is entered into after the effective date of this Act. Any provision in such a contract which provides for a waiver of attorney fees is void.

(3) As used in this section "prevailing party" means the party in whose favor final judgment or decree is rendered.

(4) As used in this section "contract" includes any instrument or document evidencing a debt.

Approved by the Governor May 19, 1971.
Filed in the office of Secretary of State May 19, 1971.

CHAPTER 203

AN ACT

[HB 1328]

Relating to privately operated chum salmon hatcheries.

Be It Enacted by the People of the State of Oregon:

SECTION 1. (1) The commission may issue a permit, subject to such restrictions and regulations as the commission deems desirable, to any person to construct and operate a chum salmon hatchery.

(2) The application for a permit to construct and operate a chum salmon hatchery shall include an application fee of $100.

SECTION 2. (1) Prior to issuance of any permit by the commission, a public hearing shall be held. Notice of the hearing shall be published at least once and at least 10 days prior to the hearing in a newspaper of general circulation in each of the counties in which the hearing is to be held, or if no such newspaper is published in that county or counties, then such a newspaper in an adjoining county.

(2) The hearing shall be conducted by either the commission or a representative designated by the commission.

(3) The commission shall notify the State Game Commission prior to any public hearing and shall obtain their recommendation on the proposed private hatchery.

SECTION 3. No permit shall be issued:

(1) Which may tend to deplete any natural run of anadromous fish or any population of resident game fish.

(2) Which may result in waste or deterioration of fish.

(3) If the proposed operation is to be located on the same stream or river or tributary thereof on which a state or federal fish culture facility is established or is planned to be established.

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(4) If the proposed operation is not consistent with sound resource management and is not in close proximity to the ocean.

(5) If the commission determines the applicant does not have the financial capability to successfully construct and operate the hatchery or may not properly conduct the operation authorized under the permit.

SECTION 4. All fish released under this 1971 Act during the time they are in the wild will be the property of the state and may be taken under angling or commercial fishing laws of this state until they return to the private hatchery.

SECTION 5. Any permit granted by the commission pursuant to this 1971 Act shall contain at least the following conditions:

(1) All propagated fish released into state waters shall as far as the commission determines practical be marked.

(2) Prior to release into state waters, the fish must be subject to examination by a qualified fish pathologist approved by the commission to determine that they are not diseased or infected with any disease which in the opinion of the commission may be detrimental to the state fishery resources. Cost of such examination shall be paid by the permittee. No fish shall be released without written approval from the commission. The commission may require diseased fish to be destroyed. The commission shall not suffer civil or criminal liability for any fish destroyed under this section.

(3) The permittee may be authorized by the commission to divert all fish returning to the stream to an inspection area, the location of such area to be approved by the commission, to examine all fish for the purpose of identifying propagated fish.

(4) Notwithstanding the provisions of ORS chapters 509 and 511, the permittee shall have the right to take for commercial purposes, only those fish the commission determines were propagated by the permittee, and the commission's decision is final.

(5) It shall be unlawful for the permittee to conduct any activity not authorized by the permit or fail to conduct activities required by the permit without approval of the commission.

(6) The permittee shall pay all reasonable costs incurred by the commission as a result of the operation of the private hatchery.

SECTION 6. (1) If the commission finds that the operation described in the permit is not in the best public interest, it may alter the conditions of the permit to mitigate such adverse effects or may cause an orderly termination of the operation under the permit. Proceedings to cause such alteration or termination shall be conducted in accordance with ORS chapter 183. An orderly termination shall not exceed a four-year period and shall culminate in the revocation of the permit in its entirety. During this period the permittee may continue to examine and take specified propagated chum salmon according to the provisions of the permit but may not release additional fish.

(2) If the commission finds the operation has caused deterioration of natural run of anadromous fish or any population of resident game fish in the waters covered by the permit, it may require the permittee to return the fish populations to the same condition that existed prior to issuance of the permit. The State Game Commission may require the permittee to return the resident game fish population to the same condition that existed prior to issuance of the permit. If the permittee fails to take appropriate action, the Fish Commission of the State of Oregon or the State Game Commission may take such action and the permittee shall bear any cost incurred by either commission.

SECTION 7. The commission, after first assuring all natural and artificial fish production needs of this state have been met, including the needs of all federal and other state fish culture facilities located on the Columbia River and its tributaries, may provide at a reasonable fee chum salmon fish or the sexual products therefrom to any person granted a permit by the commission pursuant to this 1971 Act.

SECTION 8. The provisions of ORS chapter 508 shall apply to the taking and sale of chum salmon artificially reared under any permit granted by the commission pursuant to this 1971 Act.

SECTION 9. Nothing in this 1971 Act is intended to give the permittee any equity in any of the waters or fish of the state.

SECTION 10. Nothing in this 1971 Act shall imply an intent to permit commercial fishing in any rivers south of the mouth of the Columbia River except as provided in subsection (4) of section 5 of this Act.

SECTION 11. All moneys received by the commission under this 1971 Act except those under section 8 of this Act shall be paid over to the State Treasurer to be held in a suspense account established under ORS 293.445. After the payment of costs of administration incurred by the commission in carrying out the provisions of this 1971 Act, that portion of the balance of the moneys in this suspense account as of the end of each fiscal year shall be deposited to the General Fund for general governmental purposes.

Approved by the Governor May 19, 1971.
Filed in the office of Secretary of State May 19, 1971.

CHAPTER 204

AN ACT

[SB 345]

Relating to workmen's compensation benefits; amending ORS 656.210; and declaring an emergency.

Be It Enacted by the People of the State of Oregon:

Section 1. ORS 656.210 is amended to read:

656.210. (1) When the total disability is only temporary, the workman shall receive during the period of that total disability compensation equal

POLICIES AND PROCEDURES PERTAINING TO THE OPERATION OF PRIVATE CHUM SALMON HATCHERIES IN OREGON

Fish Commission of Oregon
September 1971

The following policies and procedures have been adopted by the Fish Commission under the authority of Chapter 203, 1971 Oregon Laws, pertaining to private chum salmon hatcheries. The policies apply to all permit holders and will be amended or changed as the Commission deems desirable to protect the resource or to uphold the best public interest.

General

1. Permits are not transferable. If a permit holder sells his hatchery the new owner must apply for a new permit.

2. The private hatchery operator is responsible for obtaining his own eggs. Source of the eggs must first be approved by the Fish Commission.

3. Eggs at the state hatchery on Whiskey Creek, tributary to Netarts Bay, may be available for purchase by permit holders. We expect a few eggs to be available in 1972 and perhaps up to 3 million in 1973.

4. Eggs, and the resulting alevins, sold to permittees by the state shall not be resold.

5. Under no conditions are eggs and fish to be transferred in any way to waters other than specified in the permit.

6. Surplus chum salmon gametes from fish returning to private hatcheries may be made available to the state and/or authorized operators of other private hatcheries in Oregon. Eggs transported to other locations shall be treated as specified by the Fish Commission pathologist to prevent disease transmission.

7. Pathology examinations shall be conducted by Fish Commission pathologists.

Purchase of Eggs from Netarts Hatchery

1. Priority among permit holders to purchase eggs from the state shall be according to date application was filed with the Commission (first come - first served). In the case of persons expressing interest before the law was in effect, priority shall be according to date of written interest as filed with the Commission.

2. Term of priority for purchasing eggs will generally be 3 consecutive years. The Commission will make exceptions as it deems desirable.

3. Up to one (1) million eggs will be sold to the first permit holder before selling any to the holder next on the list; and so on down the list. If permit holders do not wish to buy the entire 1 million eggs reserved for them, the state may sell the remainder to the permit holder next in line as part of his 1 million egg quota. If eggs are still available after each permit holder has had a chance to buy 1 million eggs, the procedure will be repeated until all available eggs have been sold.

4. The charge for eggs from Netarts Hatchery shall be $5.00 per female spawned. The basis for this is $2.00 per thousand eggs and an average of 2,500 eggs per female. The eggs will not be counted.

5. Only "green" (newly spawned) eggs will be made available at Netarts Hatchery. Buyers must be willing and prepared to take small lots (10,000 or more) of eggs on a daily basis.

Services Charges

In compliance with Section 5 (2) and (6) of Chapter 203, 1971 Oregon Laws, permit holders shall be charged for "reasonable costs" for services incurred by the Fish Commission as a result of the operation of private chum salmon hatcheries. The following services are anticipated; others may arise of an unforeseen or emergency nature.

1. Biologist services for inspecting fish racks and fish sorting devices and procedures.

2. Pathologist services for examining fish prior to release.

3. Costs resulting from problems requiring Commission action; i.e., the hatchery operation causes a deterioration of the natural run of anadromous or resident populations which requires investigation and revision of the permit.

4. An overhead charge of 15% will be assessed against direct costs to cover administrative costs.

The amount charged will be the actual wages (including other personnel expenses), travel expenses, and required supplies. Permit holders will generally be informed of necessary service charges before such services are rendered.

PRIVATE CHUM HATCHERY APPLICATION

Fish Commission of Oregon
307 State Office Building
1400 S.W. 5th Avenue
Portland, Oregon 97201

Name ____
Last Middle Initial First

Address ____
Street or Box No. City Zip

Phone ______________________ ______________________
Office Home

Business (Give name and nature) ____

____

Location of Proposed Hatchery

Stream name ____,

Tributary of (Name of major stream or bay) ______________________

County ______________________

Description of Property (Legal description, landmarks, miles from stream mouth)

____

____

____

____

____

Owner of Property ____

If leased, duration of lease ____

Proposed Methods (Describe what you plan to do and how you are going to do it.)

Proposed Stock Source

Previous Experience in Fisheries Related Work

What do you expect to do with returning adults? (Describe any agreements you have with fish buyers or other industry representatives.)

Financial Statement

Condition at close of business ______________________________, 19______

ASSETS

		Amount
1.	Cash: On hand $________ In Bank $________ Elsewhere $________	
2.	Notes receivable: Due within 90 days	
	Due after 90 days	
	Past due	
3.	Accounts receivable	
4.	Deposits for bids or other guarantees: Recoverable within 90 days	
	Recoverable after 90 days	
5.	Interest accrued on loans, securities, etc.	
6.	Real Estate: Used for business purposes	
	Not used for business purposes	
7.	Stocks and bonds: Listed--present market value	
	Unlisted--present value	
8.	Materials in stock	
9.	Equipment, book value	
10.	Furniture and fixtures, book value	
11.	Other assets	
	Total Assets*	

LIABILITIES

		Amount
1.	Notes payable: To banks regular	
	To banks for certified checks	
	To others	
2.	Accounts payable: Not past due	
	Past due	
3.	Real estate encumbrances	
4.	Other liabilities	
5.	Reserves	
6.	Capital stock paid up: Common	
	Preferred	
7.	Surplus (net worth)	
	Total Liabilities*	

* The amounts shown as "Total Assets" and "Total Liabilities" must be identical.

I declare that I have examined this application, including the financial statement, and to the best of my knowledge and belief it is true, correct, and complete.

(Signature of Applicant)______________________________

XE - [illegible]
12/9/71

December 1, 1971

PRIVATE CHUM SALMON HATCHERY PERMIT

In accordance with the provisions of Chapter 203, Oregon Laws 1971, Keta Corporation, an Oregon corporation, is authorized to construct and operate a chum salmon hatchery on Sand and Jewell Creeks, Tributaries of Sand Lake, in Tillamook County.

The following restrictions shall apply to the construction and operation of the Keta Corporation's private chum salmon hatchery:

1. All of the provisions of Chapter 203, 1971 Oregon laws shall apply.
2. The permit shall be contingent upon getting an approved water right for withdrawing water from Jewell Creek to operate the hatchery.
3. The design of the fish rack and trap, as well as location shall be approved by the commission before the rack and trap are installed.
4. The rack must be attended and the fish trap emptied daily during the entire period the rack and trap are operated. Attention must be given to operation of the facility to prevent theft of fish, to adjust for changing water conditions, and to otherwise prevent damage to fish which might be blocked or trapped.

5. All species of fish caught in the trap, other than chum salmon, shall be placed upstream as promptly and carefully as possible.

6. For three years starting in 1971 chum salmon from the Sand Creek system shall be allowed to be used for hatchery stock as per the following directions:

   a. The first 25 female and 25 male chum salmon which appear at the rack(s) shall be placed upstream.

   b. The next 50 female and 50 male chum salmon may be spawned.

   c. The next 50 female and 50 male chum salmon are to be released upstream for natural spawning.

   d. The next 50 female and 50 male chum salmon may be spawned. This is all the fish that can be spawned and will provide an estimated 250,000 eggs.

   e. If any more chum are trapped they shall also be placed upstream for natural spawning.

   f. During the three years natural stocks are being utilized as hatchery brood stock the fish rack(s) shall be opened on December 1 and no more fish of that run trapped after that date.

7. All carcasses of chum salmon spawned from native stock in 1971, 1972, and 1973 shall be delivered promptly to the Fish Commission for state disposal.

8. A record shall be maintained for the commission of the species, number, and date fish are placed above the trap and of the number of fish which die in the trap or are spawned.

9. One dollar per thousand shall be paid to the State of Oregon for eggs collected from native fish spawned from the Sand Creek system in 1971, 1972, and 1973. To avoid the necessity of counting eggs, a charge of $2.50 per female will be imposed (calculated by estimating that, on the average, each female will have 2,500 eggs).

The amount charged will be the actual wages (including other personnel expenses), travel expenses, and required supplies. The permit holder will generally be informed of necessary service charges before such services are rendered.

Adopted and signed this first day of December, 1971.

FISH COMMISSION OF OREGON

CHAIRMAN

VICE-CHAIRMAN

COMMISSIONER

10. Beginning in 1974 all chum salmon returning to the Sand Creek rack in excess of the greatest number of chum handled during 1971, 1972, and 1973 will be considered as fish produced by the hatchery and may be killed and disposed of by the Kota Corporation.

11. Beginning in 1974 the greatest number of chum salmon that were handled at the Sand Creek rack in 1971, 1972, and 1973 be placed above the rack before any fish are claimed and killed by the Kota Corporation.

12. The above restrictions will be reviewed annually by the Fish Commission and desired modifications will be made after consultation with the permittee.

SERVICE CHARGES

In compliance with Subsections(2) and (C) of Section 5 of Chapter 203, 1971 Oregon Laws, the permit holder shall be charged for "reasonable costs" for services incurred by the Fish Commission as a result of the operation of this private chum salmon hatchery. The following services are anticipated; others may arise of an unforeseen or emergency nature.

1. Biologist services for inspecting fish racks and fish sorting devices and procedures.
2. Pathologist services for examining fish prior to release.
3. Costs resulting from problems requiring commission action, i.e., the hatchery operation causes a deterioration of the natural run of anadromous or resident populations which require investigation and revision of the permit.
4. An overhead charge of 15 percent will be assessed against direct costs to cover administrative costs.

SAMPLE

Permit No. ______________

WASHINGTON DEPARTMENT OF FISHERIES SALMON AQAUCULTURE QUARTERLY REPORT

Owners Name: ______________ Species: ______________

County Located: ______________ Year of Egg Take (Brood Year): ______________

Nearest Town: ______________ Origin of Stock: ______________

Geographic Area (Bay or Stream): ______________ Date Covered (check one):

____ Jan-March ____ Apr-June ____ July-Sept ____ Oct-Dec

OPERATIONAL PROCEDURES

Numbers Handled	Numbers	Pounds
1. Fish (or eggs) received during quarter:		
2. Fish (or eggs) on hand at end of quarter:		
3. Fish dying in ponds during quarter:		
4. Fish sold during quarter:		
Pounds Produced		
5. Pounds of fish on hand at end of previous quarter:		
6. NET POUNDS GAIN - add lines 2 and 4 and subtract line 6:		

Food

10. Type used (brand name if any): ______________
11. Amount of food used (in pounds): ______________
12. CONVERSION - divide line 11 by line 9: ______________

Disease

13. Diagnosis of type: ______________
14. Treatment: ______________
15. Drug or medication used - amount: ______________

-over-

Water

16. Weekly maximum-minimum temperature during quarter:

Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Max. Temp.													
Min. Temp.													

17. Water used - estimate maximum and minimum water used as expressed in average cubic feet per second (cfs)

Minimum__________cfs__________cfs__________cfs

Minimum__________cfs__________cfs__________cfs

REMARKS: Please comment on any facets of your operation which may be of interest, such as predation, biological observations, etc.

Return completed report to Hatcheries Division, Washington Department of Fisheries, Room 115, General Administration Building, Olympia, Washington 98504, within 10 days of the end of each calendar quarter.

THE AMERICAN

& WORLD AQUACULTURE NEWS

DECEMBER, 1970

75 CENTS

Multi-million Dollar Farm

This operation is now bankrupt - $3.5 million loss to private investors and govt.

Canadian Mariculture Facility Begins Operation

By Gary K. Gunstrom

SEA FARMING IN THE Canadian Maritime Provinces presently consists of the efforts of one company, Sea Pool Fisheries Ltd., located at Clam Bay, near Lake Charlotte, Nova Scotia, forty miles northeast of Halifax. An abundance of clear spring and ocean water and close proximity to the Halifax International Airport make the site ideal for the planned annual production of 4,000,000 lbs. of Atlantic salmon and trout marketed fresh to restaurants, clubs, and supermarkets.

The origins of the company date back to 1963 when a study of the feasibility of raising salmon and trout for marketing on a year around, uniform-size basis was initiated by potential investors with visits to existing fish farms in North America, an extensive literature review, and correspondence with various authorities. Convinced that such a project had good possibilities, a suitable site was chosen after much investigation. One thousand acres of woodland and tide flats fronting on the ocean at Clam Bay were purchased in 1966, and the research and feasibility phase of the project was initiated. A pilot plant was constructed and a limited number of outdoor pools installed. During the following three years the objective was to investigate the most suitable species of fish, the most profitable methods of feeding, and the best technical methods of providing a year around source of filtered, aerated water at an optimum rearing temperature of 50-55° F.

