Northwest Fish Culture Conference

COURTENAY, British Columbia

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Dorothee Kieser

PROCEEDINGS

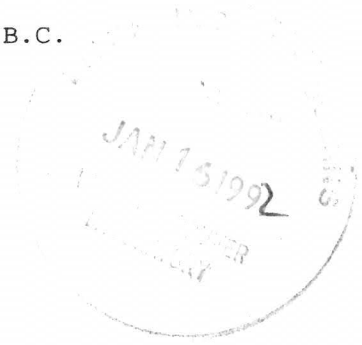
of the

Thirty-First Annual

NORTHWEST FISH CULTURE CONFERENCE

December 2 - 4, 1980

Courtenay, B.C.



Chairman

F.K. Sandercock

Fisheries and Oceans Canada

THE NORTHWEST FISH CULTURE CONFERENCE

Northwest Fish Culture Conferences are informal workshops for exchange of information and ideas concerning all areas of fish culture. Current progress reports of hatchery management practices and problems, new developments in fish culture technology and results of research studies are presented. Active discussion and constructive criticism are encouraged and contribute significantly to the information exchange that takes place. All persons interested in or associated with fish propagation are invited to attend and participate. Presentations are limited to topics that have direct application to fish culture.

The PROCEEDINGS contain unedited briefs or oral reports presented at each conference. Much of the material concerns progress of uncompleted studies or projects. THESE INFORMAL RECORDS ARE NOT TO BE INTERPRETED OR QUOTED AS A PUBLICATION.

PREFACE

The 31st Annual Northwest Fish Culture Conference was held at the Westerly Hotel, Courtenay, British Columbia, from noon December 2nd through noon December 4th, 1980. A post-conference tour of facilities operated by Fisheries and Oceans, Canada, Salmonid Enhancement Program, took place on December 4th and 5th, 1980.

Dr. David W. Narver, B.C. Fish and Wildlife Branch, gave the Keynote Address and emphasized the need for improved integration and cooperation between the fish culturists, who produce the fish, and the stock managers whose responsibilities are to regulate the harvest and assure adequate escapement.

There were 256 registrants from B.C., Alaska, Washington, Oregon and Idaho as well as a few from eastern North America and one from the U.K.

Harry Lorz, Ed Donaldson, Gordon Bell, Jack McBride, Don Alderdice, Ted Perry and Eldon Stone served very ably as Session Chairmen and kept the program on track. The job of Program Chairman was made very easy by the assistance of Ida Brown, Frances Genoe and Don MacDonald.

Particular thanks are due to Ted Perry who helped with program development, hotel arrangements, post conference tours and finally, rounding up the papers for the PROCEEDINGS.

I am sure all who attended this conference will long remember the unseasonal snow fall which was an unexpected highlight.

The 1981 Conference, now to be called the Northwest Fish Culture Workshop will be hosted by the Washington Department of Fisheries in Olympia, Washington and in 1982 will be hosted by National Marine Fisheries Service in Portland, Oregon.

Thanks to all who participated.

F.K. Sandercock, Ph.D.

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GENERAL

KEYNOTE ADDRESS

by

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In the fullness of time it came to pass that a battle-scarred old Fish Culturist and a Catholic Bishop passed on to their reward.

At the Pearly Gates, St. Peter was there to greet them. "Welcome, Mr. Fish Culturist, we are so glad to have you with us. I am sure you will enjoy your stay. The hours are good, there are no Management Biologists, no pollution control requirements and no budget cutbacks. Whatever we can do to make your stay with us pleasant, please let me know."

And turning to the Bishop, who had come in with the Fish Culturist, St. Peter said, "Hello Bishop."

"Come, let me show you both to your quarters. Here, Mr. Fish Culturist, is your suite. I am sorry we could not do better than eight rooms for you; all our ten room suites are taken by B. C. Provincial Cabinet Ministers."

The Fish Culturist was completely dazzled. Never in all the travel vouchers in the Capital, had he seen such heavenly accommodations.

Then St. Peter turned to the Bishop and said, "Oh, Bishop! your room is down the hall and to the left. You will find the bathroom at the end of the hall."

Well, by now the Bishop was really upset at the treatment he was receiving. "But, St. Peter, I am a man of the cloth. I have done many good works in the name of God. Yet you treat me as a second class citizen, and seem to canonize this Fish Culturist fellow."

St. Peter said, "Oh! please understand, my dear Bishop, we have thousands of you Bishops here in heaven, but this is the first Fish Culturist to ever get here."

****

I am pleased to be here. I enjoyed Keith Sandercock's almost apologetic rationale for asking me to be your keynote speaker. Keith suggested that I was appropriate because in the last five years I have swung from a strong anti-hatchery philosophy for steelhead to a much more moderate position. I guess I have taken most of my agency with me.

I am taking the keynoter's option of touching base on a range of subjects, some of which are retrospective and some lead into the 1980's. Please note that I am not a fish culturist, but feel that I understand the essence of fish culturists' problems and role in fisheries management. At the very least I can say that I have caught many of the fish culturists' products.

I do not need to tell you that Fish Culture has come a long way since 1954 and my first summer job with the old Oregon Fish Commission. In those day many of the hatchery managers would literally compete to see who could take the most eggs--never mind that hatchery returns were poor. Let fish past the hatchery rack to spawn naturally? Sure, they let all the jacks up! In those days there were many ulcerated fisheries managers as a result of dealing with an outmoded

hatchery system. Some of those managers are now hatchery biologists and are here today.

And then there are the Engineers. More on that later!

I am sure that many of you still have some problems between hatchery operations and fisheries management. Here in British Columbia we have a certain amount of difficulty in both the Provincial and Federal fisheries systems that we are working hard to resolve.

In our view, it is the fisheries stock manager who sets the hatchery goals--not the fish culturists. After the goals are set and the recipient waters and liberation sites are selected by the fisheries manager, it is the fish culturist's responsibility to produce fish of the appropriate numbers, size and timing. It can be disheartening to the management biologist to learn that a critical stock did not reach size or is diseased because of crowding related to an egg-take that was much larger than originally planned. Unfortunately, in all agencies this still happens more often than it should.

About five years ago when we started developing the Federal-Provincial Salmonid Enhancement Program, the Fish and Wildlife Branch was philosophically cool on hatcheries for steelhead. Our steelhead anglers were extremely cautious about hatcheries, based on the horror stories they had heard from Washington anglers. However, as steelhead populations have continued to diminish, the resignation to or acceptance of hatchery steelhead by anglers has increased markedly. They want to catch anything--never mind how many fins are missing. Moreover, the rather dramatic use of catch and release regulations in B. C. has underlined the precarious steelhead situation and the need for rapid enhancement.

Let me describe my concept of an integrated and cooperative fish culture program. This program includes nine points, some of which may seem simple and naive. However, it is surprising how many agencies have fish culture programs that lack some of these points that I consider essential.

1. Close cooperation and communication between fisheries management, research and fish culture is vital (and rare!). A simple example would start by fisheries management setting catch goals and identifying underutilized or unused rearing capacity. This is followed by the research section evaluating fry plants. Finally, fish culture produces and plants fry of the size and time and at the sites identified by management and research. Incidentally, in British Columbia we have gone through this exercise and the planting of 1-2 gm steelhead fry look promising from both a biological and economic point of view.

2. Production goals are set by the fish stock manager. Fish Culturists produce fish explicitly to meet these goals.

3. Where possible wild brood stock (naturally incubated and reared regardless of parental origin), should be used rather than recycling hatchery fish. This probably works best for steelhead, cutthroat and small lots of coho. Of course this is easy to advocate since the Fish and Wildlife Branch annual egg take of nearly 12 million is from almost totally wild fish.

4. A fish culture program should be thoroughly aware and strongly influenced by what other agencies are reporting. Certainly we in British Columbia have profited by the successes and failures you have experienced.

5. A management policy should be established identifying

at least 3 classifications of waters.

a) Wild streams have no continuous fish culture programs, although some culture using native stocks may be necessary to bring the stream up to carrying capacity.

b) Hatchery streams have little or no capability for natural production, high fishability and high demand.

c) Augmented streams are managed for both natural and fish culture production. The hatchery production, preferably using native stock, is confined to one part of the river system or run timing. The wild stock may be enhanced by temporary fish culture measures, habitat improvement and regulation.

6. Hard-nosed, national regulations should be developed to maintain wild stock at carrying capacity and at the same time harvest hatchery fish. Regulations for catch and release of wild steelhead and retention of hatchery fish are being used in Oregon and British Columbia.

7. A program of evaluation of hatchery contribution to the fisheries is vital. Such programs are well developed along the Pacific Coast for anadromous species. Unfortunately, adequate evaluation programs are usually extremely expensive.

8. Hatchery biologists should be in the lead in the development or remodelling of fish culture facilities. Engineers support the biologists and fish culturists and not the reverse.

9. A program of fish health covering nutrition, disease and transplant should be an integral part of the program.

I do not think many of you find surprises in the above nine points describing an integrated fish culture program. It happens that I have just described our recently evolved steelhead program being conducted with major cooperation by Federal Fisheries and Oceans.

Now I would like to consider a few perspectives in fish culture in the 1980's. What problems and opportunities do we face?

1. We require good hard data on stock genetics and the implications of mixing stocks of the tens of millions spent annually on the Pacific Coast in salmonid enhancement, little goes towards genetics problems. I urge that the operation of more fish culture facilities be in reality large-scale controlled experiments. Basically what is required is better stock control evaluation and record keeping. I believe that we can be learning more while still producing fish for target fisheries.

2. I believe that a major increase in sea-ranching will occur in the 1980's. It makes sense when governments are strapped for funds. It is attractive to let private enterprise finance the capital investment, put fish in the common property fisheries and live on the escapement to the rack. Certainly there are potential problems for stock managers. In mixed stock fisheries it is difficult to protect the weaker or less abundant stocks. However, there is some indication in B. C. of a move away for mixed stock net fisheries. I bet that saltwater sport fishermen would support sea-ranching of coho in the Straits of Georgia or Puget Sound.

3. Freshwater pen-rearing of steelhead, cutthroat and coho smolts will probably expand. Such pen-rearing in a suitable lake in association with a hatchery with suitable incubation and rearing capacity can essentially double production by putting fish out to the pens in late summer as growth and space dictate. We expect our first major returns from two of our small pen facilities this winter.

4. As we search for more and cheaper enhancement opportunities, the use of annual fry plants above impassable barriers will increase. Our early (3-year) assessment of steelhead fry plants appears promising enough that we are using this technique quite widely. I suspect there are opportunities in Oregon and Washington.

5. I see a continual increase of interest in commercial fish farms in the 1980's. In British Columbia we have a few viable operations, but unfortunately the payoff is often oversold. Against our best advice, enthusiastic but naive individuals often demonstrate the old adage that everyone has the right to go broke.

6. I am sure that oceanic conditions will continue to be identified as a number one question in terms of the culture of anadromous species. It seems unlikely that major programs addressing ocean carrying capacity will be funded.

These have been a few observations about fish culture, present and future, from a friendly biologist who has not been directly involved with hatcheries. Thank you for inviting me, I wish you well in your conference, and I look forward to visiting with many of you.

THE ROLE OF MINERAL ENRICHMENT IN STEELHEAD PRODUCTION AT THE DWORSHAK NATIONAL FISH HATCHERY

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The Dworshak National Fish Hatchery, located along the Clearwater River, north central Idaho, was designed and constructed in 1968 by the Army Corps of Engineers and described as the largest steelhead facility in the world. The concept of using recycled water, complex filter systems, aeration, ultraviolet light, and temperature control was beyond comprehension to most fish culturists.

The program was designed to annually release 400,000 pounds of steelhead and 100,000 pounds of resident fish (rainbow and kokanee salmon). The use of heated, recycled water would accelerate growth and allow for a one-year production program. Size of the released steelhead smolts would be 180mm.

However, since the start of fish-rearing operations in 1979, Dworshak has been plagued with design and production problems. Consequently, the hatchery has not been able to meet its program. Production goals for steelhead have since been revised downward. Even with reduced production, the hatchery has met its mitigation goals on several occasions and has always maintained sufficiently large runs to provide ample eggs for hatchery operations. Nevertheless, during some years, steelhead sport fisheries have been either closed or curtailed to ensure adequate hatchery brood fish.

White-spot disease, nitrogen gas, and the parasite "Ich" caused heavy losses in incubation and in fingerling rearing. Tail-end mortalities, usually beginning three months before releasing the steelhead, could at times exceed 10,000 a day.

A number of studies were undertaken over the past five years to investigate Dworshak's rearing problems and to determine the best program to follow to assure a healthy smolt release. As the result

of these studies, the Corps of Engineers completed several modifications of the water systems to reduce problems associated with bio-filters and water hydraulics. Construction was completed in 1979 on an 18,000 square foot building to enlarge the nursery rearing capability. Additional construction is scheduled in 1981 for improving the water filtration of System I; one of three water systems in operation for steelhead production.

The selected summer rearing temperature of 52°F has since reduced the "Ich" problem normally reaching epizootic conditions at 58° F in the reuse systems. Recent work with column degassers has lowered nitrogen gas to 100 percent. Mortalities in the past two seasons in young fingerling have now been minimized.

Dr. Tom Meade, University of Rhode Island, was awarded a research contract in 1976, that was recently extended to January 31, 1981. Dr. Meade is directing his research attention to the tail-end mortality phenomenon--also referred to as "The Dworshak Syndrome". Extremely soft water rearing conditions were suspected as the cause for Dworshak's late rearing losses. It was suggested that different levels of minerals be added to makeup water of the reuse systems to improve quality. Close monitoring of fish health was followed during this period of study. Terry Bradley, a former student of Dr. Meade's has been employed at the hatchery as a Research Biologist to further indentify the problem and offer corrective action. Mr. Bradley's work is summarized in the following report:

> Dworshak NFH has experienced perennial tail-end mortalities in North Fork Clearwater River steelhead trout reared during a one-year accelerated growth program. Increased mortalities be-

gan just prior to smoltification. Environmental ammonia, nitrite and suspended solids, have previously been attributed as the cause. Initial research indicated that lack of specific ions in the rearing water was the problem. Two production reuse systems were tested; one using minerally-enriched river water and the other unenriched water. Select blood paramters were monitored as indices of fish condition. Blood NH_4^+, ATP:Hb, hemoglobin, plasma Na^+ and intra-erythrocytic K^+ concentrations were significantly different in the two systems. No fish health problems were apparent during smoltification in the enriched system. Changes in fish health warranted mineral addition to the unenriched system in mid-February. Downstream migrants were collected and examined at Lower Granite Dam, Clarkston, Washington. Hatchery fish were virtually indistinguishable from wild fish both externally and physiologically. Mineral enrichment of the environment with small quantities of specific minerals appeared to prevent tail-end mortalities at the hatchery. At a soft water reuse hatchery, such as Dworshak NFH, mineral enrichment appears to be an effective and economical method of producing quality steelhead smolts. This study is presently being repeated to verify our results of last year. Reuse System II, with minerals, and System III, without minerals, will be tested carrying 2.1 million steelhead for release in spring 1981.

The Dworshak hatchery began to see positive results from their efforts, especially with mineral enrichment, in spring 1980. At that time, the hatchery successfully released 2.6 million healthy steelhead smolts, weighing 340,000 pounds. This was one of the finest releases in Dworshak's 11 years of operation.

TECHNIQUES FOR THE CAPTURE AND HOLDING OF WILD STEELHEAD IN BRITISH COLUMBIA.

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This short talk will reflect the rapid evolution of British Columbia steelhead enhancement, with particular emphasis on capture, transport and holding of wild steelhead. The division of Canadian fisheries management is such that the Province (in this case the B. C. Fish and Wildlife Branch) is charged with the responsibility of anadromous trout and fresh-water fisheries management, while our friends in the Federal Ministry of Fisheries and Oceans manage Canada's salmon stocks.

The province's Fish Culture Section has had a minor involvement in steelhead propagation for approximately thirty years (but only in the past four years have we made a concerted effort).

A number of self-imposed policies have made the programme a little more difficult, yet probably more enjoyable for the fish culturist. The Fish and Wildlife Branch has decided that usually only steelhead from the river to be enhanced may be used to propagate that specific river. No large "donor" populations are allowed to service many rivers. (This "donor" technique leads to homogeneous populations of steelhead in large geographic areas). The Branch has also decided to only use wild steelhead for brood stock. In rivers that contain few wild fish, obtaining

the necessary number of wild adults becomes time-consuming.

Since the creation of the Salmonid Enhancement Programme (a joint Federal-Provincial $300 million enhancement programme), greater amounts of money have been made available to the Fish and Wildlife Branch for purposes of steelhead enhancement. More and more demands have been made of workers and management to get on with the task of putting steelhead back in the rivers. (In fact, our specific task within the programme is to raise the steelhead populations to historic levels).

Capture

At present Fraser Valley is involved in nine separate capture projects on the Mainland of B. C. (there are another ten projects on Vancouver Island). We tried different, and to us unique, methods of capture, such as electro-shocking, seining and angling. We have settled on angling for nearly all of our capture projects.

Transport from River to Truck

What do you do with them when you catch them? Quite often we can park our truck close enough to the river to simply carry the fish to the truck in a hand net. Other circumstances make fish transport from the river to truck more difficult. When the truck is within walking distance, we carry the fish back. We used to use plastic garbage buckets, but this was only possible with two men - clumsily walking through 200 metres of dense brush with a garbage bucket full of water and fish. We now exclusively use back-packs when the truck is within walking distance. At most we pack four adults at one time. When the transport vehicle is

too distant to walk to, helicopters and river boats have been used - and with a great deal of success (when fish have to be held at the river for long periods of time, we usually contain them with rock pools, mouth-tethers and, most recently, holding tubes. The tubes work very well - adults have been held for up to one week in a holding tube).

Transport to Hatchery

In the sixty year history of British Columbia fish culture, we have become accustomed to hauling small lake-stocking size fish in transport trucks; but what about four to seven kilogram adults that have just been subjected to extraordinary amounts of stress? We were not too sure how they would "travel". Fortunately no real problems were encountered. Initially we used our regular 2500 litre transport truck (we wanted to "give the fish as much room as possible"). We found this was not necessary - we now use a 3/4 ton pick-up (usually a 4-wheel drive) with a 450 litre transport tank mounted on the box. The transport of the fish from the river to the hatchery proved to be of little difficulty to an experienced fish culturist. The insulated transport tank holds a maximum of 20 adults; the darkened tank is supplied continuously with gaseous oxygen.

At the hatchery

It is at the hatchery that we may be unique in our handling of steelhead. Once they come through the hatchery gates, we usually anesthetize each fish - we record sex, length, clips (if any) and remove a scale sample. They are then placed into large, darkened holding boxes (these boxes measure one by six metres by one metre deep. They can be

divided into three 1 X 2 metre compartments, for small lots of fish. Each pen receives approximately 250 litres of water per minute. Water temperature remains at a constant 10° C). As many as fifty adults are placed in each box. Or, the adults may be placed into small, compartmentalized containers. Each compartment measures 30 by 100 centimetres, with 50 cm. of water. The light-proof boxes have approximately 10 litres of water per minute flowing thru them. Only one fish is placed in each compartment. Again, water temperature remains at 10° C.