TEN-POUND COMMERCIAL PACKAGES of fresh trout are shipped four to a [illegible] Customers receive shipments promptly by air-freight.

Species Selection

Selected breeds of fish, including rainbow trout *(Salmo gairdneri)*, rainbow-steelhead hybrids, brook trout *(Salvelinus fontinalis)*, and Atlantic salmon *(Salmo salar)* were grown at Clam Bay during this research and feasibility phase. They went through the complete cycle, from egg to market size. In addition, a brood stock of these species was developed, which became well adapted to local environmental conditions.

Initial sources of eggs and fry included donations of rainbow trout from the College of Fisheries, University of Washington; Atlantic salmon and brook trout from the Canada Department of Fisheries, Maritimes Region; and brook trout fingerlings purchased from private hatcheries in the Province of Quebec. It is anticipated that within two years brood stocks on the property will yield sufficient spawn to render importation of stocks from other agencies unnecessary. Excess eggs in future years will, in fact, be used for donation to other fishery concerns, and some will be sold commercially.

Trial Marketing

Trial quantities of fresh rainbow and brook trout were marketed in Montreal supermarkets in 1968 to test the quality and flavor of the fish and the market price. Public preference for these fish over frozen, lower-priced imported products gave much encouragement for the development of the overall project.

The construction of permanent hatchery and rearing facilities began in January, 1969, and progress was such that the company was able to establish itself as a commercial enterprise in January, 1970.

The developmental years were a real learning experience, and not without their problems and misfortunes. Coldsnaps, occurring before adequate water heating was installed, floods, power failures, and a general pessimism on the part of Federal agencies all contributed to set-backs in the program to establish Sea Pool Fisheries as a new industry in the Maritimes. Most of these obstacles have been, or are being overcome, however, and the coming months will find "Sea Pool" salmon and trout in the major east coast markets.

Production

Following the establishment of commercial status, a regular marketing schedule based on numbers of fish on hand, future acquisition of eggs and fingerlings, brood stock production, projected growth rates, and average allowable mortalities, was designed. Regular weekly marketing began in January, 1970, with fresh 1/2 lb. (dressed weight) rainbow trout being shipped to Montreal. Initial marketing, although insignificant at 200 lbs. per week, will build to 40,000 lbs. per week by 1972. Also, by that time the main market emphasis will have switched from the trout, which is fast growing and relatively easy to rear, to Atlantic salmon for which there is always a high market demand. Other species marketed will include brook trout *(Salvelinus fontinalis)*, Chinook salmon *(Oncorhynchus tschawytscha)* and possibly Arctic char *(Salvelinus alpinus)*. Chinook salmon will be marketed at 15 lbs. as a smoked product. Atlantic salmon and a portion of rainbow stock will be marketed at 3 to 15 lbs. on a fresh basis. Retail price will vary with species and market location.

In order to market year around on a weekly schedule, it is necessary to rear the fish in filtered, temperature controlled, pH controlled, closed-cycle facilities. Such controlled environment systems, employing 100% sea water in the advanced growth stages, and coupled with a high quality diet, provide for the regulation of growth,

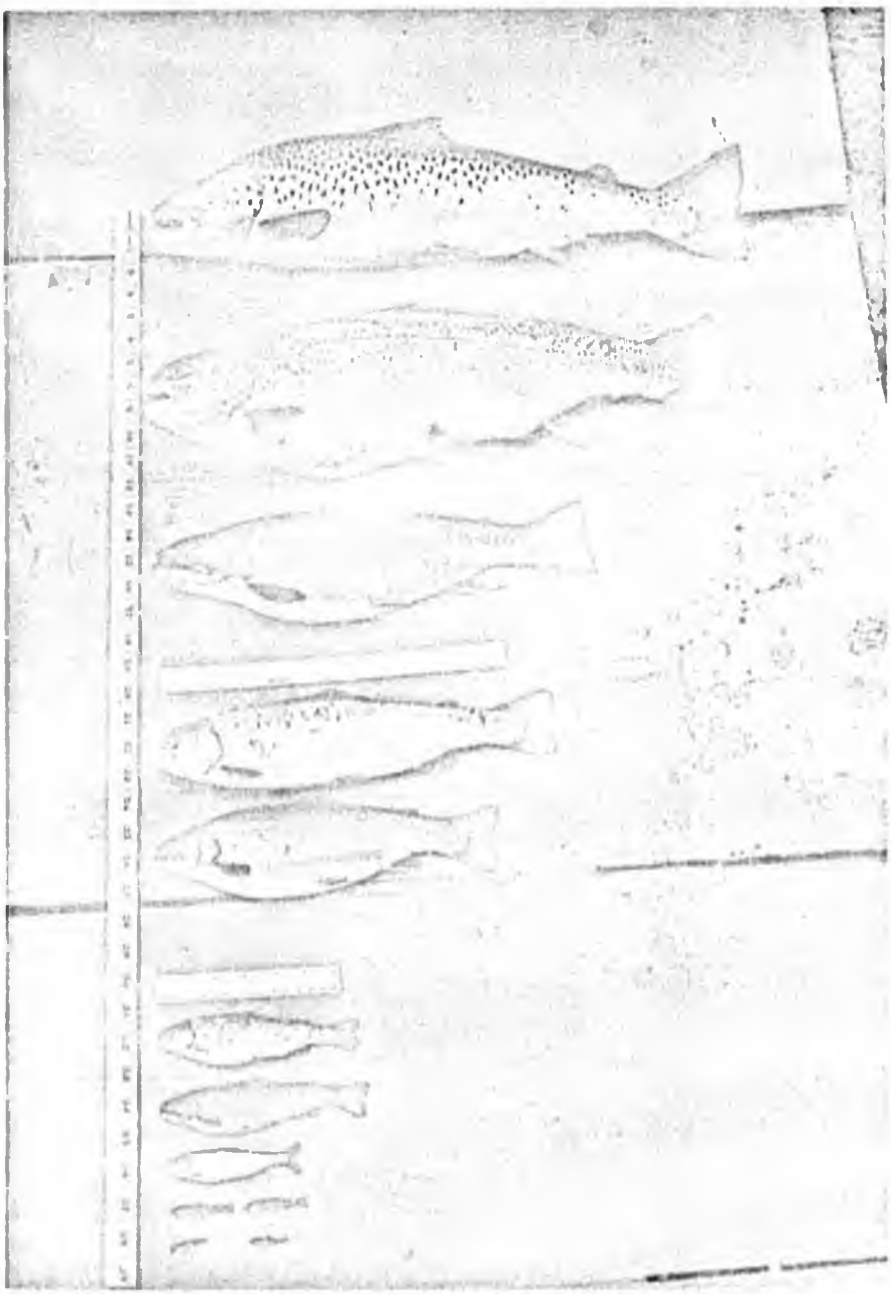
THE DOUBLE INCUBATOR at Sea Pool's mariculture facility can carry up to 4 million trout eggs at a time. The picture above shows routine egg-picking at the incubator. Below, the author is shown at work in the quality control laboratory.

color and condition of the product. These facilities, in which over 90% of the water is re-used, allow for conservation of water, removal of organic and nitrogenous wastes, lower heating costs, and as a result, easier control of the rearing environment. They are multi-pool systems with associated gravel and oyster shell filters designed and constructed along the principles developed by Burrows (Burrows and Combs, 1968).

Rearing water is heated nine months of the year by direct steam injection from boilers which total 800 H.P. and yield 20,000,000 B. T. U.'s per hour. Boiler power is also ' to operate the company's own independent electrical plant.

Growth scheduling that produces a marketable trout in eight months calls for ever increasing salinity as the fish grow. Sea water supplies trace minerals which are absorbed through their skin and gills. It lowers the disease probability, as the majority of fish diseases encountered at hatcheries are freshwater borne. Also, it has been discovered that the fish color up in it nicely. In addition, our sea water pumps are known to bring in extraneous marine supplements to the diet such as small shrimps, copepods, etc.

The rapid growth required also necessitates a high-protein diet. The production diet is the result of years of research at the College of Fisheries, University of Washington. It is manufactured on the site from autolysed, pre-digested ground-fish, fish meal, various cereal additives, vitamins, and sea food by-products high in carotenoid pigments, such as shrimp offal. The end product is a moist pellet that is eagerly accepted by the fish. It provides for rapid growth, and produces excellent internal color. This diet, which is produced at a cost of about 10¢ per pound, provides a conversion rate of 1.5:1, at present. At this time production fish feed is prepared in a small area originally designed for the preparation of research diets in small lots. When construction of the main feed production area is completed it is expected that automation will reduce production costs and at the same time enable us more easily to produce a consistently uniform diet that will result in an even lower conversion rate. On site requirements will total two to three million pounds of feed per year, and in addition, the company is seeking a market of approximately two million pounds for sale to other fishery concerns.



SPECIMENS OF FISH being raised at the Sea Pool mari-farm are shown. The top fish is a 22-month old Atlantic Salmon. The next two are 18-month old Rainbow and Speckled Trout. Next are 1/2 pound market size Rainbow and Speckled Trout that are 8 and 10 months old. The fry specimens are a 5-month old Rainbow Trout, a 7-month old Speckled Trout, a 3-month old Chinook Salmon, two 1-month old Rainbow Trout and two 2-month old Atlantic Salmon.

Installations and Facilities

A production schedule of this magnitude requires extensive site development and a large capital expenditure.

Outdoor rearing facilities on the site at present include two modules of twenty-five-foot diameter fibreglass pools. Each module consists of ten pools which are constructed so that there are five pools on either side of a 150-foot long concrete filter box. Also present is a cluster of six fifty-foot fibreglass pools which surround a central fifty-foot filter pool. Within the next year construction will also be completed on three larger plastic lined gravel pools. One of these will measure 135 feet in diameter. The other two will be oval in design, measuring 500 feet long by 80 feet wide. These pools, designed for long term rearing of large (5-15 lb.) market fish will possess self-contained filtration systems. Dyked sea water empoundments and raceways will also be used for future rearing.

Indoor rearing facilities have been installed in the hatchery building which also contains offices, an experimental diet production room, a walk-in freezer, incubation facilities and the research laboratory. Indoor rearing facilities include one module of ten eight-foot diameter fibreglass pools constructed so that there are five pools on either side of a fifty-foot long filter box, and twenty 9" x 2' x 14' rearing troughs. The incubation facility can accommodate two to four million eggs at any one time, depending on the species. The eggs are kept in Heath tray incubation units.

In addition to the main hatchery there is also a "quarantine" hatchery to accommodate newly arrived eggs or fry, or freshly spawned eggs taken from brood stock. This building contains four 3' x 4' x 24' troughs that are used for rearing, or indoor spawning of brood stock, and incubation facilities that can accommodate one million eggs.

Great care has been taken to ensure that no toxic materials were used in construction of rearing or incubation facilities. All piping is either PVC or fibreglass. Concrete filter boxes are lined with inert plastic sheeting or painted with epoxy resin.

Fresh water for the hatchery building is pumped from clear, underground springs that have a year around average temperature of approximately 50° F., and a two-acre artificial lake. Another artificial lake, approximately four acres in area, supplies fresh water to the outdoor rearing facilities via a twenty-two inch gravity-flow siphon line. These two artificial lakes are, in turn, fed via creeks from two larger natural lakes in the surrounding watershed.

A major plant facility has recently been completed. This building, 50' wide by 300' long contains administrative offices, the boiler plant, a shop, the production fish food plant and the fish processing and packaging plant.

Other major installations include two modern residences for management personnel, a warehouse, a sea water pump house, and an applied research center.

THIS HOUSE WAS BUILT at the Sea Pool facility to serve as an Ocean Sciences Applied Research Center. It contains laboratories, aquariums, a library and living facilities for research scientists.

Research

A modern laboratory facility permits detailed analysis of water quality, hematology and diets in relation to good fish culture, and also makes possible basic and applied research into various aspects of aquaculture. Laboratory studies range from the testing of new equipment and procedures to the prevention and treatment of fish diseases.

The laboratory staff is also responsible for investigating the suitability of other species of marine life for aquaculture. Rearing water, heated during the cooler months, naturally results in a heated effluent which flows through tidal channels and pools on its way to the sea. The possibilities provided by these warmer-than-normal potential rearing areas are unlimited. Commercial production of oysters, crabs, lobsters and clams will be investigated during the next few years in these areas.

Also on the property, a research facility known as the Ocean Sciences Applied Research Centre is nearing completion on a point overlooking the sea. This building will contain a wet laboratory, a dry laboratory, three fresh or sea water aquariums ranging in capacity from 2,000 to 22,500 gallons, a library and reading room, and various other sophisticated research facilities, plus accommodations for 10 to 12 visiting scientists. Applied research to be supported by private and Federal grants will be conducted in the field of aquaculture. It is hoped that this will become one of the major applied fishery research centers in North America.

Future Development

During the coming years as the company develops and expands a portion of the site will be developed as a major tourist attraction. Facilities will include a put-and-take sports fishery where Atlantic salmon and trout may be caught any time of the year, a sports shop and a restaurant.

On the success of this venture will depend, to a large degree, the future of commercial fish farming of salmonids on a large scale. It is envisaged by the planners and Directors of Sea Pool Fisheries Limited that the ground work being laid at Clam Bay will provide the impetus and knowledge that will lead to many more such developments in various parts of the world. ■

LITERATURE CITED

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Cage Culture of Trout in Warmwater Lakes

Story on page 4

To Market, To Market, To Buy A Small Salmon

By B. G. Ledbetter
Oceanic Commission of Washington

From Pacific Northwest Sea

There are only six cities in the world where you can enjoy a new culinary delight — pan-size salmon, sometimes called mini-salmon or baby salmon, reared entirely in captivity from egg to harvest. If all goes well with the Puget Sound aquaculture enterprises of Domsea Farms, Inc., a subsidiary of Union Carbide Corp., this new gourmet treat could be available throughout the country and the world in a few years.

Selected restaurants in Boston, Baltimore, Washington, D.C., San Francisco, Los Angeles, and Seattle have offered these young coho (silver) and chinook (king) salmon to customers and club members since shortly after the harvest began on 3 January.

This is the ultimate test of an aquaculture project begun in November 1970 by Ocean Systems, Inc. (OSI) near Manchester, Washington. When each salmon goes into the oven or pan, onto the dinner plate and fork, and into a man's mouth, the whole story of how it got there — after more than a year's toil by sea farmers, day and night, in cold rain and wind and ponds and tides and boats — is suddenly irrelevant, forgotten, unknown, or meaningless, as the customer's tongue, eyes, nose, and memory pass judgment on each morsel. The meat is the message. There is seldom a second chance.

John G. Martin, a San Francisco food broker, said customer and chef reaction at expense account-type restaurants has been good. "These salmon are superior to trout, there's no real comparison. When they've both been on the same menu, the higher-priced salmon has outsold the trout by as much as five to one."

Through Jon Lindbergh, OSI (an ocean engineering firm in Reston, Virginia and an affiliate of Union Carbide) became interested in salmon aquaculture research being done by scientists of the National Marine Fisheries Service. When Conrad Mahnken, biological oceanographer, and Anthony Novotny, fishery research biologist, put some Minter Creek coho into some net pens floating in saltwater in July 1969, the fish already were one and a half years old, but it took 20 of them to weigh one pound. By August 1970, however, they weighed one to three pounds each. During those 13 months their growth rate was as high as 3.3 per cent of body weight per day, and their food conversion rate was as low as 1.4 pounds of feed per pound of fish produced.

On the basis of studies of these and other salmon, Lindbergh convinced OSI to begin a co-operative pilot salmon aquaculture project, with technical assistance from NMFS, to determine if a low-cost mode of large-scale farming could be developed.

Could results as good as those in the floating laboratory be achieved on a commercial scale? The strategy was to raise enough fish so that questions and problems would arise and solutions could be found — but not so many fish that failures would be disastrous. OSI ran the pilot project to find the answers. Domsea Farms was incorporated in January 1972 to make salmon aquaculture work.

Because of the life cycle of salmon, the pilot project naturally separates into four phases: incubation, freshwater cultivation, saltwater cultivation and harvest, and test marketing and analysis.

Incubation: 700,000 coho and 463,000 chinook

After obtaining a permit from the state Department of Fisheries to purchase about 700,000 coho salmon eggs, OSI personnel, supervised by Novotny, took eggs and sperm on 9 and 19 November 1970 from ripe coho returning to spawn at the Skykomish Hatchery, located on May Creek, about four miles east of Sultan and 40 miles northeast of Seattle. The eggs filled 51 plastic one gallon jugs, and enough sperm was taken to allow one cup (one-half to two-thirds full) per gallon of eggs. Packed on ice, they were taken to the OSI hatchery at Beaver Creek near Manchester (a three hour trip), where each cup of sperm was added to five gallons of eggs, allowed to sit for one minute, then washed, drained and split into two incubator trays.

About 460,000 chinook fry were later added to this project. The chinook eggs were incubated and hatched at the University of Washington under the direction of Dr. Lauren R. Donaldson, famed selective breeder of salmonids (PNWS, Fall 1971 issue).

On 16 October 1971 the *USS Sacramento* (AOE-1) offloaded fuel at the Navy's Manchester Fuel Depot, while just around Orchard Point some 270,000 chinook and 240,000 coho salmon were enclosed in OSI's four floating net pens in Clam Bay. The surface area of the bay is about 200 acres. The *Brown Bear* is moored to the 800' pier (top center). Manchester is at the bottom of the picture.

This photograph illustrates the concept of the multiple use of coastal waters and the problem of competition for space. Here two supposedly incompatible activities, oil handling and fish farming, have coexisted since 1969. Recreational boaters and sport fishermen also use these waters, and two 302-foot state ferries steam through Rich Passage (top and right) enroute to Bremerton or Seattle every hour, about 18 hours every day. *(U.S. Navy Photo)*

No new technology was developed during the incubation phase. There have been salmon hatcheries in the state since 1895, and perhaps more is known about hatchery rearing of salmon than any other species.

Problems did occur, however, from faulty fertilization, siltation caused by heavy rains, low water temperatures, and saprolegnia (a fungus). Filtration, heating, and recirculation systems helped control the situation.

By 15 January 1971 over 95 per cent of the surviving eggs had hatched. By month's end, the overall mortality was estimated at 36 per

Continued on next page

cent. From the original 700,000 eggs, about 445,000 coho salmon were still alive.

Freshwater cultivation at Glud's Ponds

On 6-7 February about 420,000 coho fry were transferred by truck from the hatchery at Beaver Creek to Glud's upper (south) pond — (Glud rhymes with food) — near Brownsville. Very few were lost in the transportation, but 100,000 were wiped out overnight by suffocation in floating nets at the pond.

Two days later, transfer of 463,000 chinook fry from the University of Washington began. The fry, which were already feeding before the move, weighed 668 pounds and were hauled to Glud's lower (north) pond on 9-12 February. There were very few mortalities. These fish were produced from genetically selected spawners that were developed by Dr. Donaldson. For 20 years the chinook which he selected for spawning were chosen for maximum growth, disease resistance, fecundity, and early maturity. The state fisheries department permit authorizing the inclusion of these chinook in the project was to provide comparative data between Donaldson's chinook and the Skykomish coho.

Both the chinook and coho were fed a dry salmon feed. Since metabolic rate of the fish lowers with a decrease in water temperature, the growth rate during February was slow. The food conversion rate by the coho was 2.3 pounds of feed per pound of fish produced, but for the chinook it was a very high 5.75. In mid-March the chinook diet was changed to a moist pellet. Their food conversion dropped to 2.98 for the month and their health improved.

The best food conversion rate during the freshwater cultivation phase was by the coho in June, when 0.9 pounds of feed produced one pound of fish. How can a fish gain more weight than the weight of food it eats? It can't. But because the weight of the food is a dry weight (about 4 per cent moisture) and the weight of the fish is a wet weight (much greater moisture), the ratio turns out less than 1:1. Indeed, food conversion of 0.8 is possible.

The best food conversion by the chinook during this phase was 1 74 in April. Transfer of the chinook to saltwater began on 19 May, and the conversion rate for that month was 1.23.

On 9 February an oil-fired heater with the capacity to deliver 20 gallons of heated water per minute into the coho pond was installed and began operating. At the heater's outflow pipe the water was 17°C(62.6°F) above the pond temperature, and the fish showed their preference for it by schooling in the plume.

By mid-April the heater was unnecessary, but aerators had to be installed to maintain the necessary dissolved oxygen level. Several recirculation pumps and more aerators were added in May. The entire creek flow was now directed through the ponds.

Four automatic feeders, installed in March, spread pellets and mash over the ponds every 15 minutes from dawn to dusk. Supplemental hand feeding in the corners of the chinook pond was required hourly.

Disease and parasites were never a problem during the freshwater cultivation phase.

On 29 April, almost six months after the project started, a $100,000 grant was made to OSI by the Sea Grant Program. It was an unusual grant in several ways. It was the first Sea Grant awarded solely to a private firm. It was awarded by and is monitored through the Northwest Administrative Service Office of the National Oceanic and Atmospheric Administration located in Seattle, rather than the Office of Sea Grant. Sea Grant requires matching funds at the ratio of at least two to one; i.e., the grantee must at least match every two Sea Grant dollars with one of his own. In this case, however, OSI is paying about three dollars for every Sea Grant dollar.

The grant was made to aid in (a) rearing the salmon, (b) testing the product's marketability with NMFS assistance, and local agencies on aquaculture principles, compatibility laws to permit commercial salmon culture. As with all Sea Grant sponsored research projects, a public report is being perpared and should be available sometime next fall. It will include the results of a study on the environmental impact of the project.

Saltwater cultivation at Clam Bay

"Assuming the water quality is good, the three most important factors in selecting a site for saltwater salmon rearing are water temperature, current flow, and storm protection," said Lindbergh. "The temperature should not range below 6°C (42.8°F) or above 16°C (60.8°F). Continuous current flow is best. Occasional currents up to three knots can be tolerated."

Mahnken added that adjoining land for support facilities is essential. "In fact very few sites are available that embody all of the desired combination of physical, biological, and social requirements for salmon farming," he said.

Clam Bay has the necessary characteristics.

When can chinook and coho be put in saltwater with little risk of mortality? The critical factor is not age or season. Apparently is is weight. When a chinook reaches about five grams (0.17 ounces), its organs, particularly the kidney, are sufficiently developed to make the biological adjustments that all anadramous fish make at smolt size when they migrate to sea. For coho the minimum weight is 15 grams (0.5 ounces).

The early introduction of these fish into seawater is one of the unique aspects of this project. Within four months after the hatch, the chinook were ready for transfer. Some coho were ready in 6 months. Lindbergh feels these times can be shortened to three and five months, respectively.

Another unique aspect of this project is the use of large floating net pens. Lindbergh listed five advantages:

- Free flowing tidal water currents are used to bring dissolved oxygen into the pens and to flush out metabolic wastes; pumping power is unnecessary.
- Net pens are resilient and yield with the currents.
- Net pens are a low capital investment facility in comparison with fixed structures and diked ponds.
- Water temperatures are relatively constant without the sharp variations characteristic of pond cultivation, due to the large thermal mass of Puget Sound.
- Net pens are moored and therefore only permanent; their installation and use causes little change to the environment.

Fish transfers to Clam Bay between May and mid-August were made to temporary floating nets alongside the *Brown Bear*. The main 100'x24' platform for holding the four main floating net pens in the middle of the bay was launched and anchored on 15 July. The fish were moved into these in late July and August.

Some 395,000 chinook were trucked from Glud's Ponds to Clam Bay in 35 trips. An additional 7000 were given to NMFS for experiments or release. Losses at the pond due to handling and sorting were 1170, and another 10,000 were purposely released to migrate downstream. Draining the pond into the creek flushed another 1000 downstream.

Only about 900 chinook were lost in transportation to Manchester. Although the fish were in excellent health, they did weaken from the stress of the move, and the first attack of Vibriosis occurred.

"Vibrio" is an infection caused by any of several strains of bacteria always present in saltwater. Salmon most likely will succumb to it during periods of high temperatures or stress. About 19,500 small chinook died

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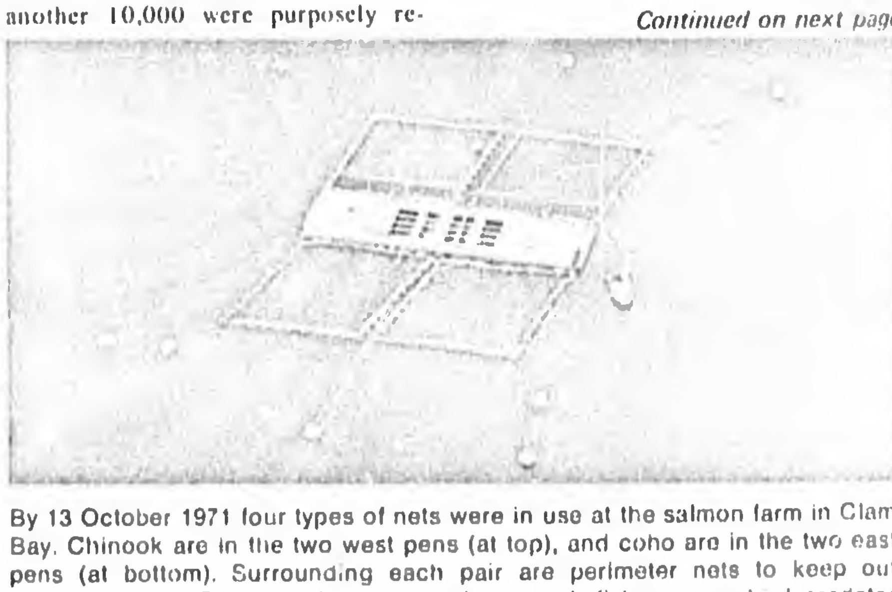
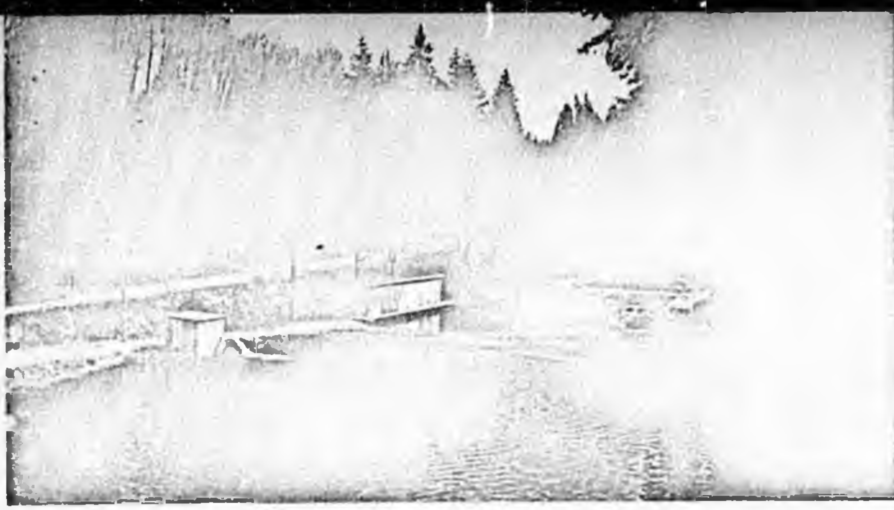


By 13 October 1971 four types of nets were in use at the salmon farm in Clam Bay. Chinook are in the two west pens (at top), and coho are in the two east pens (at bottom). Surrounding each pair are perimeter nets to keep out dogfish sharks. Suspended on poles above each fish pen are bird predator nets. Several small experimental nets are suspended below the raft's center. Each of the main pens measures 50' x 50' x 25' deep, and a system of buoys and counterweights keeps the four corners taut during all the tidal conditions. On the morning of 14 August, however, a 3/8" steel cable holding the northwest corner of the west nets broke. The 2 knot current from the northwest forced the northwest net almost flat against the raft, killing 5,000 chinook. The underdesigned mooring system forced costly repairs and alterations for several months. (Photo by Dr. Richard B. Thompson, NMFS)



Glud's Ponds, 25 March 1972. A creek runs out of the woods (right background) and then north between the road and the hatchery. Water is simply diverted from the creek to fill the ponds. By late spring when the creek flow rate decreases to about 500 gallons per minute, the whole water supply must be used. In winter the water is heated at the inlet gate into the coho pond. The pump in the chinook pond (left foreground) draws water from the pond, not the creek; its purpose is to cause circulation and keep the dissolved oxygen level high. The outlet gate is just to the left of the pump house.

from the disease between 8 and 23 June. Mortalities were averaging 1740 per day when the fish were put on a medicated diet of terramycin-treated food. The trend reversed in three days.

Vibrio struck again between 29 June and 8 July and was quickly controlled. Dead chinook: 24,826.

It was decided that in all future transfers a prophylaxis treatment of terramycin-spiked food would be used prior to and after the move to saltwater.

This was done when the chinook were transferred to the main net pens in the middle of the bay between 23 July and 12 August, and very little disease broke out. But scale loss during handling, which causes loss of body fluids, combined with water temperatures above 14°C (57.2°F) to contribute to 33,632 chinook mortalities.

Many of these dead sank to the bottom of the nets, attracting dogfish sharks. While eating the mortalities, they chewed holes in the sides and bottom of the nets. Divers took three female dogfish, 2 1/2 to 3 1/2 feet stomachs contained 58 chinook. Five days later they took another four. That these predators ate a lot of salmon was a problem in itself, but a few dogfish could never eat as many fish as could escape through those holes.

By 2 August a shark protection net was placed around the pens, providing two to five feet separation between the inside and outside nets.

On that same day a freezer capable of storing 10 tons of frozen moist pellets arrived. Various combinations of diets were tried during the saltwater cultivation phase.

By 31 August all the coho, too, had been stocked in the main saltwater pens. About 3000 were given to NMFS for release in Beaver Creek, 280 were lost in handling at Glud's Ponds, and 9000 migrated downstream. Only 10 were lost during transfer operations, but 3000 died in adapting to sea water.

Novotny monitored fish diseased throughout the project. Vibrio and Furunculosis are the most common pathogens present in these waters, but only Vibrio was of consequence. Kidney disease was a minor factor. An occasional external parasite, *Argulus*, was found.

On the last day of August there were 260,610 surviving coho and 274,920 chinook.

September was excellent. Only a few hectic periods upset the normal aquaculture routine. The average water temperature, 12.2° (54°F), was near optimum for both species.

The coho and chinook doubled in weight and size. Handlers fed the coho only dry food, and they converted every 0.955 pounds of it into a pound of fish. Some chinook ate dry food but most were fed moist food; their food conversion rate was 1.03. Only 3470 chinook (1.26 per cent) and 2917 coho (1.12 per cent) died. Any greater death rate is suspicious.

This little fish went to market

Test marketing of pan-size coho salmon began at the request of Mahnken and Novotny, according to Arne E. Einmo, fishery marketing specialist with NMFS in Seattle.

"In July 1970," said Einmo, "we took samples to major marketing areas — New York, Boston, Baltimore, Washington, D.C., Tampa, Minneapolis, Los Angeles, San Diego, and Seattle — and we asked questions about the fish. What size should they be? Should they be dressed, heads on or off, fileted, boned or what? What was the best flesh color? What price would firms pay for this fish?"

He said NMFS polled 27 brokers, wholesalers, retail chain buyers and merchandizers, chain restaurants, gourmet seafood restaurants, and airlines. All but one were enthusiastic, and vebal commitments were made for about 300,000 pounds, Einmo said.

As a result, Domsea salmon are eviscerated, dressed heads-on and either fresh or frozen. Marketing is under the direction of Don Mowat, broker at Swiftsure Fisheries, Inc., 3440 E. Marginal Way S., Seattle, Wa. 98134.

Mowat said he's satisfied with the reception of the fish, although it has been on the market only three months and the demand for it is still being created.

"The best reaction has been in San Francisco," he siad. "We've tried to concentrate on the middle to upper class reataurants. Some buyers are very enthusiastic and have creatively pushed the product. Others, to whom a salmon is a salmon, have not.

"However, many persons don't compare the Domsea salmon with full grown salmon," Mowat said. "They compare it with trout. But this is not trout. It's a baby king or silver salmon, far superior to trout in appearance and flavor. It belongs in the expense account market, not in the local supermarket."

John Martin, San Francisco food broker, agrees. He said the movement of the product there has been steady and good, although they have not publicized it much because so far the supply of fish is too limited to meet the demand they could create.

Art Davis, chef at a leading restaurant at Fisherman's Wharf in San Francisco and president of the Chef's Association of the Pacific Coast in 1970-71, said his customers' reaction has been very good. "They come back to order it again," he said, "and they bring friends to try it, too."

What's next in salmon farming?

Dr. Timothy Joyner, who heads the NMFS research on the *Brown Bear*, said the next steps in salmon aquaculture research should be in developing brook stock, controlling disease, and improving nutrition.

Mahnken said the technological problems facing aquaculture are the lack of control over predators, disease and viruses, and cannibalism, the ignorance of the species' life histories, and the absence of specific criteria for the selection of species and sites.

But Mahnken believes that the most serious threats to aquaculture development are "vigorous competition for use of the coastal zone and the ever-increasing problem of water pollution."

Domsea Farms, Inc. was formed to carry on the aquaculture work begun by Ocean Systems. Lindbergh is now a vice-president and director of Domsea, and Frederick E. Naef is the

By sliding out the end of the grader, this lucky coho has escaped death and can now live its full life cycle to sexual maturity as a member of Domsea's select brook stock. Smaller fish drop through the slots and into one of three side chutes. The smallest are returned to the pens for more feeding. Those of harvest size fall into holding nets before going into the chill-kill tank.

general manager.

Naef said that while Domsea has to deal with about 19 federal, state, and local institutions to operate in Puget Sound, this state is "head and shoulders above others," in terms of receptivity towards aquaculture.

Domsea now has a new site in Clam Bay nearer Orchard Point where a larger net complex was anchored on 1 March.

Naef stressed that 1972 operations are not merely a repeat of the pilot project. "Domsea is still testing."

He hopes Domsea can eventually develop a system of year-round harvesting of different salmon races, species, or hybrids that reach market size at different times.

Perhaps by then anyone, any day can go to market, to market, to buy these new salmon.

Trout Farmers Hear Alarming News From Feed Producers

U.S. Trout Farmers at their annual convention in Colorado Springs, October 4-6, listened to the alarming comments of fish feed manufacturers. With fish meal production from Peru halted and feed manufacturers holding only small reserves, the industry faces a serious feed shortage. Fish meal makes up the major (usually about 30%) part of the trout diet which is manufactured in a pelleted form. No satisfactory substitutes are now known to replace fish meal in the feed formulas. Industry members felt that a reduction in the available supply of rainbow trout would begin to appear early in 1973 as a result of the critical feed shortage which is now pending.

One of the nation's major fish feed manufacturers made the following points. Don Nelson of Murray Elevators, a Utah feed producer said,

"On September 2?, 1972, the Peruvian government announced ad edict labeled as Supreme Resolution No. 0208-72-PE which states in essence the following.

1. The warming trend of the ocean waters off the coast of Peru by several degrees has caused a partial disappearance of raw fish stocks to a point that what reserves are left will be conserved.

2. Export of fish meal and fish oil after October 1, 1972 is prohibited.

3. Pending sales contracts made as future sales will be completed once normal production is resumed.

"No dates were mentioned as to when normal production would be resumed. The rumor is that other than exploratory fishing, normal production will resume in March, 1973.

"More than 80% of the world production of salable fish meal is manufactured by the Peruvian fishery. In comparison the U.S.A. supplies less than 5% of the world production. 'To add a little frosting to the cake', the Canadian government has announced a quota of but 5,000 tons of fish meal for their winter fishing season which commences in December-April. It is our understanding that the United Kingdom has purchased more than half of this proposed production at prices as high as $4.00 per unit/protein which is more than 30% higher than prices obtained for their summer production this year.