For reasons of disease prevention, all adult steelhead holding is done at a site completely separate from our production facility.

At Fraser Valley we find it necessary to hold our adults for a long period of time - sometimes nine months. Our capture season begins in July (June this year) and continues until March and early April. Our spawning season begins later in the year than most areas of the Pacific Northwest - it starts in early March and continues until mid-May. Every individual is pathologically checked upon completion of spawning. While a late spawning period usually creates difficulty in raising a one-year smolt, Fraser Valley, with its temperature controlled rearing water, has no trouble in raising steelhead to 75 grams by March 1st.

EFFECT OF TOTAL GAS PRESSURE, TEMPERATURE, AND TOTAL WATER HARDNESS ON STEELHEAD EGGS AND ALEVINS

A PROGRESS REPORT

by

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INTRODUCTION

Exess total gas pressure (TGP) at saturation levels of 103% or greater has reportedly caused white spot disease (coagulated yolk) in salmonid yolk sac fry. Wedemeyer et al. (1976) and Wood (1979) report that N_2 levels of 103% cause white spot disease. Harvey and Cooper (1962) noted mortalities in sockeye alevins exposed to N_2 levels of 106%. Similarly, a survey of 49 hatcheries indicated, among 29 stations with excess N_2 saturation, that 70% of these reported white spot problems (Nelson 1979). Temperature effects, either high or low

levels or sudden fluctuations, have also been suggested as a cause of white spot disease (Nelson 1979). A third factor that appears related to incidence of white spot disease is the mineral content of the incubation water. MacKinnon (1969) demonstrated that white spot disease in brook trout could be controlled by the addition of $CaCl_2$ to increase the total water hardness to 50 $mg \cdot L^{-1}$ as $CaCO_3$. The hatchery survey (Nelson, 1979) also indicated a higher incidence of white spot disease occurred at soft water stations.

Accordingly, water quality monitoring was undertaken at two federal hatcheries with histories of significant white spot disease in steelhead fry. Total gas pressure levels in excess of 107%, temperatures greater than 13°C, and water hardness levels of 15-20 $mg \cdot L^{-1}$ as $CaCO_3$ were recorded. It therefore appeared that any or all of the above factors could be related to the occurrence of white spot disease. This report describes preliminary experiments undertaken to determine the effects of the three factors, excess TGP, temperature, and water hardness on viability of steelhead eggs and alevins.

MATERIALS AND METHODS

A 3 x 3 x 2 factorial experiment was conducted with steelhead eggs and alevins exposed from fertilization to yolk absorption. A total of 18 treatment combinations were maintained with three replicates for the egg stage and two replicates for the alevin stage. Excess TGP was maintained using compressed atmospheric air and

water mixtures, mixing heated and chilled water, and by adding an appropriate concentration of $CaCl_2$ to achieve the desired level of water hardness. Heath trays were used for the duration of the experiment. The factor levels were as follows:

Factor	Factor Level		
	-1	0	1
TGP (%)[a]	102	106	110
Temperature (°C)	8	10	12
Hardness ($mg \cdot L^{-1}$ as $CaCO_3$)	10	-	100

[a]Ratios of % O_2 and % N_2 levels were 1:1

Egg mortality, time to 50% hatch, alevin growth, and alevin mortality were recorded.

RESULTS

Experimental conditions were maintained constant for the duration of the experiment (Table 1). Egg mortality was unaffected by any of the 18 treatment combinations, with mean mortalities ranging from 2.0 to 6.3% (Table 2). Hatching and alevin growth were unaffected by TGP or $CaCO_3$ levels. Higher temperatures decreased time to 50% hatch and increased growth rate, as expected. Time to 50% hatch was 45, 34, and 27 days at 8, 10 and 12°C, respectively (Table 2). Similarily, the

time to reach a K_D index $\left(K_D = \frac{10\sqrt[3]{\text{weight}}}{\text{length}}\right)$ of 2.1, for example, was 86, 65, and 53 days at 8, 10, and 12°C, respectively.

Only one treatment combination resulted in a significant (α=.05) increase in alevin mortality. A mortality of 13% was observed in 110% TGP, 12°C, and 10 $mg \cdot L^{-1}$ as $CaCO_3$ (Table 2). These mortalities were due to severe growth deformities of the opercula, which resulted from large bubbles that formed and enlarged in the alevins' mouth cavities shortly after hatching. These bubbles also were noted in the 110% TGP, soft water treatments at 8° and 10°C but no deformities or increased mortalities were noted. The mortalities in the 12°C treatment occurred at the time of yolk absorption, probably due to asphyxiation resulting from impaired water movement past the gills.

DISCUSSION

White spot disease was not observed in any of the treatments. The combination of factor levels tested appear to be only marginally detrimental; with 13% alevin mortality occurring in the 'worst' combination (i.e. 110% TGP, 12°C, and 10 $mg \cdot L^{-1}$ as $CaCO_3$). No significant egg mortality was noted, indicating that eggs were more resistant than alevins. This is in agreement with Nebeker et al. (1978) who found that steelhead eggs were unaffected by TGP levels of up to 126%. The levels of TGP and hardness tested did not appear to cause any

sublethal effects since no premature hatching or differences in growth rate were detected in response to any of the TGP or hardness levels.

The fact that white spot disease was not observed suggests either that inappropriate factor levels were chosen or possibly that TGP may act in another manner in promoting white spot disease. Rucker (1975) demonstrated that the time to 50% mortality in coho fingerlings was reduced when O_2/N_2 ratios were altered at a constant TGP level of 119% and 13.6°C. It is possible that this response to differing O_2/N_2 ratios also applies at lower levels of TGP. This hypothesis will be examined in further tests with chinook salmon and steelhead alevins. Our approach will be to set up similar TGP levels as described in the present experiment but O_2/N_2 ratios other than 1:1 will be examined.

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Table 1. Experimental conditions (mean and standard deviation) during steelhead egg incubation and alevin yolk absorption in Heath Techna incubation trays[a].

Treatment	Temperature (°C)		Duration of exposure from fertilization		Hardness ($mg \cdot L^{-1}$ as $CaCO_3$)		T.G.P.(%)[b]		D.O. (%)[c]		N_2+Ar (%)[d]
	$\bar{X}$	S.D.	Days	°C-days	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$
1	8.1	0.2	91	737	10.6	1.5	102.4	0.5	102.4	1.1	102.5
2	"	"	"	"	96.5	19.2	102.2	0.6	102.0	1.7	102.3
3	"	"	"	"	10.6	1.5	106.1	0.4	105.4	1.8	106.4
4	"	"	"	"	96.5	19.2	106.4	0.5	106.0	1.3	106.7
5	"	"	"	"	10.6	1.5	110.3	0.9	110.4	1.8	110.4
6	"	"	"	"	96.5	19.2	110.0	0.6	109.9	1.6	110.1
7	10.1	0.2	78	788	10.6	1.5	102.2	0.5	102.2	1.6	102.4
8	"	"	"	"	93.0	14.9	101.5	0.6	100.9	1.8	101.9
9	"	"	"	"	10.6	1.5	105.8	0.5	105.1	1.3	106.3
10	"	"	"	"	93.0	14.9	105.8	0.6	104.9	1.3	106.2
11	"	"	"	"	10.6	1.5	110.0	0.6	109.5	1.2	110.4
12	"	"	"	"	93.0	14.9	110.5	0.8	110.5	1.7	110.8
13	12.0	0.1	65	780	10.6	1.5	101.4	0.6	102.0	1.0	101.6
14	"	"	"	"	99.4	15.3	101.3	0.6	100.7	1.6	101.8
15	"	"	"	"	10.6	1.5	105.6	0.6	105.4	1.5	106.1
16	"	"	"	"	99.4	15.3	105.3	0.4	105.4	1.2	105.8
17	"	"	"	"	10.6	1.5	110.0	0.5	110.1	1.2	110.5
18	"	"	"	"	99.4	15.3	109.7	0.4	109.8	1.4	110.2

[a]Water flow rate for each treatment was approximately 6 $L \cdot m^{-1}$.

[b]Total gas pressure measured with a Novatech Tensionometer and % saturation calculated based on barometric pressure.

[c]Dissolved oxygen measured by Winkler method.

[d]Nitrogen plus argon were calculated using the mean T.G.P. and D.O. levels.

Table 2. Steelhead egg mortality, time to 50% hatch, and alevin mortality responses (mean and standard deviation).