"All proteins, vegetable or animal, are tied in price-wise to the cost of fish meal protein. During the past three months, meat meal, soybean meal, corn gluten meal, blood meal and wheat middlings have increased in price from 10% - 30%. Only two items in our diet have not increased in price and they are the vitamin premix and the added salt. By weight, this represents less than 2% of our diets.

"During the past ten years, fish food prices have remained fairly stable. The future spells out higher prices because of ingredient costs. The shortage of fish meal is the basic cause of price increases, however, the billion dollar sale of grain concentrates to the U.S.S.R. is also responsible. A dollar increase in the

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CONAGRA SALES

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contract program is in line with the company's goal to provide complete catfish service to the industry. He added: "We felt that there was a need in the industry for someone to offer good catfish farmers with limited financial resources a way to stay in the fish business without having to borrow large sums of money for purchase of feed and fingerlings, and bear the entire risk. Under its contract program, ConAgra supplies feed and fingerlings at its expense, and thereby shares the risk with the farmer. And the farmer's worry about marketing his product is eliminated."

He expressed the belief that the farm-raised catfish industry continues to be a dynamic one where conditions change very rapidly. For example, at times there is an excess of live fish for sale, and at other times, a shortage. The company is currently working on other methods which will improve the predictability of its operations, and thereby provide for more effective short and long range planning.

Hinote said that demand for the firm's Country Skillet brand of processed catfish continues to increase rapidly in major marketing areas of the nation. ConAgra's total sales of all forms of farm-raised catfish more than doubled in its last fiscal year (ended June 25, 1972). This trend is continuing during the early months of this fiscal year. Fresh ice-pack sales are increasing more rapidly than frozen sales for the company. During fiscal year 1972, ice-pack sales accounted for 75% of total sales, an increase from only 32% the previous year. "Having a year round supply is more critical with ice-pack than with frozen sales," Hinote said. "Customers are depending on you to have fish for them every week of the year, and with ice-pack, you can't store up a supply as you can with frozen product. The industry has improved considerably in having live fish for sale throughout the year, but there is still room for improvement. For the first time since ConAgra entered the business in 1969, we were able to process a good volume of fish every month of our fiscal year 1972. Although the needs of all our customers were not completely filled each week, we were able to provide a good percentage of their total orders. Our goal for this fiscal year is to improve even further the year round availability of processed catfish from our two plants. Our contract production will help us in reaching that goal. And we feel that as we make farmers more aware of the need for a year round supply, they will respond to that need."

Pink Salmon Stocks Restored in Alaska Stream

Fourteen thousand adult pink salmon observed returning to spawn in a small Alaska creek last August and September represent an increase of 13,992 — of 1,750 per cent — over the eight salmon counted in the same stream a decade ago.

The "population explosion" was seen by National Marine Fisheries Service scientists as a tangible result of eight years of experimentation with techniques by which adult fish are transplanted into depopulated waters to re-establish once-productive pink salmon runs.

The studies were carried out by fishery biologists at the NMFS Biological Laboratory, Auk Bay, Alaska. NMFS is part of the Commerce Department's National Oceanic and Atmospheric Administration.

Sashin Creek, located in the remote wilderness of Baranof Island in southeast Alaska, was the site of the experiments, begun in 1964. Assessments made in the 1950's of many of Alaska's spawning streams revealed that a combination of heavy exploitation and high natural mortality had taken a heavy toll of once abundant stocks of pink salmon, a highly valued commercial species. Sashin Creek had joined a growing list of depleted runs as early as 1948 when only 597 adult pink salmon were counted in the stream, compared to a thriving population of 92,000 fish six years earlier.

Norway Farms Salmon

By 1975, Norway should be producing as many salmon in salmon farms as in her present high-seas catch, according to an article in Sports Illustrated.

The firm of Mowi, Inc. predicts that its two-acre farm on Flogoyk-jolpo, an island southwest of Bergen, Norway, will produce about 100 tons of marketable salmon this year. Within four years, it is expected the total will reach 500 tons, and this, coupled with the output of other Norwegian firms which are also experimenting with salmon farms, means that by 1975 Norway should be producing around 1,500 tons of farmed Atlantic salmon, equal to the present high-seas catch.

Farm reared salmon have advantages over wild fish. Quality control is easier. Last spring Mowi salmon fetched a better price on the Norwegian market than wild fish because they had a higher fat content; the 'curd' so prized in well-conditioned fish.

It is unlikely that salmon farming will remain confined to Norway, according to the article. Already the British firm of Unilever is setting up a plant in Scotland. Mowi itself is looking at the coast of southwestern Ireland, where sea temperatures are slightly higher than Norway and more favorable to quick growth.

Calibration Offered

The Oceanographic Institute of Washington (OIW) has signed a contract with the National Oceanographic Instrumentation Center (NOIC) establishing a regional laboratory for the calibration of instruments used in oceanographic research and water quality monitoring.

Gilbert Jaffe, director of NOIC, flew to Seattle to make the $115,000 contract award. The new Northwest Regional Calibration Center is to be established at the Benaroya Industrial Park in Bellevue. It will be managed by ohe OIW. Richard vanHaagen of Oceanic Associates, Inc. has been retained as the director of the facility.

Jaffe said, "One of the most significant problems encountered in today's oceanographic and related environmental data collection and exchange programs is the poor quality of the instruments that are used to collect these data. The NOIC and its regional offices are responsible for developing standards and calibration techniques.

Events Calendar

A Catfish Processors work-shop has been scheduled for May 25-26 at Mississippi State University. Dr. Fred King, Chief of the NMFI Research Laboratory at Glouchester, Massachusetts will demonstrate the FIBUN fish seperator.

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COVER PHOTO: At this time of the year, when winter has its icy grip on the sea, some fishermen may not return to share Christmas with their families. To those families, and to the other families whose breadwinners did not return in previous Christmases, we extend our pray-

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FISH FARMING: a thriving new industry in Norway

Fish farming was the main theme at this year's conference of *Det Kgl. Selskap for Norges Vel*, an organization devoted to encouraging new forms of economic activity, particularly in rural areas.

Much of Norway's coastline offers good natural conditions for fish farming, also called aquaculture, which is a potentially very important field of endeavor for many of the nation's fishing communities.

Serious attempts at fish farming in Norway did not start until the 1950's. In 1972, the fish crop is estimated at 1,500 tons, consisting mostly of salmon and trout. With an annual growth rate of 15-20 per cent, output by 1990 is estimated at 20,000 tons per year. There are now between 70 and 80 fish farming installations in Norway, most of which are in the Sunnmore area on the west coast. The majority are concerned with raising salmon and trout to a marketable size.

Fish Breeding Experiments

Sunndalsora, in *More og Romsdal* county, is located at the head of a fjord and at the mouth of one of Norway's best-known salmon rivers, the Driva. Here, the Norwegian Agricultural College, in cooperation with a number of other institutions, has established a center for fish-breeding experiments, aimed at developing strains of salmon and trout suitable for commercial fish farming.

In two large buildings the Sunndalsora fish breeding center has 400 plastic fresh-water tanks for raising fish from the egg. There are also larger salt-water tanks where the fish can be kept until they can, in turn, breed and produce eggs. The aim is to keep the fish for several generations in order to have the broadest possible base for million fish are under continuous ob- fish strain selection. Altogether one servation at this establishment.

Salmon for Export Market

Supported by the industrial concern Norsk Hydro, the Bergen firm A/S MOWI has spent a reported 20 mill. in kroner on fish farming development since 1969. It is today one of the world's leading companies engaged in the industrialized breeding of salmon. It has four plants near Bergen, two for hatching and breeding of smolt and two for raising the fish to a marketable size.

The salmon eggs are hatched in special hatching troughs from roe from Mowi's own stock salmon. The fry are kept in freshwater tanks until they grow into smolt, and then they are removed to seawater enclosures. Mowi's hatching capacity is 2 million fry, while smolt capacity is up to 300,000 a year. The two salt-water plants have a combined capacity of more than 500,000 kilos of salmon.

In 1971, the firm marketed 60 tons of their "farm salmon" in Sweden, Denmark, West Germany and Norway. Sold fresh in chilled condition, the salmon was praised by connoiseurs. Top prices were obtained.

Within a few years, Mowi hopes to achieve an annual output of about 1,500 tons of salmon, which would be worth some 30 million kroner at present prices.

When sold, Mowi salmon weighs about three kilo (6 lbs.) and has lived two years in seawater.

The firm employs 15 persons on a full-time basis, 25 during the busiest season.

Small Investment at Hitra Fish Farm

Another fish farm that has achieved notable success is the one owned by the brothers Ove and Sivert Grontvedt at the island of Hitra in Sor-Trondelag county. Here relatively simple and inexpensive installations have yielded good results. Using floating cages, 4 meters deep and 120 square meters in area, the Grontvedts in less than three years have succeeded in raising large salmon which have achieved an average price of 25 kroner per kilo. For some fish, prices up to almost 60 kroner a kilo have been obtained.

The high-quality Grontvedt salmon are fed with capelin, a small fish caught in enormous quantities in North Norway every year.

Industrialist to Turn Fish Farmer

Christian Sommerfelt, joint managing director of Elkem-Spigerverket A/S, now Norway's largest industrial enterprise, will retire from day-to-day management duties at the end of this year. He recently revealed that he hopes to establish an aqua-culture center on the island of Svanoy in *Sogn og Fjordane* county, where he will raise salmon and trout and various other fish and shellfish. "It is essential," he said, "that we work to develop new possibilities for our economy in the years ahead — and especially in connection with our maritime resources."

Baby Oysters and Crabs for Export

The raising of shellfish and crabs under controlled situations is also making headway in Norway. The biggest oyster farm is run by A/S Osters, Vagastranda near Alesund, and apart from raising 200,000 oysters a year for consumption in Scandinavia, it is also developing an important export of baby oysters for replenishing oyster farms abroad which have lost stocks due to water pollution.

The Society for the Promotion of the Norwegian Fisheries, in Bergen, is seeking to develop "an elite oyster, a super race that will grow faster and multiply quickly," says a spokesman. The Society has its own trial oyster breeding pools where the effects of various types of pollution are being studied.

In 1971, Norway exported 10 tons of baby oysters.

In 1972, a notable development is a scheme for feeding crabs before sale to ensure that no "empty" crabs are offered on the market. The Government has bought from inventor Olaf Johnsen the rights to a method of crab feeding which will now be adopted by many of Norway's crab fishermen. Since 1962, Norway's Fisheries Directorate has trial-fed 120,000 crabs according to this method and with excellent results.

Help for Traditional Fisheries

Fisheries Counselor Hallstein Rasmussen of the Norwegian Embassy in Washington, D.C. tells *News of Norway* that fish farming may become economically important to many areas along Norway's coastline, not only for those who engage in this new industry, but also in terms of providing a market for certain products of the traditional fishing industry which are not suitable for human consumption. These products may be used as feed in the aquaculture. Mr. Rasmussen notes that fish farming is dependent on a number of factors and expresses satisfaction that research is now being conducted in order to solve the remaining problems in this field. ⚓

(As reported in "News of Norway")

Refrigeration on fishing vessels meeting planned

A meeting of refrigeration experts is planned in Tokyo, Japan, from March 2nd to 4th, 1974. Subjects to be discussed include refrigeration and freezing of fish aboard ships. For further information: Organizing Committee, Meeting of Commissions D3 and B2 of I.I.R., c/o Japanese Association of Refrigeration, San-ei Bldg., 8 San-ei-cho, Shinjuku-ku, Tokyo 160, Japan. ⚓

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THE ONLY INDEPENDENT MONTHLY JOURNAL SERVING CANADA'S WEST COAST FISHING INDUSTRY

COVER

Lief and John Hofstad of Burnaby own these 38-ft. troller-gillnetters. Both boats are powered with Caterpillar 3160 diesels, developing 210 HP at 2800 rpm and turning a 28 x 24 wheel through a 2.42:1 Twin Disc MG506 gear. Both boats were built by Chris Frostad's Boat Works.

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Eight Times Better

Spawning Channels Pay Handsome "Profits"

Spawning channels built in recent years by the Salmon Commission on the Fraser have been paid for many times over through increased returns, the director of the Commission told the annual meeting this month.

By Ed Cooper

The Commission has spent nearly $1.9 million on construction programs since 1964. Approximately $1.4 million of that has been spent on spawning channels at Seton Creek, Weaver Creek, Gates Creek and Nadina River. In addition, a small channel costing $35,000 was put in operation at Seton Creek in 1961, and an experimental hatchery, costing $84,000, started operating at Upper Pitt River in 1961. This hatchery was modified to include a gravel incubation system in 1963. The total expenditure to build these channels, which provide 84,115 sq. yd. of gravel, has been approximately $1.53 million, or approximately $18.14 per sq. yd.

Starting in 1963, you have been harvesting the sockeye and pink salmon produced by the channels at Weaver Creek, Pitt River, Seton Creek and Gates Creek, and between 1963 and 1972 a total of 1,505,000 sockeye and pink salmon combined have been caught (Table 1). These fish have a value of $2,678,000 to the fishermen, compared to the cost of $917,700 for the five producing channels. The seven years of returns from the Pitt River sockeye channel have produced catches valued over 10 times the capital cost, and the five years of returns from the two Seton Creek pink salmon channels have produced catches valued at almost four times the capital cost, and the four years of returns at Weaver Creek have produced catches valued nearly three times the capital cost. Both the Weaver Creek and Gates Creek channels returns are from operation at only 30 to 40 percent capacity.

Table 1. Catches Attributable to Existing Spawning and Incubation Channels

Brood Year	Upper Pitt	Weaver Creek	Gates Creek	Seton Creek	Totals
1961	—	—	—	85,347	—
1963	84,796	—	—	12,992	—
1964	97,376	—	—	—	—
1965	16,176	121,309	—	106,740	—
1966	49,096	52,844	—	—	—
1967	51,289*	43,724*	—	117,732	—
1968	28,404*	59,130*	72,104*	—	—
1969	—	—	—	506,164	—
Totals, Fish	327,137	277,007	72,104	828,975	1,505,223
Weight, lb.	1,995,536	1,767,305	425,414	4,948,981	9,137,236
Value	$878,036	$777,614	$187,182	$925,459	$2,768,291
Channel Capital Cost	$84,000	$275,074	$305,495	$253,154	$917,723

* Preliminary.

Table 2. Total Run Produced by 1,000 Eggs

Brood Year	UPPER PITT		WEAVER		GATES		SETON
	River	Channel	Creek	Channel	Creek	Channel	Channel
1961							14.5
1962							
1963	2.54	30.0					1.25
1964	3.40	31.30			2.94		
1965	1.75	9.69	2.33	14.10			14.66
1966	0.96	14.69	0.43	4.43			
1967	0.72*	13.08*	0.73*	8.30*			4.65
1968	0.78*	10.56*	2.98*	25.80*	1.71*	10.06*	
1969							24.66
Averages	1.69	18.22	1.62	13.16			11.94
Ratio	10.8		8.0				

* Preliminary.

Data on comparative production of the channels (Table 2) shows that they are continuing to produce on the average about eight times more sockeye than the adjacent natural spawning ground. At the Seton Creek pink salmon channels, production per 1,000 eggs deposited averages quite close to the sockeye channel average.

The Chairman mentioned that the primary reason for construction of the first channels was to obtain evidence of their effectiveness. This we now have. The channels were constructed at the stream selected to compensate partially for lost or deteriorated spawning grounds, so that they would serve a dual purpose. Another valuable aspect of these installations is the operating experience gained, which provides background knowledge for effective and efficient design of larger channels, and guards against errors in design which would be expensive to correct.

The key factor in the success of spawning channels is the clean, graded gravel. It was recognized at the outset, that it would be necessary to prevent fine materials from entering the channels, and settling basins were constructed for this purpose where considered necessary. Operating experience has disclosed some unexpected results, which have given us opportunity to prove the old adage that necessity is the mother of invention.

Bob Christianson

OCEAN RANCHING OF PINK AND CHUM SALMON

by

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INTRODUCTION

Pink and chum salmon together contribute about 60 percent of the total U.S. harvest of Pacific salmon. Historic catch records suggest, however, that the ocean is capable of growing at least twice the number of pink and chum salmon than are presently available for harvest. Reduced recruitment of juveniles to oceanic nursery areas is thought to be mainly responsible for reduced production.

North American streams and lakes produce five species of salmon which differ in age and size at maturity. Chinook are the largest and typically weigh over 20 pounds and are 3 to 6 years old at maturity. Pink salmon are the smallest, averaging only four or five pounds at maturity, and living only 2 years from the time the egg is fertilized. Coho, sockeye, and chum salmon are intermediate in size and typically live 3 to 5 years. All five species spawn only once, and die a few days after spawning.

Neither pink nor chum salmon require a freshwater nursery area as do Chinook, coho, and sockeye salmon. Pink and chum obtain their early growth in estuaries and inshore waters before spreading westward across the North Pacific Ocean (Figure 1).

Catches of North American pink and chum declined rapidly through the 1940's, and landings remain depressed. Southern stocks have been depleted more than northern stocks. Oregon chum salmon, for example, were decimated in the 1950's, and the fishery was closed south of the Columbia River in 1962. Even in Alaska, trends in annual landings (Figure 2) offer little comfort. The once prolific southeastern Alaska pink stocks have suffered about a two-thirds reduction in landings (Figure 3).