Treatment	Egg mortality (%)		Time to 50 (%) hatch (days)		Alevin mortality (%)	
	$\bar{X}$	(S.D.)	$\bar{X}$	(S.D.)	$\bar{X}$	(S.D.)
1	3.6	0.2	46.2	0.3	2.6	2.6
2	5.9	1.7	45.3	0.3	0.6	0.8
3	5.1	1.4	45.9	0.2	0.4	0.6
4	4.0	0.5	45.1	0.4	0.5	0.7
5	6.3	1.6	45.8	0.2	1.4	0.9
6	3.4	0.8	45.9	0.2	0.0	0.0
7	4.6	2.2	34.4	0.1	2.0	0.9
8	3.2	0.2	34.2	0.1	1.2	0.4
9	3.4	1.0	34.3	0.1	1.0	0.0
10	3.6	0.6	34.4	0.1	0.8	0.4
11	5.1	1.8	34.3	0.0	1.0	0.5
12	2.6	1.3	34.4	0.1	0.8	0.4
13	2.3	1.3	27.1	0.4	1.4	1.0
14	3.6	1.3	26.7	0.1	2.4	2.0
15	3.7	2.1	27.3	0.2	1.6	0.0
16	2.0	1.4	27.8	0.6	3.7	0.4
17	5.7	3.9	27.4	0.1	**13.0	3.7
18	3.6	0.5	26.9	0.3	4.5	1.6

**Significant mortality (α = .05).

WINTER STEELHEAD TROUT

BROODSTOCK STRATEGIES IN OREGON

by

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Winter steelhead trout of Alsea River stock are annually released in 23 of Oregon's large coastal streams and tributaries. The importance of Alsea stock to the coastal steelhead hatchery program has resulted in intensive monitoring of biological characteristics basic to population stability and evaluation of the health of a hatchery stock. Records at the Alsea Hatchery indicated that the body sizes of the propagated steelhead trout were more homogeneous, the variance in date-of-return reduced and the age structure simplified from comparable measures of fish in the past. A research program was initiated to determine to what extent time of return, age at maturity and body size of hatchery propagated steelhead trout can be altered by selective breeding. Comparison of adult offspring from select and control parental groups will yield data adequate to establish the relative roles of additive genetic and other factors in the control of these traits.

METHODS

Selective breeding experiments with steelhead trout at the Alsea Hatchery were initiated with adults from the 1974, 1975 and 1976 spawning populations. Parents selected on the basis of early return, late return, and above average body length provided eggs for these respective groups in each brood year. During the winter of 1976-77, returns from each of the 1974-brood select groups were artificially spawned to produce an F_2

or second generation of each of the select groups except 3-salt fish and repeat spawners. During the winter of 1977-78 returns from the 1974-brood 3-salt and repeat-spawner groups were spawned to produce an F_2 generation.

Each winter the entire escapement to the upstream trap at the hatchery is examined for fin marks, age, sex and size. Time of return to the trap is recorded. A creel survey program is conducted to estimate the catch and effort by area, month and angler type (boat or bank). The steelhead smolts released into the Alsea River have been 100% marked since 1975, allowing a catch estimate of the total fishery contribution of hatchery releases.

RESULTS

Preliminary results indicate that time of return is influenced by genetic factors. Time of return was successfully altered in both directions (early and late) within environmental limitations (flow). Catch data suggest that environmental effects are a large component of the variation in time of return.

Significant differences in length have been achieved between fish of the same age selected for large body size and control fish. The length at return in 1979-80 exemplifies the additive effects governing body size. Significant differences were observed between select and control group lengths yet the body length of all 2-salt adult returns was significantly smaller than in previous years.

Selection for older age at maturity has been successful. Significantly more 3-salt adults have been produced by 3-salt parents than by 2-salt parents. No gains in repeat spawners have been realized in the two years of returns from repeat select groups.

CONCLUSIONS

1. Spawning at the Alsea Hatchery is spread to include eggs from early, middle and late portions of the run in order to maintain variability and stability in time of return.
2. Selection for large body size is discouraged since it has a high inbreeding potential and results are not pratical on a production scale.
3. Selective breeding of 3-salt adults can be used as a method to increase variability in age composition of a hatchery run to that of wild populations.

THE INFLUENCE OF OCEAN AGE OF PARENTS ON FRESHWATER GROWTH OF STEELHEAD PROGENY

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There is a real need by hatchery managers to understand and thereby control the production of 2-ocean and 3-ocean adult steelhead. The larger, older fish are more desirable and are prized and sought after in the sports fishery. It is well documented, relative to wild fish, that the proportion of 3-ocean fish in the stock may be severely reduced by some standard hatchery operations. The study currently in progress at Rosewall Creek, Vancouver Island, B.C., bears on the extent to which age at return is genetically and/or environmentally controlled.

On April 30, 1979, four experimental groups of steelhead smolts of Big Qualicum River stock were released from Rosewall Creek. Two groups were progeny from 2-ocean males crossed with 2-ocean females, and two groups were progeny from 3-ocean males crossed with 3-ocean females. At release the progeny from 2-ocean parents averaged between 39 and 40 g in weight and the progeny from 3-ocean parents averaged between 26 and 28 g in weight. Hence, there was a weight difference of approximately 12 to 13 g between the progeny from the two age crosses. Rearing temperature was virtually the same for both groups. Although the weight of the 3-ocean progeny was initially greater by 2,000 degree days the progeny of the 2-ocean parents were larger in size and the difference continued to increase with time. At 3,000 degree days the mean weight of the progeny of 3×3 cross was approximately 24 g and the progeny of the 2×2 cross approximately 29 g.

On April 26, 1980, a second release of progeny from 2-ocean and 3-ocean parents was made. At release the progeny from 2-ocean parents were smaller than those from 3-ocean parents, weighing on the average 31 and 36 g, respectively. Thus a difference of 5 g was observed. Rearing temperature for both groups was the same. Initially, the size of the progeny from the two groups was almost the same. However, by 2,000 degree days the 3-ocean progeny were larger than 2-ocean progeny and the weight difference between the two groups continued to widen. At 3,000 degree days the mean weight of the progeny of the 2 × 2 cross was approximately 24.5 g and the progeny of the 3 × 3 cross was approximately 30 g.

The reason for the progeny of 2-ocean parents growing faster than those from 3-ocean parents in 1979, and then growing slower than the 3-ocean progeny in the 2nd year, is not known. Possibly size of the individuals comprising the two ocean-age parent brood stocks had an influence on the subsequent growth rates of the progeny.

QUINSAM RIVER PINK SALMON REHABILITATION AND STUDIES

by

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INTRODUCTION

The pink salmon escapement to the Quinsam River has dropped from the historic level of 100,000 or more down to a low of 4,500 in 1977.

We decided to utilize some of the excess capacity of the Quinsam Hatchery to rehabilitate the pink run commencing with the 1979 brood.

Our main thrust to rehabilitate this run was attempted using a combination of Heath trays and gravel boxes and releasing unfed fry directly into the Quinsam River.

Our second objective was to gain as much information as possible on rearing techniques.

Holding and Spawning:

Standard hatchery methods and procedures were used to capture, hold, and strip approximately 1,100 females and 250 males. Two million eggs were taken from September 21st to October 12th, 1979, and incubated to hatch in Heath trays.

Hatch:

After hatching, the alevins were divided into two groups. 1.8 million were placed in gravel boxes and 50,000 remained in Heath trays (Figure 1).

Gravel Boxes:

The gravel boxes used are described by Bams and Crabtree (1976). We used four 4-cubic foot boxes, each filled with 2 feet of 1-2 inch rock. The water, 100 to 120 litres per minute, was distributed across the bottom of each box from a header.

Once the hatch was completed, the alevins were spread over the gravel and they disappeared into the gravel at the rate of approximately 100,000 per hour.

Premature emergence, flow, and water quality were monitored. Fry were counted as they migrated from the boxes.

Marking:

As the fry migrated, two groups of 100,000 each were marked with a single ventral fin clip.

Released as Fry:

1.5 million fry, including 100,000 right ventral-clipped fry, were released directly into the Quinsam River.

Reared Box Fry - Estuary:

290,000 fry, including 100,000 left-ventral clipped fry, were transferred to the estuary site for rearing. (This group of marks was vaccinated against Vibrio anguillarum).

Rearing, Box Fry, Hatchery:

17,000 fry were reared in troughs at the hatchery and then released to the river.

Heath Tray:

The fry that remained in Heath trays were divided into three groups:

2 trays - no media
2 trays - bio rings
2 trays - gravel
(operated at 12 l/min.)

When the fry were buttoned they were ponded into troughs at the hatchery and reared.

Hatchery Rearing:

OMP II was fed by hand and by automatic feeders over the 68 days of rearing. These fry were then transferred to the estuary site and reared in salt water.

All the fry that were reared at the hatchery, those from the trays and those from the gravel box, were from the same egg-take and incubated in the same water. At ponding, they were transferred to a warmer water supply.

Estuary Rearing (Figure 2):

Tubs

Pumps supplied five 6 foot diameter tubs with water. One pump located near the surface supplied low salinity water (1 - 5 ppt), and another pump located near the bottom supplied high salinity water (25 - 30 ppt).

These tubs improved our opportunity to observe the fry and also added more flexibility compared to seapens.

Pens

We used two types of pens; one type made from marquissette and the other from 1/8 inch punched aluminum. Both were 4 feet wide, 6 feet high, and 8 feet long.

The pens were mounted between the fingers of a commercial boat dock in the Campbell River estuary. The lower sections of the pens extended down into the salt water, giving the fry a choice of salinity.

Summary of Comparisons during Estuary Rearing:

In summary, we compared:

- vaccinated versus unvaccinated
- 2 types of pens
- 2 types of food
- high salinity, low salinity, and estuary water (combination).

Observations:

1. General
   - mortality from green egg to hatch was 8%.
   - water quality of the Campbell River estuary is sufficient to support rearing fish.

2. Gravel Box Fry

- there was no difference between the number of alevins planted and the fry counted out.
- there was no significant difference in size between the fry from the gravel boxes (0.225 grams) and natural river fry (0.22 grams).
- the migration of fry from the gravel box preceeded the natural migration by approximately 11 days.
- we used 1,200 females for our program and 2900 spawned naturally. Our program produced 1,500 fry per female as compared to 540 fry per female from the river. (Natural fry production was monitored at the Quinsam Hatchery fence.)
- expected adult return to the river from the gravel box fry is 11,000 adults.

3. Heath Trays

- the size of the fish in the 3 groups at ponding was:

  no media - 0.190 gram
  bio rings - 0.213 gram (box fry = 0.225 gram)
  gravel - 0.226 gram

- the fry from the trays were ponded on February 1/80, and those from the gravel box were ponded on March 12/80, almost 6 weeks later. These fry were from the same egg-take and incubated in the same water at the same temperature.