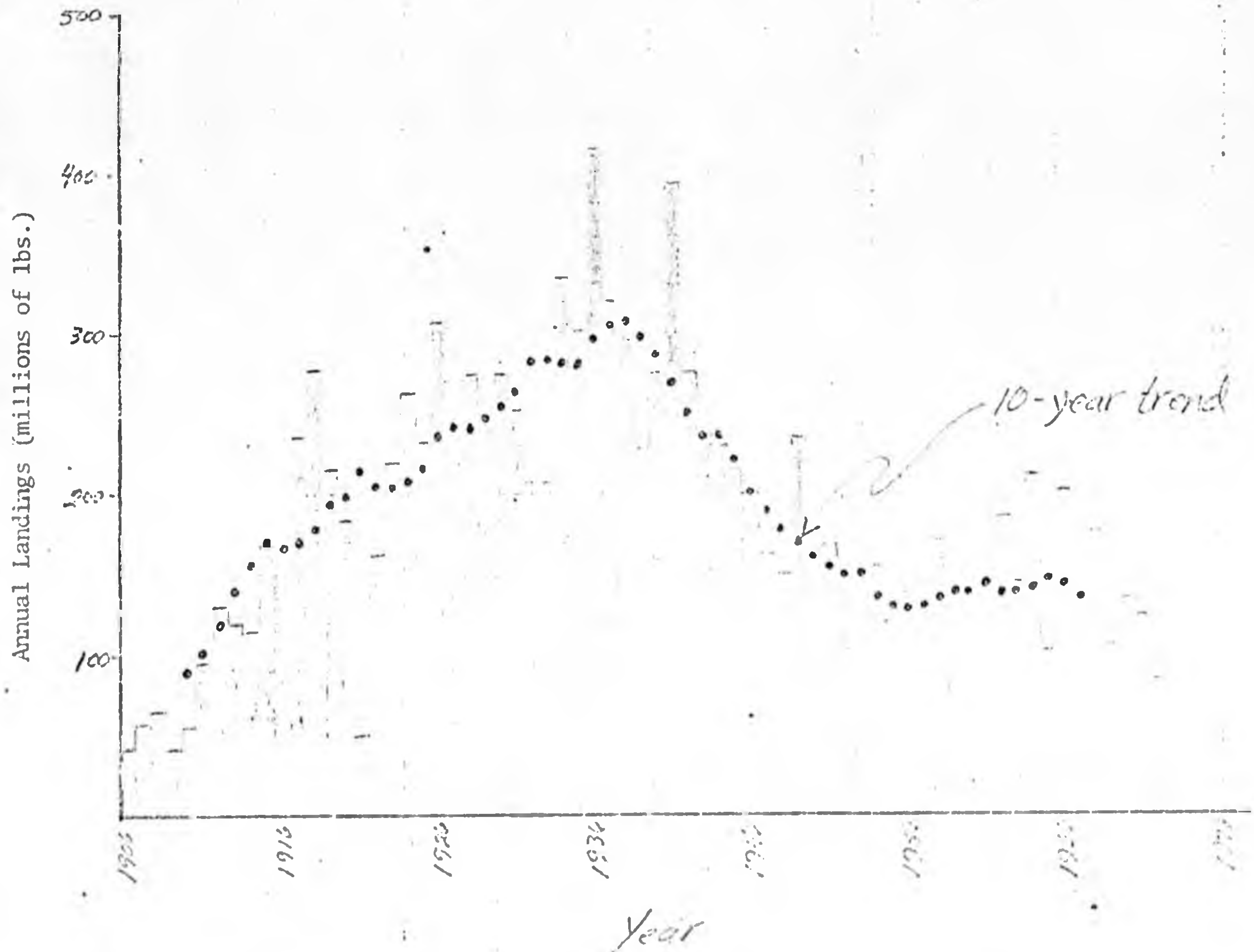

Figure 2.--Annual landings of pink and chum salmon in southeastern and central Alaska.

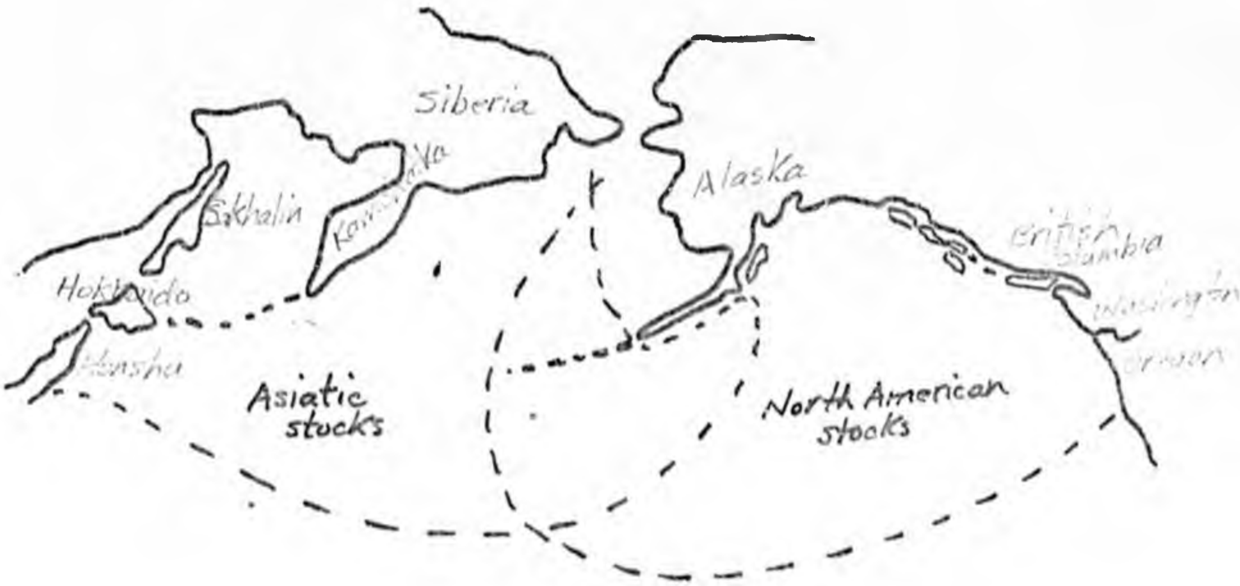

Figure 1.--General ocean distribution of pink and chum salmon.

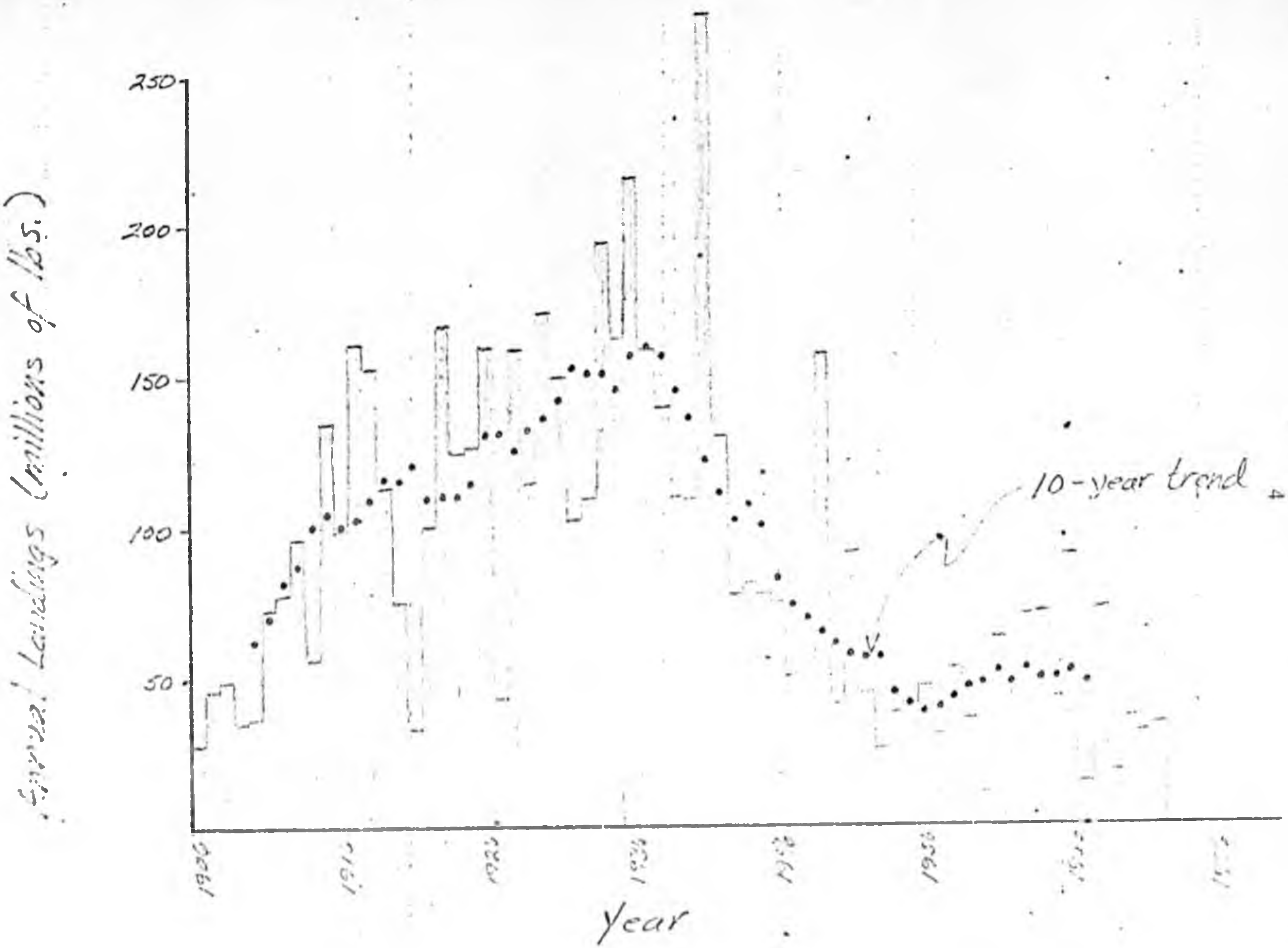

Figure 3. Annual landings of pink salmon in southeastern Alaska.

Overfishing is strongly implicated as the dominant force which initiated a rapid decline of pink and chum in the 1940's. However, reduced survival of eggs and young in streams and estuaries, resulting from damaging land and water-use activities, is probably contributing to the present depressed state of stocks in many areas. Provided natural or man-caused imbalances have not reduced the capacity of oceanic feeding grounds, there is a good possibility that numbers of harvestable fish can be increased through strict management of wild stocks and the application of artificial propagation.

Many pink and chum stocks can be revived with known management techniques, particularly in areas of Alaska where man has not yet exerted a major impact on spawning streams and estuaries. However, severe restrictions will be required on harvest, perhaps for several cycles where runs are seriously depressed. There is no scientific basis to expect that closures alone will suffice for those stocks which have been reduced to remnant runs. It will probably become necessary to propagate pink and chum salmon artificially where chronic over-exploitation occurs or where spawning habitat has deteriorated.

The Japanese have a highly successful hatchery program for chum and raise substantial numbers of pink salmon. The Russians have recently constructed several large hatcheries which release more pink and chum than Japanese hatcheries. Spawning channels have become popular in Canada as an alternative to hatcheries. Public hatcheries in the United States no longer produce many pink and chum salmon. Instead, they propagate primarily Chinook and coho salmon which are popular recreational species as well as valuable commercial fish. Private hatcheries are being tried with chum salmon in the Pacific Northwest in an attempt to rehabilitate this formerly important commercial species without committing public tax funds.

This report reviews the status of technology for propagation of pink and chum salmon in hatcheries for the purpose of ocean ranching. The concept of ocean ranching relies on a natural "herding instinct" that causes salmon to return to their home stream at maturity. The biological feasibility of hatcheries is discussed in detail, and questions are raised on the control of harvest of mixed stocks of wild and hatchery fish to avoid overfishing wild stocks and institutional arrangements for operating hatcheries.

STATUS OF ARTIFICIAL PROPAGATION

The Japanese began to build hatcheries in 1876; and numerous state, local, and private hatcheries now release 400 to 600 million juvenile pink and chum salmon annually to sustain coastal fisheries on Hokkaido and Honshu Islands. Chum is the most important species in Japan, and approximately four million hatchery adults return annually to coastal waters to provide an annual harvest of about 30 million pounds (Anon, 1966). Furthermore, marking studies indicate that Japanese vessels fishing on the high seas harvest at least an equal quantity (Kanid' yev, et al., 1970).

The Russians were forced into a large-scale hatchery program for pink and chum salmon in the 1960's to compensate for overexploitation of many of their stocks by the Japanese high seas fishery. The Russians presently release more pink and chum salmon from hatcheries than the Japanese; their 21 Sakhalin Island hatcheries alone produce more than 600 million juveniles. Although they obtain only about 0.4 percent return of hatchery chum to their coastal fisheries, the Russians believe that Japanese high seas fleets harvest most of their hatchery fish.

The relative importance of Japanese and Russian hatchery programs can best be comprehended by comparing the annual release of hatchery chum into the western North Pacific Ocean with recruitment of wild chum fry into the eastern North Pacific from all North American spawning streams combined. Published reports suggest that about one billion juvenile chum are released annually from hatcheries in Asia, which is probably a larger number than originate from all wild stocks in North America. This conclusion is based on the following statistics and assumptions:

1. Over the past 10 years, approximately 8 million chum have been harvested annually by U.S. and Canadian fishermen. There is no indication that Japanese fishermen harvest many North American chum.

2. Based on an assumed 50 percent rate of exploitation, the average total return (catch plus escapement) of chum to North America was 16 million fish annually. (This is a conservative estimate of rate of exploitation.)

3. Based further on an assumed two percent marine survival of wild fish (Bakkala, 1970, p. 53-54), 800 million fry were required to produce 16 million adults. In all probability fry production has averaged somewhat less than 800 million.

In marked contrast to recent successful hatchery programs in Russia and Japan, attempts to raise pink and chum salmon in public hatcheries in the Pacific Northwest have mostly failed. Although the Washington Department of Fisheries continues to raise a few million chum at two hatcheries, large-scale production of pink and chum came to an end in the late 1930's after consistent failure to establish runs of hatchery fish. Very low marine survival of hatchery pink and chum at Pacific Northwest hatcheries has contributed to the belief that hatcheries are less efficient than natural reproduction (Noble, 1963 and 1964).

In seeking suitable alternatives to hatcheries, fish culturists began to experiment with spawning and egg incubation channels in the 1950's. Promising results from early tests prompted the International Pacific Salmon Fisheries Commission and the Canada Department of Environment to construct commercial-scale spawning channels in British Columbia. The early indications are that marine survival of channel fry is much higher than experienced previously in Pacific Northwest hatcheries.

A spawning channel is usually a water diversion canal with a bed of silt-free gravel for spawning. Waterflow is controlled at a head gate, and spawner density by a fish weir. In most cases the adult salmon are allowed to spawn naturally, but their numbers are held between one and two spawners per m^2 (both sexes) to achieve optimum density. In a few instances, fertilized eggs are planted artificially. The protected environment of the channel ensures higher survival of embryos and alevins (larvae) than in a natural spawning bed.

Recent advances in our understanding of the requirements of pink and chum alevins has led to development of hatchery incubators which use a gravel substrate. The technique of spreading pink and chum alevins on gravel is widespread in Russian hatcheries, and is used also in some Japanese hatcheries (Kanid' yev, et al., 1970). It affords alevins a more natural environment than standard trough or tray incubators.

Two different designs of gravel incubation hatcheries are being field tested in Oregon, British Columbia, and Alaska. One type involves burial of newly fertilized or eyed eggs in gravel-filled tanks receiving an upwelling flow of water. In the other type newly fertilized eggs are placed on screen trays and suspended in a water column with an upwelling flow. After the eggs hatch, the alevins drop through the screens and repose on the surface of a shallow layer of gravel. Lids exclude light.

CRITERIA FOR HATCHERY DESIGN

The incubation of salmon eggs and alevins to the fry stage requires relatively little water or space. Conventional hatchery practices involve the concentration of newly fertilized eggs in trays which are arranged horizontally in troughs or stacked vertically. Water is directed through a series of trays before it is discarded. Provision is usually made for re-aeration of water as it passes from one tray to the next. Alevins may be retained in incubation trays until the yolk is absorbed, or they may be transferred to open troughs or ponds to complete their development.

Hundreds of millions of pink and chum fry have been raised by conventional techniques and released, but there have been no documented cases in North America where survival of hatchery fry has approached survival of wild fry. In almost every case survival has been too low to justify the propagation of pink and chum in hatcheries. We now recognize some reasons why these hatchery fry probably possessed a low fitness for survival.

The velocity of water flowing past alevins in conventional troughs and trays greatly exceeds the velocity under natural conditions in spawning beds. Furthermore, movements of the alevins are not restricted as in gravel beds of streams, and the smooth troughs or screen trays may fail to satisfy the tactile requirements of alevins (Bams, 1969). Although conventional hatchery methods yield high egg to fry survival, the resulting fry are undersized (Brannon, 1965; Poon, 1970), show a reduced capacity to perform work (Bams, 1967), and exhibit a high incidence of malformed yolks (Disler, 1953; Emadi, 1972).

The ability of fry to feed and grow also may relate to their early incubation history. An unpublished experiment with pink fry[1] compared growth and survival of fish from a tray incubator with fish from a gravel incubator. Average weight of surviving fish after 75 days of feeding on an unrestricted diet was 4.2 grams for the tray incubator and 6.5 grams

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[1] McNeil, W. J., 1971. Culture of salmon acclimated to seawater. Fourth Progress Rpt. - May 15, 1971. Oregon State Univ. Mar. Sci. Center. 4 p. (processed).

for the gravel incubator. The survivors from the tray incubator represented only 37 percent of the initial number of fry; whereas, the survivors from the gravel incubator represented 88 percent. The incidence of non-feeding "pinheads" was high among tray incubator fish and low among gravel incubator fish.

Nonfeeding fry are a common problem where pink and chum are raised at public hatcheries. The high incidence of malformed yolks with associated structural deformities may explain in part why pink and chum fry from tray and trough incubators have experienced very low marine survival. Bams (1972) feels that poor survival of hatchery fry is due primarily to poor conversion of yolk to body tissue, and the resulting small size and poor condition of fry.

The first evaluation of marine survival of pink fry from a gravel incubation hatchery has recently been reported by Bams (1972), who compared 77,000 marked hatchery fry with 75,000 marked wild fry. Bams estimated a 6.6 percent marine survival of hatchery fry and a 6.5 percent survival of wild fry, but the difference was not statistically significant. His estimate of six to seven percent marine survival of pink is consistent with observations of wild fish.

Combined observations on 17 brood years[2] of pink salmon at Sashin Creek, southeastern Alaska (Ellis, 1969), and 11 brood years at Hook Nose Creek, British Columbia, (Parker, 1964) revealed that 2.7 percent of the outmigrating fry returned to spawn. Although rates of exploitation are unknown, they

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[2] The term "brood year" refers to the year of spawning.

probably exceed 50 percent most years and may approach 80 percent for individual stocks some years. This means that marine survival has averaged in excess of 5.4 percent for Sashin and Hook Nose Creek pink salmon. A marking experiment on 1960 brood year Hook Nose pink salmon yielded an estimated 22 percent marine survival and 95 percent exploitation (Parker, 1964). Three similar marking studies on Bella Coola River, British Columbia, pink yielded 5.2, 4.4, and 1.9 percent marine survival of 1961, 1962, and 1963 brood years (Parker, 1968).

Marine survival of chum is more difficult to evaluate because of variable age of return. Chum live one to 3 years longer than pink, and marine survival would be expected to be lower. Parker (1962) estimated marine survival of Hook Nose Creek chum to be 2.8 percent. Parker's estimate is consistent with information available on spawner-recruit relationships for Alaska chum (Anon, 1966).

It is largely beyond our capability to exercise control over marine survival, but it is important that we have some idea of what to expect in terms of fish returning for harvest from a release of a known number of fry. In freshwater we have an opportunity to control and increase survival to much higher levels than observed in nature.

Statistics on freshwater survival of pink and chum for streams in Canada (Pritchard, 1948; Hunter, 1959; Parker, 1962), Alaska (Wright, 1964; Olson and McNeil, 1967; Ellis, 1969), and Russia (Semko, 1954; Kanid'yev, et al., 1970) show that outmigrant fry usually represent less than 20 percent of potential egg deposition. A recent compilation of data for Sashin Creek pink salmon (Ellis, 1969), reveals that there is a 27-fold difference in annual freshwater survival (0.8 to 21.7 percent).

Gravel incubation hatcheries are capable of increasing average egg to fry survival five to 10 times over natural streams. Hatcheries also afford a means to avoid broad annual fluctuations in fry production and to make efficient use of a relatively small number of spawners.

Hypothetical examples of surplus production from wild and gravel incubation hatchery pink salmon stocks are compared in Table 1. The survival figures used in Table 1 are representative of wild pink stocks reported already for Canada and Alaska and of hatchery stocks in Japan, Russia, and Canada (Anon, 1966; Kanid'yev, et al. 1970; Bams, 1972).

Just how effective gravel incubation might become in North America remains to be determined, but the last two columns of Table 1 reveal the potential advantage of hatchery stocks over wild stocks.

HARVEST OF WILD AND HATCHERY STOCKS

The operation of large hatcheries would not relieve the need for continued restriction of harvest of pink and chum salmon in the common property fishery, because the conservation of wild stocks will continue to demand high priority. Even when conditions favor good survival, it is unlikely that wild stocks will support more than 75 percent exploitation. Much lower exploitation will be required most years for conservation. Hatchery stocks, on the other hand, should sustain much higher exploitation, perhaps as high as 95 percent because of the small numbers of brood fish required to restock hatcheries. In the face of differing requirements for conservation, how do we provide for complete utilization of hatchery fish and avoid overharvesting wild fish on the fishing grounds?

Table 1.--Surplus production of pink salmon from wild and gravel incubator hatchery stocks with various assumed survival schedules.

Initial no. of eggs	Survival to fry	No. of fry	Survival to adult	No. of adults	Replacement spawning stock[1]	Surplus production	Exploitation rate
				WILD STOCKS			
1,000,000	.07	70,000	.04	2,800	1,000	1,800	.64
1,000,000	.10	100,000	.02	2,000	1,000	1,000	.50
1,000,000	.02	20,000	.05	1,000	1,000	0	0
				GRAVEL INCUBATOR STOCKS			
1,000,000	.80	800,000	.04	32,000	1,000	31,000	.97
1,000,000	.85	850,000	.02	17,000	1,000	16,000	.94
1,000,000	.80	800,000	.005	4,000	1,000	3,000	.75

[1] Assumes an average fecundity of 2,000 eggs per female.

Because it is imperative that the common property fishery be managed to achieve adequate escapements of wild fish to spawning streams, large surpluses of artificially propagated fish will return to successful hatcheries. These surplus hatchery fish would become available for harvest after they segregate themselves from wild fish. Such segregation will occur at the mouth of the hatchery stream in most instances.

State hatcheries in Oregon and Washington began to receive substantial numbers of surplus hatchery coho and Chinook salmon about 10 years ago. In 1970, these public hatcheries placed more than five million pounds of surplus salmon on the commercial market (Jeffries, 1971; Ellis, 1971). It is very likely that they also contributed another 20 to 30 million pounds to common property commercial and recreational fisheries from California into southeastern Alaska.

Even though commercial salmon fishermen are dependent upon hatchery fish in the Pacific Northwest, they have been very vocal in criticizing management agencies for allowing too many fish to return to hatcheries. It seems probable, however, that the present high rate of exploitation already threatens wild coho and Chinook stocks in the Northwest, and any further increase in exploitation could be disasterous unless it is selective for hatchery fish.

It is unlikely that wild pink and chum stocks could sustain as high of a rate of exploitation as coho and Chinook. This comes about because of differences in factors which limit recruitment of young to the ocean.

In the case of pink and chum, utilization of spawning habitat limits recruitment of young, and relatively large numbers of spawners are required for maximum production of fry. On the other hand, only relatively small numbers of coho and Chinook spawners are required to provide sufficient fry to stock limited stream nursery areas which are occupied by young fish for periods up to 3 years before they migrate to sea.

Surpluses of fish escaping the common property fishery and returning to a hatchery potentially will be much larger for pink and chum than for coho and Chinook because of the need to hold exploitation below 75 percent most years to conserve wild stocks. Only limited information is available on marine survival of hatchery pink and chum, but Kanid'yev, et al. (1970) report 1.5 percent return (catch plus escapement) of chum from northeastern Hokkaido, Japan, hatcheries over a 12-year ~~the~~ period.

It is instructive to use this information to predict surplus production of chum returning to a hypothetical hatchery:

Assumed number of eggs placed in hatchery	=	50,000,000
Fry production (85 percent of eggs)	=	42,500,000
Adults returning to common property fishery (1.5 percent of fry)	=	637,500
Harvest in common property fishery (60 percent of returning adults)	=	382,500
Adults returning to hatchery	=	255,000
Brood stock (2,700 eggs per female)	=	37,000
Surplus for harvest at hatchery	=	218,000

Many surplus pink and chum salmon escaping the common property fishery and returning to a hatchery will be mature fish which are no longer in prime condition for canning. Nevertheless, these mature fish retain considerable market value for caviar and bait eggs, smoking and drying, animal food, and bait. Even the carcasses of artificially spawned fish can be used for animal food and bait, so all adults returning to a hatchery, including brood fish, have potential markets.

Public fishery agencies in the Pacific Northwest are faced with substantial marketing problems which have been created by the sizeable surpluses of hatchery coho and Chinook. Roberts (1972) cites some common complaints voiced by fishermen.

"Salmon sold from hatcheries is of poor quality, this hurts our markets."

"A public agency shouldn't be in the fish business."

"Those returned hatchery fish are lowering the price of salmon caught by commercial fishermen."

These problems are symptomatic of a public hatchery program, because any successful hatchery will have a surplus, even with heavy exploitation. Serious consideration must be given to institutional arrangements for raising, harvesting, and marketing hatchery fish. Ideally, the value of surplus hatchery fish should underwrite the cost of hatcheries without threatening the economic security of fishermen. It seems a paradox that a technology which offers the promise of increasing the supply of salmon could also complicate the management of wild stocks and marketing.

One step to insure that surplus fish will underwrite the cost of operating hatcheries is to create a legal basis for private hatcheries. This is being tried on a restricted basis in California, Oregon, and Washington. Except where hatcheries are constructed by indian tribes on tribal lands, private hatcheries are licensed and regulated by state fishery agencies, but no public tax funds are used for construction and operation. In Oregon, any administrative costs incurred by the state are charged to the private hatchery. Salmon from private hatcheries become public property from the time they are released until the time they are recaptured in trapping facilities operated by the hatchery.

Private hatcheries presently licensed by state fishery agencies include one coho hatchery in northern California and four chum hatcheries in Oregon. The Washington Department of Fisheries has authority to license hatcheries, but to my knowledge they have not yet approved any applications. At least two indian tribes (Quinault and Lummi) operate private salmon hatcheries on their reservations in Washington.

Should "proprietary" fisheries created by private hatcheries prove to be financially successful, a salmon farming industry will most likely emerge over the next several years. Such a proprietary fishery conceivably could attain economic importance in its own right, while at the same time contributing substantial numbers of fish to the common property fishery. Figure 4 shows a systems model for pink and chum salmon which integrates production from wild and hatchery stocks to provide fish for harvest in a common property and a proprietary fishery.

The speculative risk of private salmon hatcheries is undoubtedly high, because we have very little information to pass judgment on economic feasibility at this time. Even if fish returning to a private hatchery do not have sufficient value to cover costs, there is a possibility that fishermen would tax their catches to cover the deficit, provided they are convinced that the added value of hatchery fish in their catch makes the added subsidy worthwhile to them. There may even be circumstances where the operation of hatcheries by fishermen's associations might become practicable, especially where limited entry to the fishery would give the participating fishermen a proprietary interest in any hatchery fish returning to a particular fishing ground.

Even though private pink and chum hatcheries are highly speculative, there is a likelihood for significant economies in costs of constructing and operating gravel incubation hatcheries. If costs of producing 1,000 fry can be held at about $6 (including amortization), then a 1.5 percent return of chum or a three percent return of pink to the common property fishery would be sufficient for a self-supporting hatchery under the following hypothetical conditions:

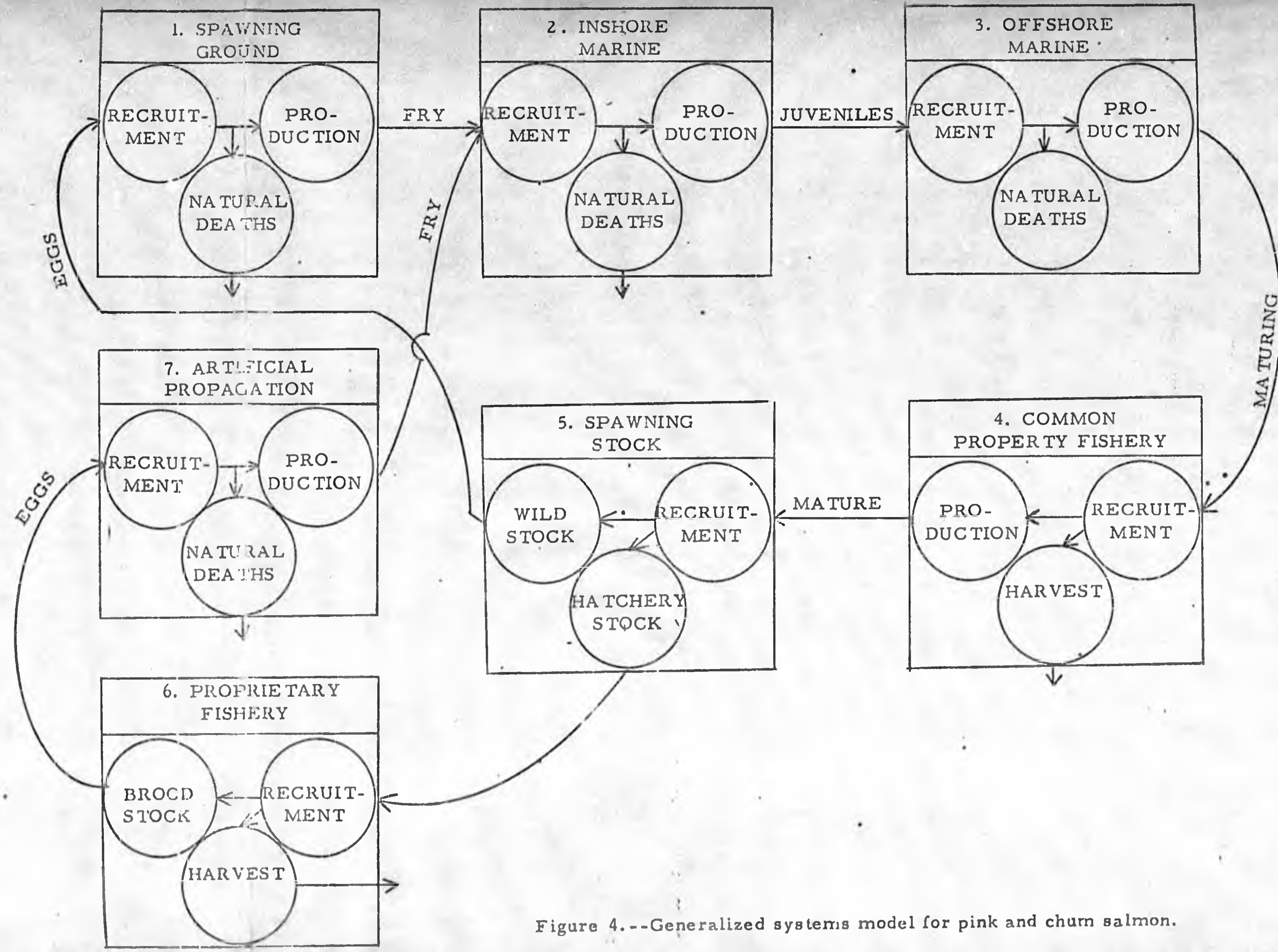

Figure 4.--Generalized systems model for pink and chum salmon.

	Chum	Pink
Cost of fry	$6/1,000	$6/1,000
Total return/1,000 fry	15 adults	30 adults
Harvested by commom property (60% exploitation)	9 adults	18 adults
Return to hatchery	6 adults	12 adults
Required for brood stock	1 adult	1.5 adults
Surplus for proprietary harvest	5 adults	10.5 adults
Value of surplus ($1.30/chum; $.60/pink)	$6.50	$6.30

The above examples provide slim margins for profit. If cost of fry production, market value of surplus fish, or exploitation in the common property fishery should be underestimated, the hatchery would lose money. Money would also be lost if marine survival should be overestimated. The example serves to identify the key elements which require evaluation:

1. Cost of producing fry.
2. Marine survival.
3. Exploitation in common property fishery.
4. Market value of surplus hatchery fish.

Emergence of a salmon hatchery industry will require intensified support from government in research, development, and advisory services. Private hatcheries will require assistance on criteria for design and operation of hatcheries, genetics and selective breeding of stocks, disease control, nutrition where short-term rearing of fry is involved, harvesting, processing, marketing, and socio-legal problems. Because State fishery agencies will administer and regulate private hatcheries, it is imperative that they participate in research, development and advisory projects along with National Marine Fisheries Service laboratories and

Sea Grant universities.

We may have already entered a period of transition from strictly public artificial propagation of salmon to a partnership between public and private propagation. Many questions need to be resolved by state legislative and administrative bodies before we can convert a "problem" of surplus hatchery fish into an "opportunity" to allow these surplus fish to pay the cost of operating hatcheries and to avoid continued heavy subsidization of public hatcheries. It is prudent for state fishery agencies to proceed with caution as they broaden their salmon management programs to include the assignment of limited proprietary rights to salmon. If properly executed, a partnership between government and private sectors of the economy can greatly broaden the financial base for expansion of salmon resources for the benefit of fishermen, processors, and the public.

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AUKE BAY FISHERIES LABORATORY

ANADROMOUS FISHES INVESTIGATIONS

A Systems Approach for Alaska Sockeye Salmon Research and Development Programs

Staff members of the Alaska Region of the National Marine Fisheries Service have reviewed the general status of knowledge on management and development of Alaska sockeye salmon stocks. One outgrowth of this review has been the description of a generalized systems model which will serve as an aid to planning of future research and development projects for Alaska sockeye salmon. Eight functional areas (subsystems) represent the core of the model:

Subsystem 1 - Spawning Ground
Subsystem 2 - Lake Nursery
Subsystem 3 - Inshore Marine
Subsystem 4 - Offshore Marine
Subsystem 5 - Common Property Fishery
Subsystem 6 - Spawning Stock (Escapement)
Subsystem 7 - Proprietary Fishery
Subsystem 8 - Artificial Propagation

These eight functional areas determine the biomass of sockeye salmon available for harvest and reproduction. Their interrelationships are outlined in Figure 1.

Two of these eight functional areas (numbers 7 and 8) do not presently play a significant role in Alaska. Early attempts at "proprietary" farming of sockeye salmon in Alaska ended in failure for a variety of economic and biological reasons. Nevertheless, scarcity and high value of salmon combined with greater knowledge about requirements of salmon and development of improved technology may reopen opportunities for proprietary salmon farming.

Other subsystems are important to the success of any program of management and development of Alaska sockeye salmon stocks besides the eight already listed. For example, a subsystem for forecasting the size of runs returning to western Alaska (Figure 2) plays an essential role in allocation of catch and escapement and in determining the number of canning lines to be operated. Examples of additional subsystems which provide inputs into the generalized systems model shown in Figure 1 include:

Subsystem 9 - Abundance and distribution of juveniles.
Subsystem 10 - Environmental parameters which affect survival and growth.
Subsystem 11 - Forecast of returning runs.
Subsystem 12 - Identification of separate stocks.