4. Hatchery Reared Fry from the Gravel Box and Heath Trays

- the Heath tray fry gained approximately 0.7 grams over 70 days of rearing and the gravel box fry gained 0.8 grams over 60 days. Due to the later ponding date of the box fry, they were reared in slightly warmer water (approximately $1^{o}C$).
- mortality averaged 48% with no significant differences between groups.
- the Heath tray fry were transferred to salt water where they gained an additional 0.4 grams over 20 days. At this time, space became a factor and all but 250 were released. The fish gained one gram over the next 7 days.
- in summary, the Heath tray fish gained 2.1 grams over 91 days with a mortality of 51%.

5. Estuary Rearing of Gravel Box Fry Pens:
   - the fry in the aluminum pens were 0.9 grams versus 0.76 grams in the marquissette pens.
   - the most significant difference was the heavy algae growth on the marquisette pens. They were difficult to keep clean and flow was restricted. The aluminum pens had very little fouling and consequently much better water exchange, probably accounting for their better performance.

6. Vaccinated Versus Unvaccinated:
   - there was no noticeable difference between the vaccinated and unvaccinated groups in growth and survival during rearing.

7. Food
   - we used Silver Cup and OMP fortified with euphausids. The Silver Cup diet produced a smaller fry in the low salinity tub, 0.49 grams, versus OMP at 0.98 grams. Fish reared in pens on different diets were of similar size.

8. Salinity
   - there was no consistent difference in response to the different salinities.

9. Growth and Mortality
   - in the aluminum pens, the fry gained 0.67 grams over 50 days of rearing; the fish in the marquissette net pens gained 0.54 grams.
   - the mortality was 8%.

10. Costs

Estuary rearing:

8½ man months (feeding and marking)	$10,000.00
pump rental	1,080.00
aluminum pens (2)	3,600.00
marquissette pens	1,200.00
site rental and electricity	840.00
	$16,720.00

PLANS

This spring we are planning to release 2 million fry from gravel boxes and rear 250,000 in aluminum pens in the estuary.

QUESTIONS

- survival differences between box fry, river fry and reared fry
- what affect will the advanced timing of the box fry have on their survival
- could a less expensive rearing container be designed
- quality of fry which were left in Heath trays until ponding
- where will the estuary-reared fry return to spawn
- will the marked and unmarked fish survive at a different rate.

REFERENCE

R.A. Bams and D.G. Crabtree. A method for pink salmon propagation: the Headquarters Creek experimental hatchery. Technical Report No. 627, Fisheries and Marine Service.

FIGURE 1. Incubation and Rearing Components, 1979 Brood Pinks

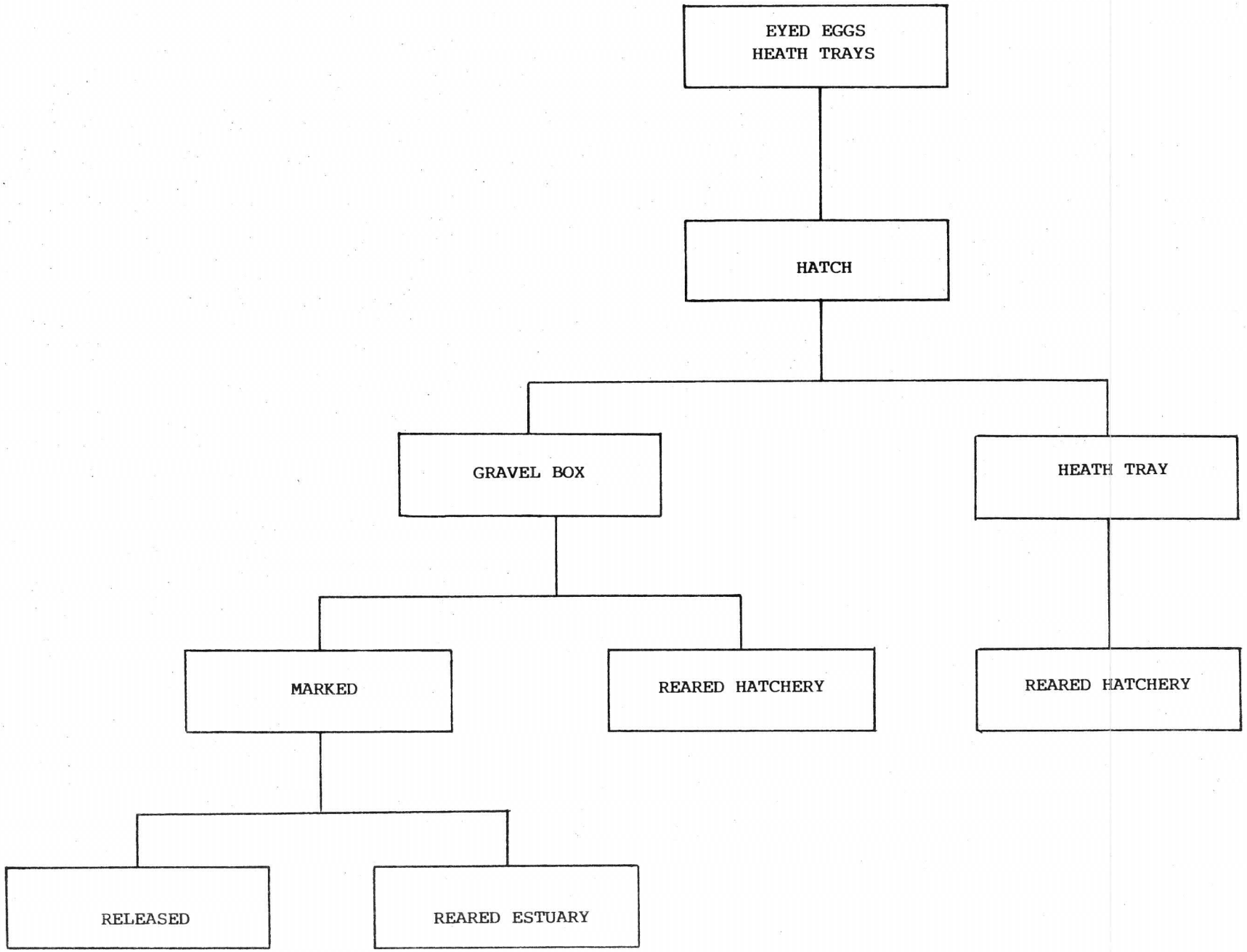
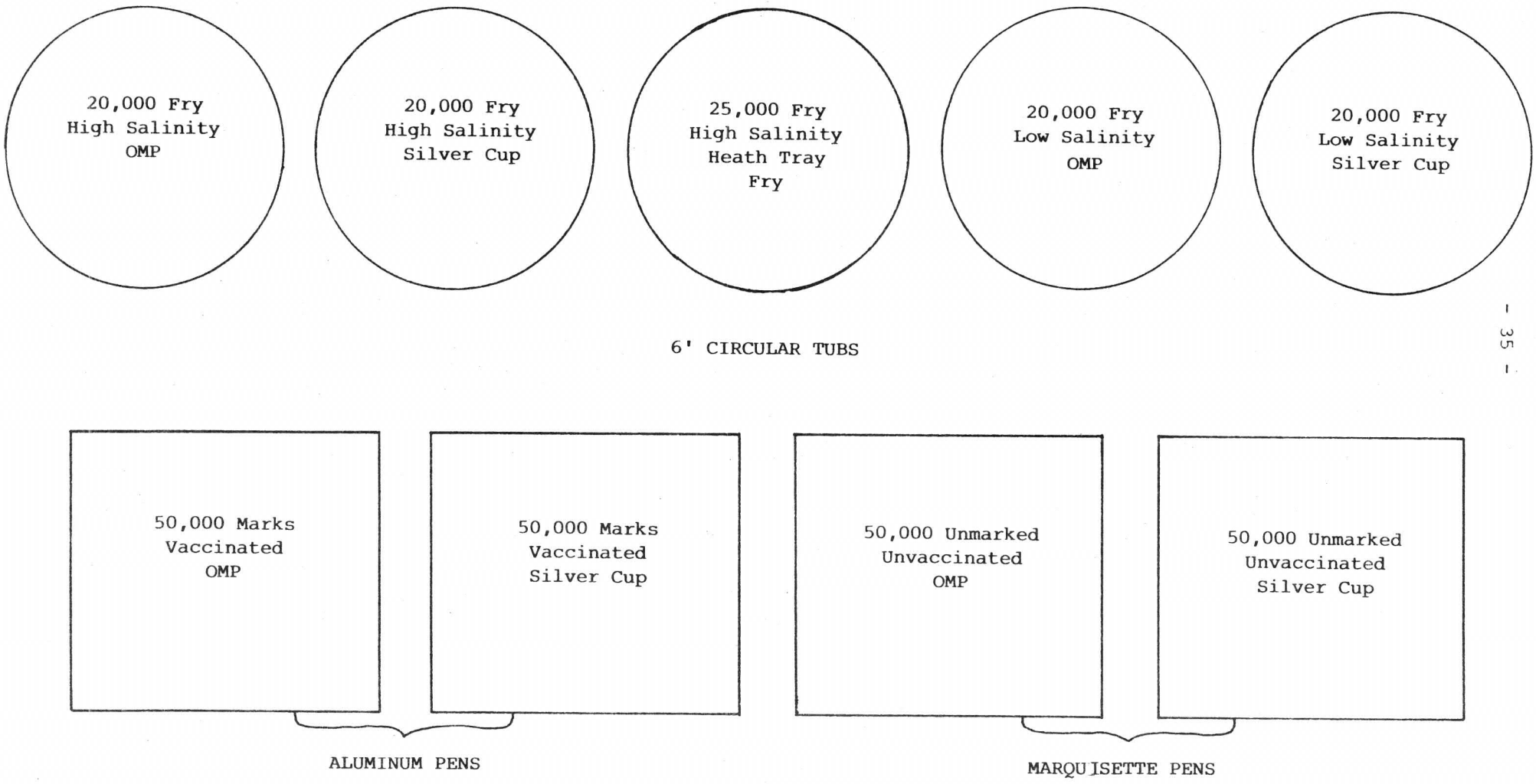


FIGURE 2. Treatment Groups during Estuary Rearing of 1979 Brood Pinks



ADULT RETURNS TO THORNTON CREEK

(The Salmonid Enhancement Program's first Japanese-Style Chum Salmon Hatchery)

by

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Introduction

Current techniques for enhancing chum salmon including spawning channels and gravel upwelling incubation boxes. Spawning channels require large flat areas of land adjacent to a stream and large amounts of water. Incubation boxes require only one-tenth as much land and water but require high quality water.