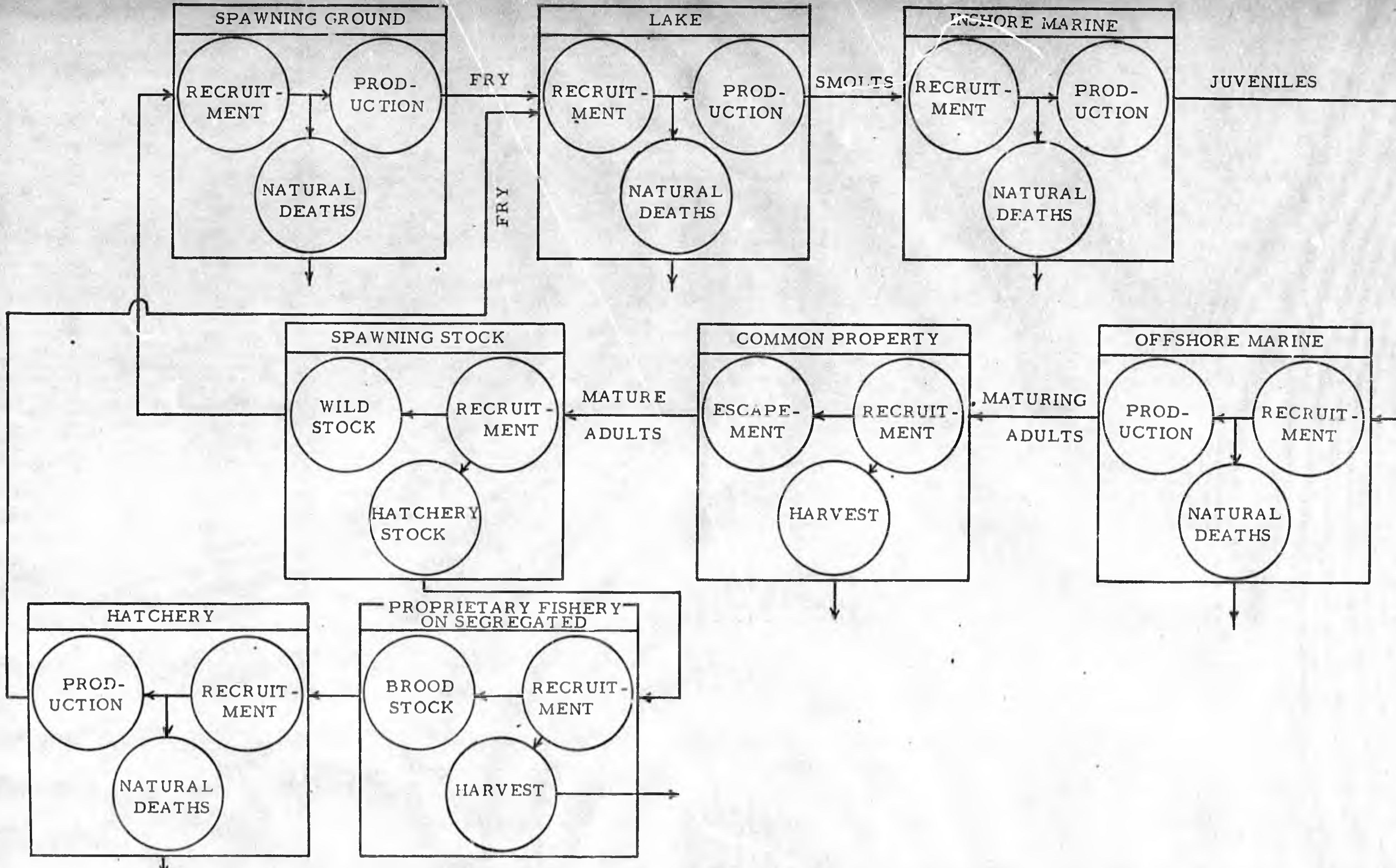

Figure 1. --Generalized systems model for sockeye salmon.

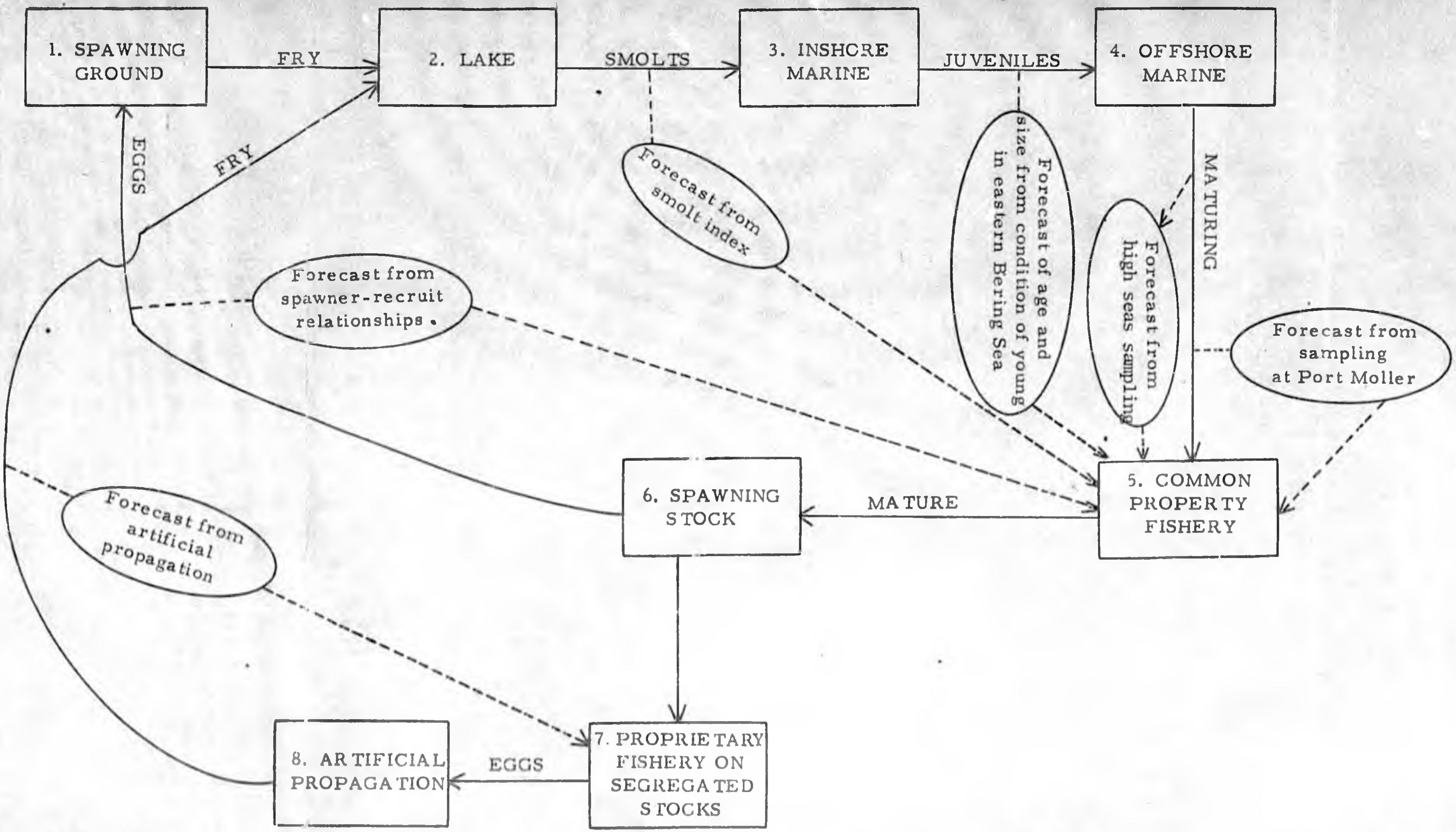

Figure 2. --Role of forecast subsystem in generalized systems model for Alaska sockeye salmon.

Subsystem 13 - Evaluation of physiological fitness.
Subsystem 14 - Heritability and selective breeding.
Subsystem 15 - Biogenic enrichment of lakes.
Subsystem 16 - Control of predators and competitors.
Subsystem 17 - Other habitat improvement.
Subsystem 18 - Fishery oceanography.
Subsystem 19 - Environmental impact studies.
Subsystem 20 - Fishery management planning.

This planning document attempts to clarify those areas where incomplete knowledge seriously impairs effective management and development of Alaska sockeye salmon stocks. You are encouraged to examine statements which follow under each of the subsystem titles for clarity, correctness, and applicability. In many instances, the statements could benefit from further amplification. Written and/or oral critiques on research and development programs for sockeye salmon are most welcome along with recommendations on priorities. Comments should be directed to William J. McNeil, Chief, Anadromous Fishes Investigations, Auke Bay Fisheries Laboratory, P. O. Box 155, Auke Bay, Alaska 99821.

Subsystem 1 - Spawning Ground

Our present understanding of fry production from spawning beds is probably adequate in most instances for managing and developing sockeye salmon stocks. Field studies show that the curve relating production of fry per unit area of spawning ground to density of females spawning approaches a maximum of about 300 fry per m^2 at a density of about 1 female spawner per m^2. We infer five important conclusions which serve as tentative guidelines for assessing the capacity of spawning beds to produce fry:

1. Fairly efficient reproduction (i.e., relatively high egg to fry survival) can be obtained at densities of 1 female spawner per m^2 and lower.

2. This first conclusion is qualified by the possibility that efficiency of reproduction declines at very low spawner densities (i.e., mortality may be inversely density dependent and a low threshhold to escapement may exist along with a high threshhold).

3. Mortality in spawning beds becomes strongly density dependent when escapements exceed 1 female per m^2.

4. Where conditions of over or under-escapement do not exist, egg to fry survival will average about 8 percent. It is recognized however, that actual survival can fluctuate between 1 percent and 20 percent from nondensity dependent mortality usually induced by weather.

5. Carrying capacity of spawning beds can be estimated from measurements of surface area, allowing a maximum of 1 female per m^2.

Information essential for the management of sockeye salmon stocks includes the description of natural spawning areas. Yet, the inventory of spawning grounds appears to be incomplete for most major lake systems, and the publication of spawning ground catalogs has lagged. It is important that inventories be completed and catalogs be published.

Subsystem 2 - Lake Nursery

There still appears to be no expert concensus on the level of fry recruitment to a lake which produces the maximum outmigration (number or biomass) of smolts. It is generally recognized that optimum fry recruitment varies among lakes, but there appear to be no estimates of the limits of stocking density that might be assigned to relatively productive and relatively unproductive lakes.

Perhaps we can infer answers to estimates of optimum stocking densities for western Alaska lakes from an examination of escapement and return statistics to individual lakes. Historic records at Karluk Lake reveal, for example, that about 700,000 spawners consistently generated returns of about 3 million adults. Karluk is recognized as one of the the more productive sockeye salmon lakes in western Alaska. It has about 350,000 m^2 of spawning gravel, which would barely accommodate 700,000 spawners (equal sex ratio) at a density of 1 female spawner per m^2.

Past research at Karluk Lake indicates that average fecundity is about 3,300 eggs per female and egg to fry survival is about 8 percent. If we were to achieve an escapement of 700,000 adults to Karluk Lake, we might expect the recruitment of fry to average about 92 million (2,300,000 per km^2) annually. If we were to further assume 10 percent survival of fry to migrating smolt, which conforms with field observations, we would realize an annual production of about 9 million smolts. This number of smolts would generate a returning run of 3 million adults to the fishery if one-third of them survived. It is significant that relatively high marine survival (30 percent and higher) has been measured consistently at Karluk.

The Wood River lakes are considered to be less productive than Karluk Lake but more productive than several other western Alaska lakes. The production of juvenile sockeye salmon in the Wood River lakes appears to increase up to a density of 5,000 spawners per km^2 of lake area. If we assume 8 percent egg to fry survival and an average fecundity of 4,000 eggs per female in the Wood River lakes (Bristol Bay fish are more fecund than Karluk fish), we would realize a stocking density of 800,000 fry per km^2. Spawning area is very extensive in the Wood River system and is not considered to be a limiting factor. If we further assume 10 percent survival from fry to smolt, average peak smolt production from the Wood River lakes would amount to about 34 million from an annual stocking of 340 million fry (800,000 fry per km^2 for a lake area of 425 km^2). A marine survival of about 18 percent would return some 6 million adults to the Wood River, which is approximately the level of abundance observed during the early period of the fishery (1900-1918).

Unfortunately, we can only speculate if a recruitment of 2,300,000 fry per km^2 at Karluk Lake and 800,000 per km^2 in the Wood River lakes would re-establish historic levels of sockeye in these systems. Perhaps a decline of biogenic enrichment from a lack of salmon carcasses has reduced the basic productivity of all western Alaska lakes. Regardless of the present or historic capacity of these lake systems to grow sockeye salmon, one very important question to be answered is: Will overstocking with fry cause biomass and/or numbers of smolts to approach an asymptote or decline after reaching a peak?

Observations at Iliamna Lake and at Kitoi Bay on Afognak Island suggest that production tends to level off at an asymptote, and overstocking a lake with fry may not threaten maximum production of smolts. The experiments at Kitoi further suggest that smolt production rapidly levels off at fry stocking densities of about 1,000,000 per km^2 and higher. This agrees with an estimated optimum recruitment of 800,000 fry per km^2 to the Wood River lakes.

Further studies on the carrying capacity of sockeye salmon lakes are required to fill important gaps in our understanding of the role of fish behavior and biological and physical environmental factors as determinants of production. The distribution and movement of young sockeye salmon are known to vary considerably among lake systems, but the surveillance of young fish in lakes has been facilitated by the application of acoustical devices. The routine application of acoustics combined with depth integrating trawling to determine species composition of acoustic "targets" is highly desirable for the assessment of recruitment from naturally and artificially propagated stocks. An overall evaluation of the effect of fry recruitment and of environmental factors on smolt production necessitates a continuation of smolt sampling in outlet streams.

Subsystem 3 - Inshore Marine

Recent studies have shed light on the distribution and movement of young sockeye salmon passing through Bristol Bay and into the eastern Bering Sea. An understanding of the role of environment on growth and survival is beginning to unfold from exploratory fishing, synoptic oceanography, and comparative studies on growth and osmotic adaptation.

Intensive sampling from oceanographic vessels in Bristol Bay and the eastern Bering Sea has generated a back-log of oceanographic data and biological samples. Routine sampling of juvenile sockeye salmon from shore-based vessels at Port Moller is recommended to provide information on annual variation in timing of migration and growth. Remote censusing of surface water temperature with aircraft or satellite-mounted radiometers is also recommended to provide data necessary to evaluate annual differences in marine environmental conditions potentially affecting juvenile sockeye salmon.

There is a considerable body of information on total marine survival of western Alaska sockeye salmon, but we have little knowledge beyond assumption about the relative magnitude of inshore-marine vs offshore marine mortality. Tagging studies have been planned to estimate inshore-marine mortality, but their execution will require a major expenditure of resources. Alternative approaches to estimation of mortality through changes in fishing success (catch per unit of effort) should be explored to determine if costs can be reduced and reliability of mortality estimates increased over that to be expected from tagging studies.

The decision to undertake a large-scale mortality study should depend in part on the outcome of analyses of whether or not ocean mortality is density dependent. Perhaps an answer to this question can be inferred from a study of recent records from individual Bristol Bay lake systems. Heavy outmigration of smolts from the Kvichak River is known to dominate total recruitment to Bristol Bay in some years but not in others. Perhaps the impact of heavy Kvichak runs on survival of other stocks can be evaluated from past records. If density dependent marine mortality cannot be reasonably established, then it is unlikely that inshore-marine mortality is limiting at stocking densities resulting from recent levels of natural recruitment. Should this be the case, the dominant justification for a costly inshore-marine mortality study would be to evaluate the effect of harvest of juvenile sockeye salmon on the high seas by Japan on total annual yield in weight of Bristol Bay sockeye. This does no appear to be a compelling reason to undertake a costly mortality study at the present time.

Subsystem 4 - Offshore Marine

Long-term studies of Alaska sockeye salmon have been continuing in the North Pacific Ocean for 18 years, and substantial knowledge has been acquired on distribution and movement of stocks. Considerable numbers of Bristol Bay sockeye salmon are harvested by the Japanese high seas fishery, and any eastward extension of the abstention line would expose additional stocks of Alaska salmon to the Japanese fishery.

In addition to information on distribution and movement of salmon, offshore sampling provides data on relative abundance of sockeye salmon which can be used to forecast the number of fish returning to Bristol Bay. Limited high seas sampling for purposes of forecasting seems justified based on benefits to industry and salmon management, but the necessity for continued tagging studies should be critically evaluated.

Subsystem 5 - Common Property Fishery

Completion of the Bristol Bay data file and programming for instant retrieval of historical data on catch and escapement statistics will probably assist management of the fishery.

Preliminary evaluation of an analytical model to estimate the contribution of fish from major Bristol Bay nursery lakes to the catch in three fishing districts indicates considerable intermingling of stocks. The assumption that western and eastern Bristol Bay stocks do not intermingle in the eastern district is, therefore, in doubt, and the rate of exploitation of the Ugashik stock may be considerably underestimated in some years. This work emphasizes the need for further studies on migration patterns of individual stocks through the Bristol Bay fishery.

Test fishing off Port Moller provides the fishery manager and the industry with essential information on age composition and timing of the run. Rough seas make sampling difficult in this area, and a larger vessel would ease this problem somewhat.

Forecasts of the size of returning runs still lack a high degree of precision, but they do provide valuable information for planning the allocation of the run for escapement and harvest and for planning the operation of canneries. Should programs for limiting entry into fisheries emerge, licensing of fishing gear might provide for liberalization and restriction of the amount of gear on an annual basis depending on the anticipated size of runs. Such an approach to management would require reliable advanced forecasts of size of runs.

Subsystem 6 - Spawning Stock (Escapement)

Escapement goals established for western Alaska sockeye salmon stocks are based largely on Ricker-type curves fitted to spawner-return relationships. Data used for fitting these curves have mostly been obtained since the mid-1950's, and they cover a period typically dominated by runs of smaller than average size. The possibility that escapement goals are too small cannot be ignored. More emphasis should be placed on alternative approaches to estimating optimum escapement, especially analyses of carrying capacity of spawning grounds and lake nursery areas.

Subsystem 7 - Proprietary Fishery

Hatcheries (and in some instances spawning channels) can increase average egg to fry survival from 5-10 percent for wild stocks to 80-90 percent for artificially propagated stocks. This represents at least an 8-fold increase in efficiency of reproduction. If fitness for survival should prove to be equal for hatchery and wild fry, then the hatchery requires only one fish for eight or more required for natural spawning.

Hatchery stocks theoretically can sustain up to 96 percent rate of exploitation, but the harvest of fish in the common property fishery will have to be restricted to less than 70 percent of the total run most years in order to afford continued protection of the wild stocks where hatchery and wild stocks intermingle. This means, for example, that a common property fishery harvesting 700 of a returning run of 1,000 adults would still allow 260 hatchery fish to be harvested at the hatchery stream (40 fish would be required for brood stock); whereas, all 300 wild fish surviving such a fishery would be required for natural spawning. If surplus hatchery fish could be harvested by a proprietary fishery, their value might contribute a substantial portion of the cost of operating a hatchery.

Assignment of proprietary rights to hatchery fish that have escaped a common property fishery provides dual opportunities to supplement the common property fishery and to expand the economic base of the salmon industry with minimum commitment of public tax funds. Successful application of the proprietary concept requires that surplus hatchery fish have sufficient value to support the operation of hatcheries or that fish harvested in the common property fishery be taxed to subsidize hatcheries.

A trend to establish proprietary fisheries on surplus hatchery fish is already well established by state fishery agencies in the Pacific Northwest where private firms acquire surplus coho, Chinook, and chum salmon from public hatcheries on bids. California, Oregon, and Washington have also started to license streams to private hatcheries which derive their income entirely from surplus fish which escape the common property fishery. Thus, use is being made of private capital to expand production at locations where tax funds are not available or are insufficient to support public hatcheries.

Many interacting technological, legal, economic, and social questions will influence public policy on proprietary fisheries. A detailed study of these interacting questions should be undertaken, probably by a university team.

Subsystem 8 - Artificial Propagation

Several techniques are available for artificial propagation of sockeye salmon. No attempt will be made here to compare the relative merits of the various methods, but the method that appears most promising at the moment is the gravel incubation hatchery. This type of hatchery is experimental, but it holds the promise of substantially reducing costs over spawning channels and producing fry which have a fitness for survival comparable to wild fry.

Operation of low-cost gravel incubators has not been tried under severe winter conditions comparable to those experienced in Bristol Bay, and this should be a preliminary objective of a hatchery research and development project with sockeye salmon. Another objective should be to stock an isolated lake with hatchery fry and to evaluate their survival. If successful, this work could lead to large-scale sockeye salmon development projects for western Alaska lake systems. Karluk Lake is under consideration as a site for such a demonstration project.

Fishery biologists and other observers who are familiar with Karluk Lake are somewhat divided in their opinions on what factor or factors caused the drastic decline in sockeye salmon that occurred there. We know that the decline resulted in decimation of the middle portion of the run. Assuming there are no permanent ecological imbalances in the nursery lake, it is estimated that a 20- to 30-year closure of the fishery would be required for runs to rebuild to former peak levels of abundance.

The application of hatchery technology to increase efficiency of reproduction by about 10-fold has great theoretical appeal in the case of Karluk Lake. It is believed by some biologists that a hatchery system producing 50 million fry annually would stock the lake to about 50 percent of its carrying capacity, provided the young fish enter the lake at the proper time when food organisms predominantly consumed by fry are at their seasonal peak of abundance. The addition of 50 million artificially propagated fry to Karluk Lake at the proper time of year might be sufficient to "trigger" the recovery of Karluk Lake sockeye within a 10-year period. About 20,000 female spawner would produce 50 million fry in a hatchery; whereas, about 200,000 would be required to achieve the same production with natural spawning. It is likely that the remnant mid-season run still has sufficient fish to provide seed stock for a hatchery program.

Subsystem 9 - Abundance and Distribution of Juveniles

Techniques are well developed for measuring abundance of eggs and alevins in shallow streams but not in deep water, including lake beaches. Evaluation of success of lake spawning has lagged, however, because of lack of suitable sampling equipment and techniques.

There has been rapid progress in the development of advanced sonic and trawling techniques to evaluate abundance and distribution of young sockeye salmon in lakes. Although some developmental work remains, routine monitoring of distribution and abundance of young fish in lakes should receive high priority along with detailed studies of behavior.

Sampling of young fish migrating in streams and passing through inshore marine waters can be accomplished with present fishing techniques.

Subsystem 10 - Environmental Parameters

No serious deficiencies are presently recognized concerning our ability to measure or monitor environmental parameters. Over-expenditure of resources for routine monitoring should be avoided, and a listing should be made of minimum environmental measurements required for each lake system. Opportunities appear to be emerging for remote sensing of parameters such as surface water temperature from satellites.

Periods of transition are generally recognized to be critical to the success of a particular brood year. In the case of sockeye, these periods include spawning, hatching, entry to the lake, and entry to the ocean. We possess a fairly good understanding of the processes which affect survival during spawning and hatching, but we have only a sketchy understanding of the processes which affect survival during entry of fry to the lake and of smolts to the ocean. We need to focus more attention on sockeye salmon ecology during these two critical periods.

Subsystem 11 - Forecast

Most research on the ecology of sockeye salmon is undertaken to understand factors that limit production. However, major by-products of such research include the development of means to exercise control over production and to forecast the abundance of salmon available for harvest. The accuracy of a forecast reflects to a large extent our understanding of the various biological and physical factors which interact to limit production.

Examination of Figure 2 indicates that a considerable amount of research and development work on sockeye salmon relates to the forecast problem. The varied sampling programs which have evolved over the past 15 years now provide a complex array of inputs which contribute to the several forecasts made annually for major sockeye salmon fisheries. These sampling programs should be analyzed and evaluated to determine if modifications might reduce costs and increase the reliability of forecasting.

Subsystem 12 - Identification of Stocks

The identification of stocks is made especially difficult in Bristol Bay because the timing of returning migrations to the Bay coincides for all major stocks. Development of analytical techniques for stock separation based on trace mineral content of bony structures is under study. Genetic separation of stocks based on differences in enzyme systems and chromosome morphology should probably be explored, also. Development of analytical techniques for stock identification is essential for improved management programs and mortality studies.

Subsystem 13 - Physiological Fitness

The application of gravel incubation hatcheries for propagation of sockeye salmon will necessarily include an evaluation of the physiological fitness of hatchery fry as opposed to wild fry.

The possible effects of size of smolts and timing of migration to sea on survival has not been adequately evaluated. Emphasis should be placed on osmoregulatory capacity of smolts of different size, genetic stock, age, and body condition.

Subsystem 14 - Selective Breeding

The operation of hatcheries will create opportunities for selective breeding, but every attempt should be made to retain wild-type gene pools through random matings of a sufficiently large brood stock until such time that a decision is made to breed selectively for chosen traits. There is an immediate need to evaluate heritability of defined traits in sockeye salmon.

Subsystem 15 - Biogenic Enrichment

There has been considerable field experimentation on artificial fertilization of sockeye salmon lakes. The Fisheries Research Board of Canada is presently involved in such experiments on Great Central Lake, B. C. Nevertheless, more basic research is recommended on nutrient cycling in sockeye salmon lakes before large-scale field experiments are repeated in Alaska. The participation of university personnel in studies of nutrient cycling should be encouraged. One practical application of such research might be the control of timing of the spring bloom to coincide with fry emergence.

Subsystem 16 - Predator Control

Recent studies in the Wood River lakes have implicated larger char and trout as major causes of mortality of sockeye salmon smolts. The experimental control of predators in Little Togiak Lake combined with measurements of survival of sockeye smolts should probably be encouraged to gain further insight into the possible significance of predation.

However, the long-range solution to predation may require increased recruitment of sockeye salmon fry along with selective removal of predators or screening of predators from smolt migration pathways.

Subsystem 17 - Other Habitat Improvement

Criteria for calculation of cost-benefit ratios are reasonably well-established for poisoning lakes to remove predators and competitors and for laddering falls. Although there are no clear criteria for evaluating flow control, removal of silt from spawning beds, and other physical improvements of the environment, there appears to be little urgency to pursue these questions at the present time.

Subsystem 18 - Fishery Oceanography

The role of the marine environment in determining survival and growth of sockeye salmon is poorly understood. Annual variations in ocean temperature, for example, are suspected to affect growth and survival, but the routine monitoring of oceanographic conditions is a formidable task requiring resources beyond the capability of an individual salmon research group. Close coordination is required, therefore, between the salmon and oceanographic research groups to insure that oceanographic observations provide data which are meaningful to salmon biologists. Opportunities to use satellites to acquire environmental data should be explored.

Subsystem 19 - Environmental Impact Studies

Man's detrimental impact on salmon resources through a variety of land and water use activities is well documented. Where physical alteration of the environment is anticipated, it is important for the salmon investigation group to evaluate the probable impact on salmon resources and to recommend means to alleviate or mitigate damage to salmon.

Subsystem 20 - Salmon Management Planning

Effective management of salmon resources requires the fishery manager to have ready access to knowledge of factors which limit production and of techniques which can increase production. The research biologist should participate in management planning to insure that new knowledge is being applied and to insure that research programs are relevant to the needs of salmon managment.

It seems unlikely that the impact of land and water use activities on salmon streams and lakes has played a major role in the decline of Alaska salmon resources. With proper application, known resource management and development techniques could potentially revive the salmon resource to historic high levels. Major impediments to enlightened management relate significantly to the tremendous user demand on salmon. The recovery of many wild stocks will require severe restriction on harvest, perhaps for many cycles in the case of decimated stocks such as Karluk. It will be difficult for many segments of the industry to face up to this problem and accept closures which lead to serious, immediate economic dislocation. The fishery manager is in many instances faced with an almost impossible task of satisfying an ever increasing user demand with a shrinking or, at best, a constant resource base.

The application of hatchery technology to increase egg to adult survival can compound this problem if the user groups fail to recognize that the common property fishery must be constrained to conserve the wild stocks. The implementation of large-scale hatchery programs without some form of limited entry and proprietary harvest of surplus hatchery fish could lead to the ultimate failure of major wild stocks from overfishing should they intermingle with hatchery stocks.

Concluding Comments

A sockeye salmon research and development program must place emphasis on those functional areas which are limiting production. The major blockages to maximum production are thought presently to relate to a lack of fry recruitment to the lake nursery areas. Inadequate escapement of spawners, limited spawning grounds, low egg to fry survival, and poor distribution of fry contribute to this problem.

Our ultimate aim is to exercise the greatest possible degree of control over the sockeye production system outlined in Figure 1. Inputs into the system actually begin with the spawning stock (Subsystem No. 6). We presently exercise control over the system through allocation of escapement by restricting the fishery. If this single control is to function effectively, we must have realistic guidelines for establishing escapement goals. There is concern that existing guidelines based on spawner-recruit curves are tending to underestimate the number of adult spawners required to stock lake nursery areas with fry.

What level of fry recruitment do we require for each lake system? Unfortunately, this question remains largely unanswered. Because of differences in basic productivity, we strongly suspect that lake systems differ in required stocking densities. Based on present knowledge about primary productivity (carbon fixation) and standing crop of phytoplankton, western Alaska sockeye salmon lakes appear to fall into three categories, viz:

1. Relatively productive--Karluk, Chignik.

2. Of intermediate productivity--Igushik, Wood, Kvichak, Naknek.

3. Relatively unproductive--Alagnak, Ugashik, Snake, Nuyakuk, Egegik.

Preliminary estimates of fry stocking densities required to produce maximum adult returns have already been made for Karluk Lake and the Wood River Lake system. It has been suggested that Karluk requires 2,300,000 fry per km^2 of lake surface and the Wood River lakes 800,000 fry per km^2. For purposes of discussion we will accept these figures as generally desirable for lakes in the first two categories listed above, and we will further assume that 400,000 fry per km^2 is a desirable target for lakes in the third category. With these assumed figures on fry stocking densities, we can calculate tentative target escapements for each of the western Alaska sockeye salmon lakes (Table 1).

Although Table 1 may represent largely a theoretical exercise, several points of potential significance are, nevertheless, brought into sharper focus. A comparison of columns (5) and (8) suggests consistent under-escapement to all lake systems based on the assumed figures for target fry recruitment. In fact, if the assumptions are reasonably correct, column (9) portrays a very dismal outlook for western Alaska sockeye salmon from escapements observed since 1955.

Based on this preliminary examination, it would appear that the fishery should be restrained to allow increased escapements for those systems where spawning area is not a limiting factor. With regard to spawning grounds, Table 1 shows that inventories have been completed on only five of the 11 major lake systems. Spawning ground inventories should be completed for the remaining lake systems as quickly as possible.

Another approach for increasing fry recruitment is to operate hatcheries and/or spawning channels. This would be a formidable undertaking in western Alaska, but if the benefit:cost ratios from artificial propagation should prove to be favorable, there could be compelling economic justification for such a course of action. Furthermore, there is considerable precedent for the application of artificial propagation of sockeye salmon fry to supplement wild stocks.

There are two massive sockeye salmon development projects in Canada (Fraser and Skeena River systems). These projects involve primarily spawning channels, and there are preliminary indications that the channels will provide highly favorable benefit:cost ratios. However, access of construction equipment to spawning areas is much easier in Canada than in Alaska.

For western Alaska sockeye salmon, we are exploring the potential application of a newly emerging hatchery technology--the gravel incubation hatchery. We believe that gravel incubation hatcheries will be the least costly propagation systems to construct and operate, will yield higher survival than spawning channels, and will produce fry of much higher quality than standard hatchery incubators. Construction of a pilot demonstration gravel incubation hatchery is planned for the northwest basin of Naknek Lake.

Table 1.--Hypothesized fry stocking densities and escapement goals for western Alaska sockeye salmon lakes.

(1) Lake system	(2) Surface area (km^2)	(3) Target fry recruitment No./km^2	(4) Target fry recruitment No. for lake	(5) Required total spawners	(6) Required spawning area	(7) Actual spawning area	(8) Average no. since 1955	(9) Frequency of under-escapement
Karluk	40	2,300,000	92 million	697,000	34.9 ha.	35 ha.	344,000	8/8
Chignik	64	2,300,000	147 million	919,000	45.9 ha.	160 ha.	510,000	16/16
Igushik	74	800,000	59 million	369,000	18.5 ha.	?	280,000	11/17
Wood	425	800,000	340 million	2,125,000	106.2 ha.	3,074 ha.	906,000	16/17
Kvichak	2,889	800,000	2,311 million	14,444,000	722.2 ha.	951 ha.	5,562,000	15/17
Naknek	790	800,000	632 million	3,950,000	197.5 ha.	354 ha.	933,000	17/17
Alagnak	297	400,000	119 million	744,000	37.2 ha.	?	304,000	14/17
Ugashik	385	400,000	154 million	962,000	48.1 ha.	?	515,000	7/8
Snake	89	400,000	36 million	225,000	11.2 ha.	?	26,000	8/8
Nuyakuk	279	400,000	112 million	700,000	35.0 ha.	?	120,000	17/17
Egegik	1,132	400,000	453 million	2,831,000	141.6 ha.	?	826,000	8/8

Egg to fry survival is assumed to be 8 percent in all lake systems. Average fecundity is assumed to be 4,000 eggs per female in all systems except Karluk, where the average is assumed to be 3.300 eggs per female. Becharof Lake on the Egegik system is placed in the category of low primary productivity, although pertinent limnological data are not available for this lake.

The gravel incubation hatchery affords the promise of minimal demands on water and brood stock to achieve maximum production of quality fry. Furthermore, the pattern of voluntary emigration of fry from the hatchery is similar to that from a natural spawning stream or a spawning channel.

Based on research findings to date, we project that 1 cfs (450 gpm) of water passing through gravel incubators will produce approximately 3,250,000 fry from approximately 4,000,000 eggs collected from 1,200 brood females. The hatchery tanks would occupy less than 3,000 ft^2 of space. They are designed to operate without external support systems (other than gravity water supply). The major problem in Bristol Bay will be to protect tanks and the water supply system from freezing.

If in some future time we are able to effectively utilize the capacity of western Alaska lakes for production of sockeye salmon, other questions will become increasingly important. For example, will it become economically feasible to manage the lake ecosystems for increased growth and survival of juvenile sockeye through control of predators and competitors or through artificial fertilization? Other important problems relate to the capacity of the inshore marine waters to absorb increasing numbers of smolts, or whether we can exceed the capacity of this important marine nursery ground.

The development of technology will play an increasingly important role as we exercise increased control over recruitment of fry and production of smolts. We will need to sharpen our capabilities to measure environmental parameters and abundance and distribution of young. We will strive to improve techniques of forecasting, of identifying stocks, and of determining physiological fitness of young fish. Selective breeding of hatchery stocks, biogenic enrichment of lakes, and control of predators and competitors will become increasingly important as we achieve a capability to regulate fry recruitment to nursery lakes.

Realization of increased production of sockeye salmon will depend ultimately upon a unity of purpose and effort on the part of fishery management, fishery research, fishermen, processors, and political leaders. Not every idea will find a successful application, but all interests must be willing to cooperate on any positive endeavor to resolve the problem of a shrinking resource if the fishery is to remain a viable part of Alaska's and the nation's economy.

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Aquaculture Regulations Adopted by Washington

Regulations authorizing the commercial aquaculture of salmon and other food-fish in Washington state were adopted recently by the Washington State Department of Fisheries.

The regulations deal with aquaculture in general, but only the commercial culture of salmon will be developed at this time, Fisheries Director Thor C. Toliefson said. Policy on culture of other foodfish will be developed as the need arises, he said.

Salmon may be cultivated under permit from the Department of Fisheries and payment of a $100.00 annual license. Applicans for a permit must state location and description of project facilities, and demonstrate technical and financial capability.

Surplus salmon eggs may be obtained from the Department of Fisheries. They may not be resold and no eggs or fish may be brought into the state without written approval from the Director of Fisheries.

Fish farm facilities, fish cultural activities, and fish cultural and disease control records are subject to inspection by the Department of Fisheries. Major operation changes and disease outbreaks must be reported to the Department.

Director Tollefson said private culture of salmon, the state's most valuable fishery resource, will be conducted only with fish surplus to public needs, and "in a manner that avoids environmental competition with wild or hatchery-produced fish".

It is also essential, he said, that eggs not be wasted and adequate attention be devoted to nutrition, genetic and disease control.