Japan has been very successful in enhancing chum salmon stocks using a modified hatchery technique which consists of three elements:

1. Incubation of eggs to near hatching in Atkins, modified Atkins, or freestyle incubators.
2. Incubation of alevins in gravel-lined concrete incubation channels until the yolk sac is absorbed.
3. Rearing of fry in raceways or earthen ponds for 30-40 days to about a one gram size before release. In many cases additional feeding also occurs in the stream below the release site.

Using these methods the Japanese obtain fry-to-adult survival rates of approximately 2.6% (2.3-2.9% 1966-72 broods) for fed fry.

A pilot hatchery, utilizing the above concepts was established at Thornton Creek near Ucluelet on the west coast of Vancouver Island in 1976. Thornton Creek, which flows west into Ucluelet Inlet, was selected because:

1. The site and water supply could be developed at minimum cost.
2. Sufficient brood stock was easily available in an adjacent stream.
3. The project could be expanded into a production facility at a later date with minimal stock interaction.
4. The possibility exists for future salt water rearing experiments.
5. The water supply was typical for streams located on the west coast of Vancouver Island i.e. the water in the creek is

warm (2-10°C), tea-coloured (as it originates in cedar swamps), contains high levels of organic silt and water levels fluctuate widely with each rainfall.

The hatchery complex consists of:

1. A 0.9 x 2.1m slotted screen intake installed horizontally into a gravity flow of 57 l/sec (2 cfs).
2. A 19m long, 20cm diameter plastic sclair pipe which connects the intake to the incubation building and ponds.
3. A 20 x 12m steel "Quonset" building on a concrete pad housing the incubation facilities.
4. Twelve modified Atkins incubators and one freestyle box; the cells and box are supplied with an upwelling flow from two head tanks.
5. Four incubation channels 12.2m x 1.8m x 20.5cm with a total surface area of $89m^2$.
6. Two 10.7m x 5.5m, 1.2m above ground "swimming pool" type rearing ponds with a volume of $59.4m^3$ each.
7. A 5.5m x 4.9m wood extension to the Quonset building containing a laboratory, office and washroom.
8. Also included in the hatchery complex were two 50,000 egg capacity mini-incubation boxes, one supplied with unfiltered water and the other with filtered water, and two 3.0m diameter fibre-glass rearing tanks.

Broodstock Capture

Thornton Creek has an insignificant run of chum salmon. All available spawning area is subject to tidal inundation, the result of an impassible falls located some 0.6km upstream of the mouth. Therefore, broodstock were obtained one mile north-west of Thornton Creek from Salmon Creek, which has an average (1966-75) reported salmon population of 4,100 chum (400-15,000) and 100 coho (25-400). Peak chum spawning occurs about October 30 (October 15-November 30). Chums were observed to spawn in the first 2.4kms of Salmon Creek; while coho utilized the area between 0.8 and 3.2kms. Fecundities for the Salmon Creek chum ranged from 2,300 to 2,700 eggs/female.

Trapping and holding facilities were constructed in conjunction

with highway culvert construction on the Port Albion Road about 0.4km from the mouth of Salmon Creek. A 6m 1.5m x 1.0m concrete adult holding pond was constructed at the mouth of the culvert. During adult trapping a temporary 1.2m high fence with a V-shaped lead-in was installed in the creek.

Egg Incubation and Fry Rearing

Eggs in Group I were incubated in the Japanese Style in modified Atkins incubators until just before hatching, then transferred to four incubation channels for incubation until mirgration (without enumeration) into two oval rearing ponds. Eggs in Group II were layer planted in an incubation box with filtered water; at migration fry were enumerated and transferred to a circular rearing tub #1 for rearing. Eggs in Group III were layer planted in an incubation box with an unfiltered water supply; fry were enumerated and reared in tub #2.

Flow rates in the incubation and rearing containers were: modified Atkins - 13.3 to 22.7 lpm (3.5 to U.S. g.p.m.); freestyle box - 41.6 lpm (11 U.S. g.p.m.); gravel box 26.5 lpm (7 U.S. g.p.m.); incubation channels - 227 to 284 lpm (60 to 75 U.S. g.p.m.); rearing ponds - 2 exchanges per hour or 1 c.f.s. Maximum rearing density was 0.3 kg/lpm (2.54 lb. per U.S. g.p.m.) or .56 lb. per cubic foot. The alevin density in the gravel incubation channels was 11,200 per square meter. Normal loading density in Japan is 15,000 alevins per square meter.

Incubation and Rearing Results

Incubation and rearing data for all groups in the 1976, 1977 and 1978 broods is summarized in Table 1. An egg to migrating fry survival of 94% was obtained for the 1976 brood chum incubated and reared in the Japanese style (Group 1). Comparable survival in two layer-planted gravel mini-incubation boxes, one filtered (Group II), one unfiltered (Group III) was 79% and 62% respectively. Overall mortality for the 1976 brood was 7.96% (Table 1). Japanese style fry (Left Ventral fin clip) migrated 22 days ahead of the incubation box fry (Right Ventral fin clip) and 35 days ahead of the wild fry from Salmon Creek. Consequently, at release, the Japanese style fry were 1.15, .87, and 1.16 g. for the 1976, 1977 and 1978 broods compared to the incubation box fry which were .66 g. in 1976 and .72 g. in 1977. Thornton Creek fry were released at the peak of the wild fry migration from Salmon Creek.

Adult Returns

Escapements to Thornton Creek are summarized for 1979 in Table 2 and for 1980 in Table 3. Marked adult survival was considerably lower than the unmarked adult survival for the 1979 return (.19% L.V. and .27% R.V. vs 2.26% unmarked) and somewhat lower for the 1980 brood (1.22% L.V. and 1.40 R.V. vs 3.48% unmarked). Total survival for the 1979 escapement was 20,132 fish or 2.34% composed primarily of 3-year-old adults (96%) (Table 2). Catch estimates and escapement records for the 1980 return indicate that survival of 3-year-olds which made up 88% of the population was 3.48%. Four-year-old survival was .64% making the total survival for the 1976 brood 2.98%.

A preliminary analysis of a portion of the data on age composition and sex ratios of marked and unmarked adults returning to Thornton Creek and unmarked adults from Salmon Creek is detailed in Table 4. For Thornton Creek marked age 3 males and unmarked age 3 males accounted for 38.9% and 37.5% of their respective populations. Age 3 females both marked and unmarked, made up an identical 50% of each population. This sex ratio contrasted markedly from 3-year-old adults returning to Salmon Creek where males were more prevalent 42.9% compared to 35.6%. Four year-old adult escapement was considerably higher in Salmon Creek where males made up 11.2% of the population. This result contrasts with Thornton Creek's male population where 4.2% of the four year olds were marked and 6.9% of the fish were unmarked. The results were similar for four-year-old females. Salmon Creek had 10.3% returns while Thornton Creek accounted for 7.0% marked and 5.6% unmarked females in this age class.

Conclusions

1. The total fry-to-adult survival of the 1976 brood (3's and 4's) is estimated to be at least 2.98%.

2. The three year-old fry-to-adult survival for the 1977 brood is estimated to be at least 3.48%. The complete return of the 1976 and partial return of the 1977 brood exceeds the Japanese survival rates of 2.3% to 2.9%.

3. The fry-to-adult survival for the incubation box (R.V.) was marginally higher than survival for the Japanese style (L.V.) for both the 1976 and 1977 broods. However, survival of marked fish for both broods were considerably reduced from that observed in the unmarked fish.

4. The rate of straying for marked Thornton Creek adults recovered in Salmon Creek was 5.4% in 1979 (5.5% L.V. and 5.3% R.V.) and an almost identical 5.2% in 1980 (4.1% L.V. and 6.4% R.V.)

5. Short term rearing increases the numbers of three year-old females returning (50% vs. 35.6%) and increases the overall number of adult females (3s and 4s) returning, 57% compared to 45.9% for wild adults from the donor stream.

6. Short term rearing appears to cause a substantial decrease in the number of four year-old males returning and a slight decrease in the number of four year-old females. This phenomena is apparent in both the 1979 (96% age 3) and 1980 (88% age 3) adult returns as 3 year-olds were the dominant group in 1976 (78.7%) and four year-olds in 1977 (63.9%). The rearing process also seems to reduce the number of 3 year-old male adults slightly from the number observed in Salmon Creek.

Table 1

THORNTON CREEK CHUM HATCHERY - SUMMARY - INCUBATION AND REARING

	1976/77	1977/78	1978/79
PEAK ADULT MIGRATION	OCT 24 - 27	OCT 27	OCT 24
DOMINANT AGE CLASS (%)	3(78.7)	4(63.9)	3(73.9)
NUMBER EGGS	1,099,078	1,201,877	1,776,370
MEAN TEMPERATURE (C)	6.53	6.13	4.30
NUMBER FRY REARED	1,011,646	1,104,963	1,618,852
MORTALITY E/S (%)	7.96	8.1	8.87
NUMBER FRY MARKED	98,000 LV 60,500 RV	102,598 LV 79,563 RV	145,038 LV
NUMBER FRY RELEASED	874,100	1,076,127	1,387,092
RELEASE DATE	APRIL 12 - 13	APRIL 20 - 21	APRIL 16 - 30
MEAN FEED RATE (%)	2.11	2.66	2.3
MEAN RELEASE WEIGHT (g)	0.90	0.80	1.16

Table 2

THORNTON CREEK ADULT ESCAPEMENT 1979

	THORNTON CREEK DEAD PITCH		SALMON CREEK DEAD PITCH	
FEMALES	7,698	44.9%	4,601	48.4%
MALES	9,434	55.1%	4,900	51.6%
TOTAL	17,132		9,501	
ESTIMATE OF FISH LOST	3,000			
TOTAL ESCAPEMENT	20,132		9,501	

MARKED FISH RECOVERED

JAPANESE STYLE - LV	188 (.19%)		11	.20% TOTAL
INCUBATION BOX - RV	162 (.27%)		9	.28% TOTAL

MAXIMUM SURVIVAL 3 YEAR-OLDS $\frac{20,482}{874,100}$ =2.34%

AGE COMPOSITION 3 96%

Table 3

THORNTON CREEK ADULT ESCAPEMENT 1980

	THORNTON CREEK DEAD PITCH		SALMON CREEK DEAD PITCH		
FEMALES	11,063	56.8%	5,028	50.2%	
MALES	8,404	43.2%	4,996	49.8%	
TOTAL	19,467		10,024		
MARKED FISH RECOVERED					
JAPANESE STYLE - LV	1,251	1.22%	54	1.27%	TOTAL
INCUBATION BOX - RV	1,115	1.40%	76	1.50%	TOTAL
TOTAL ESCAPEMENT	21,833		10,154		
AGE COMPOSITION					
MARKED	3	88.9%			
UNMARKED	3	87.5%		78.5%	

TOTAL CATCH (est.) 30,000

THORNTON CATCH (30,000 - 5,000*) 25,000

THORNTON (C+E) 46,833

SURVIVAL

3 $\frac{46,833 \times .88}{1,076,127} = 3.48\%$

4 $\frac{46,833 \times .88}{874,100} = .64\%$

*5,000 est. portion of catch attributable to Salmon Creek to equal maximum reported escapement of 15,000 fish.

Table 4

SURVIVAL BY AGE, SEX, MARK FOR THORNTON CREEK AND SALMON CREEK

1980 ADULT RETURNS

THORNTON CREEK

AGE	MALE	%	AGE	FEMALE	%
3	LV	29.2	3	LV	31.9
	RV	9.7		RV	18.1
		38.9			50.0
4	LV	2.8	4	LV	5.6
	RV	1.4		RV	1.4
		4.2			7.0

SALMON CREEK

AGE	MALE	%	AGE	FEMALE	%
3		42.9	3		35.6
4		11.2	4		10.3
		54.1			45.9

UNMARKED THORNTON CREEK

AGE	MALE	%	AGE	FEMALE	%
3		37.5	3		50.0
4		6.9	4		5.6

A TIDAL PLANKTON ACCUMULATOR FOR IN-SITU REARING OF PINK AND CHUM FRY

by

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Traditional laboratory approaches to the rearing of larval marine animals involve costs which render such approaches impracticable for commercial application. Seawater and lighting systems require electrical power, and provision of live planktonic food is labour-intensive, whether it involves culturing of food organisms or live capture of wild plankton with a boat and plankton net. This paper presents a concept which allows for exploitation of tidal currents to eliminate labour, energy and feed costs in mariculture. As these costs can amount to 85% of operating costs in salmon pen farming, plans are being considered for evaluating this methodology for rearing fry of pink and chum salmon.

The "field culture chamber" consists of a large tub provided with floatation to keep its open top above the water surface and attachment to an anchor chain so that one side of the tub always faces tidal currents. Alternately, the tub can be provided with a rudder and a floatation collar in which it swivels to face tidal currents from a fixed position, as when attached to a floating dock. The side of the tub facing the current has openings cut in it to form deflection vanes which will allow current to enter the tub in a flow around the interior periphery. The bottom of the tub is perforated with holes to permit flows to exit the tub. The inlet vanes are covered with a mesh of predetermined size to prevent entry of potentially damaging organisms and to permit entry of microzooplankton suitable as food for developing marine animals which are stocked into the

tub. The outlet holes in the bottom are covered with filtration material (bio-rings) to provide for biodegradation of waste and to prevent exit of the organisms being cultured and their food plankton. The filter bed and tub are black, and the top covered with a translucent lid, so that the tub interior has highly directional lighting from above, comparable to light conditions encountered only in relatively deep water. The result of the lighting, peripheral circular currents and uniform downwelling is for viable organisms to remain near the center surface of the field culture chamber, where feeding can occur without disruptive physical encounters with the tub walls or bottom. The above method provides for current flows, feeding and sanitation without any operating costs, simply on the basis of tidal currents and the positive phototaxis and negative geotaxis of planktonic animals. Considering the obvious commercial potential for this approach, the method and apparatus have patents pending in the U.S. and Canada.

A prototype of relatively elaborate design, embodying all patent claims, was constructed and deployed at the N.M.F.S. Manchester Aquaculture Experiment Station, where its physical performance was evaluated and its plankton accumulation documented. This prototype was then returned to Vancouver and deployed in southern Indian Arm, near the NE boundary of Vancouver Harbour. Here the first second-generation captive propagation of NE Pacific marine fishes was achieved, with the cockscomb prickleback and the sailfin sculpin (Anoplarchus purpurescens and Nautichthys oculofasciatus). The tendency for freshwater influence to lower salinities and cause collapse of the local zooplankton community, however, led to the removal of the prototype from Indian Arm.

Based on the experiences at Manchester and in Indian Arm, a small inlet on Nelson Island was selected which has strong tidal currents (up to six

knots), minimal freshwater influence and complete protection from storm action. This is the location of Tidal Rush Marine Farms, where pilot rearing of pink and chum salmon fry will take place. A "strip-down model" of the field culture chamber has been constructed and deployed along with the prototype, in order to determine how inexpensively these devices can be produced; the total cost of the second version was about $1,000, including labour.

The objectives of the salmon culture pilot project are intended to be as follows:

1. Determine the effects of seasonal changes in temperature and plankton abundance on fish production.
2. Determine the optimum period for using culture chambers, as opposed to chambers and then sea pens with prepared foods.
3. Determine the effects of daytime versus 24-hour feeding on natural plankton on the growth and survival of salmon.
4. Compare growth and survival of salmon in culture chambers, feeding on natural plankton, versus in sea pens, with pellet food.
5. Compare growth and survival in culture chambers of pink versus chum salmon.
6. Determine whether vaccination is required to protect fish health in culture chambers, with natural food.

The economic advantages of this method over traditional hatchery methods should bring the newly emerging industry of salmonid pen farming into profitable status, for the first time. Pan-sized salmon will have to be priced competitively with pan-sized trout from hatcheries in Japan, Utah and Idaho, where tremendous economies of scale exist,

but where this tidal power technology is inapplicable. Thus, tidal power offers an economic break for British Columbia salmon farmers. Furthermore, the utilization of the entire spectrum of natural wild plankton as food for cultured salmon fry offers the prospect of a new era of improved fish nutrition and health.

This "field culture chamber" method is intended for pink and chum salmon fry, as well as early life stages of marine crustaceans and fishes, as it requires high salinity sea water removed from fresh water influence. Thus, new geographic areas along the B.C. coastline, without the streams required for the hatchery stage of coho and chinook culture, would be opened for salmon farming. The methodology finally offers immediate adaptability to polyculture, the diversification of species under culture.

EVALUATION OF AN EXPERIMENTAL *AEROMONAS SALMONIDA* VACCINE

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Furunculosis of salmonids, caused by *Aeromonas salmonida*, has been a main subject of bacterin research for nearly forty years. Many significant developments have been made with bacterins for this disease over ten years but problems with artificial challenge and inconsistant protection have hampered the development of a commercial vaccine. Research at Tavolek over the last three years has resulted in the bacterin trade-marked CIDAVAX*. An application for a license was recently filed with the USDA for an injection claim for this bacterin. All laboratory data presented in this paper was generated using a waterborne challenge with virulent *A. salmonida*

Potency Tests: Challenge mortality rate with coho salmon (8g) injected ip with 0.1ml CIDAVAX bacterin resulted in 2-16% loss in vaccinates compared to 51-58% loss in controls.

Onset of Protection: Fall chinook salmon (4g), vaccinated by ip injection with 0.1ml of bacterin, were as well protected 7 days post vaccination as at 28 days post vaccination. Evidently, the onset of protective immunity at a holding temperature of 10C was as rapid as had been found for HIVAX vibrio bacterin used with the immersion method.

Species Tested: To date, coho, chinook, and sockeye salmon and rainbow trout have all responded to ip vaccination. Protection was very good in rainbow trout up to 150g in size.

Immersion Vaccination: A single immersion of 5 minute duration did not result in an acceptable level of protection compared to injection. Multiple immersions, however, have resulted in protection which approaches injection in efficacy.

Field Tests: The results of three field tests failed to demonstrate increased survival of vaccinates compared to controls. These tests were complicated by a low level of A. salmonida challenge and losses to other bacterial pathogens. However, recovery of A. salmonicida from mortalities in all three field tests was considerably lower for vaccinates than controls.

Verbal acceptance of the injection claim for CIDAVAX* furunculosis bacterin was recently received. It should prove useful for protecting trout broodstock from furunculosis. Further work with immersion vaccination should provide an expanded claim for that delivery method as well.

SURVEY OF KIDNEY DISEASE BACTERIA IN THE QUILLAYUTE RIVER SYSTEM

by

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INTRODUCTION

Kidney disease is recognized as one of the most important infectious bacterial diseases of hatchery reared salmonids, with recent documentation of its occurrence in feral fish populations (salmonids). The presence of the causal agent (Renibacterium salmoninarum gen. nov. sp. nov., Sanders and Fryer, 1980) in feral salmonid populations suggests a reservoir of bacterial kidney disease (BKD), or the exchange of the bacterium between hatchery and wild stocks. Indeed, it appears to be the riddle of the chicken and the egg.

The Quileute Tribe is interested in preserving wild and native salmon stocks and wishes that any enhancement effort has minimal impact on the wild fish. Prior to development of an enhancement program on Spring chinook, the Quileute Fishery disired to document the occurrence of BKD in salmonids in the Quillayute River System. A survey of BKD was initiated to assess the effect enhancing present stock (Quillayute-Cowlitz-Dungeness chinook) may have on true wild and native stock, and to predict potential problems with BKD in the Quileute Fishery enhancement facility.

The survey was to encompass both fluvial systems and various salmonid stocks. The Quillayute River System, including the Soleduck and Bogachiel Rivers, which have been enhanced by the Washington State Fisheries Department, were periodically sampled as well as a small stream (Ellen Creek) which has received no enhancement. These two extremes should provide some information concerning whether BKD is an integral part of fluvial ecosystems regardless of enhancement.

PROCEDURES

1. Adult salmonids were obtained from the Quileute Indian gillnet fishery, the sport fishery, and from hatchery operations.

2. Juvenile salmonids and non-salmonid fish were obtained by beach seine in the mainstreams and electroshocking in the tributaries.

3. Smears from the anterior and posterior kidney from each specimen were made on glass slides, fixed in acetone and the presence of kidney disease bacteria determined by the Indirect Fluorescent Antibody Technique (IFAT).

4. Museum samples from the upper Soleduck River (September 1960) were processed by making a 1:10 dilution of kidney and liver in phosphate buffered saline (pH7.4). A smear was made in the manner as described and subjected to IFAT.

5. Samples were quantified as the number of fluorescent bacteria observed in 150 microscope fields (calibrated). However, only positive or negative samples are reported here.

6. Some organ samples were subjected to counterimmunoelectrophoresis using rabbit serum against washed whole cell bacteria. Electrophoresis was carried out at 8v/cm for 30 minutes.

RESULTS AND DISCUSSION

The number of salmonids demonstrating a positive IFAT was 39 of 249 fish, or 15.7% overall incidence (Table 1). Evidence for the presence of R. salmoninarum was obtained from the Quillayute River, Dickey River, the gillnet and sport fishery, and from Ellen Creek. Samples obtained from the Soleduck Hatchery revealed the presence of kidney disease bacteria (KDB) yet samples taken from the Soleduck River were all negative. However, hatchery samples were of chinook salmon while no chinook were taken from the Soleduck River. Examination of the data suggests a ubiquitous distribution of KDB.

Chinook salmon

Chinook salmon constituted the most frequently sampled stock (47% of the fish sampled). Nearly 20% of the 118 chinook examined demonstrated a positive IFAT (Table 2). Significantly, the proportion of adults harboring

Table 1. Positive IFAT kidney smears. Number and percent positive, by location.

Location	No. Fish	No. Positive	%Positive
Quillayute R.			
Salmonids	85	9	23.1
Non-salmonids	10	1	16.7
Soleduck Hatchery	23	11	47.8
Soleduck R.			
Salmonids	11	0	0
Non-salmonids	2	0	0
Ellen Creek			
Salmonids	59	10	16.9
Non-salmonids	12	1	8.3
Gillnet	34	3	8.8
Bogachiel R.	6	0	0
Sport Fishery	5	3[a]	60.0
Dickey R.	1	1	100
Spring Creek	1	0	0
TOTAL	249	39	15.7

[a]Pink salmon (1), Coho(2)

KDB is higher than in juveniles. These adult fish could be a source of KDB to various hatchery and water systems, particularly in view of the straying reported for chinook stocks. Chinook obtained from the Soleduck Hatchery revealed the highest incidence of KDB (Table 3), however juveniles taken by beach seining of the Quillayute River and estuary demonstrated a 13% occurrence among the juvenile (0+) population.

Ellen Creek

The occurrence of KDB in Ellen Creek, which has received no enhancement, is significant (Table 4). Juvenile trout showed a 27% incidence compared to a 34% overall occurrence of KDB among juvenile trout. Ellen Creek also hosts a stock of coho salmon, yet only 1 of 36 coho sampled was positive by IFAT (Table 5). In general coho salmon revealed a lower number of positive samples, i.e. a 6.7% incidence. However, the adult population displayed a higher proportion of positive samples.

Table 2. Positive IFAT kidney smears in chinook salmon (Oncorhynchus tshawytscha).

	No. Fish	No. Positive	% Positive
Adults	36	12	30.6
Juveniles	82	11	13.4
TOTAL	118	23	19.5

Table 3. Positive IFAT kidney smears in chinook salmon (O. tshawytscha), by location.

Location	No. Fish	No. Positive	% Positive
Quillayute R.			
Adult	1	0	0
Juvenile	73	10	13.7
TOTAL	74	10	13.5
Soleduck			
Adult	24[a]	11	45.8
Juvenile	1	0	0
TOTAL	25	11	44.0
Gillnet	11	1	9.0
Bogachiel	6	0	0
Dickey R. (Juvenile)	1	1	100
Spring C. (Juvenile)	1	0	0

[a]Hatchery (23), River (1)

Table 4. Positive IFAT kidney smears in trout.

	No. Fish	No. Positive	% Positive
Salmo gairdneri	2	1	50.0
Juveniles	43	9	34.8
Ellen C.	33	9	27.3
Quillayute R.	1	0	0
Soleduck R.	9	0	0
TOTAL	24	10	22.2

Table 5. Positive IFAT kidney smears in coho salmon (O. kisutch).

	No. Fish	No. Positive	% Positive
Adult[a]	24	3[b]	12.5
Juvenile[c]	36	1[d]	2.8
TOTAL	60	4	6.7

[a] Sport Fishery/Gillnet

[b] Sport Fishery

[c] Ellen Creek (26), Quillayute R. (10)

[d] Ellen Creek

Bacterial incidence

The average number of observed bacteria per 150 microscope fields was 32 with a few as 1 and as many as 500 bacteria per 150 fields. The median number of bacteria observed was 12 per 150 fields. Since these low numbers are inconsistant with overt disease it must be presumed that fish with such bacterial populations represent a reservoir of KDB, or carriers. The majority of fish sampled appeared disease free. Only rarely was a kidney observed which appeared pathological, and these individuals demonstrated higher numbers of bacteria.

Table 6. Examination of museum samples taken in 1960 from the upper Soleduck River. Samples preserved in formalin.

Sample	Date	Organ	No. Bacteria/ 150 fields Direct*	Indirect*
Coho	9-60	Kidney	0	0
		Liver	0	0
Coho	9-60	Kidney	0	0
		Liver	0	0
Coho	9-60	Kidney	0	0
		Liver	0	0
Coho	9-60	Kidney	3	5
		Liver	0	0
Steelhead	60	Kidney	0	0
		Liver	0	0
Steelhead	60	Kidney	0	0
		Liver	0	0
Steelhead	9-60	Kidney	0	0
		Liver	0	0
Steelhead	9-60	Kidney	0	0
		Liver	0	0

*Fluorescent Antibody Technique

Museum samples

Formalin preserved samples of four coho and four steelhead taken in 1960 were examined by FAT. Only one coho demonstrated KDB in the kidney (Table 6). Remaining samples were negative. This suggests KDB were present prior to completion of the Soleduck Hatchery. Interestingly, indirect FAT gave clearer results than direct. Direct FAT positive cells were clearly visible but less brilliant than IFAT preparations. There was also less background fluorescence with IFAT.

Non-salmonids

Non-salmonid specimens were also examined (Table 7) and 2 of 24 individuals demonstrated positive IFAT smears. Both specimens were sculpin, a staghorn (Leptocottus armatus) from the Quillayute River and a prickly-back (Cottus asper) from Ellen Creek. Remaining samples were negative.

Table 7. Positive IFAT kidney smears in non-salmonids.

Location	No. Fish	No. Positive	% Positive
Quillayute R.	10	1[a]	10.0
Soleduck R.	2	0	0
Ellen C.	12	1[b]	8.3
TOTAL	24	2	8.3

[a]Staghorn sculpin (Leptocottus armatus)

[b]Pricklyback sculpin (Cottus asper)

Neither of the two positive fish showed any evidence of disease. We presume the bacteria represented cross reactivity of antigens even though morphology of the observed bacteria was consistant with KDB. However, a gram stain was not performed nor was isolation attempted. Counterimmuno-electrophoresis of the positive pricklyback sculpin (Ellen Creek) was negative, suggesting the organism observed was not the KDB.

Counterimmunoelectrophoresis (CE)

Using serum from rabbits immunized with a whole cell suspension of KDB, liver and kidney samples obtained from fish taken from Ellen Creek in September of 1979 were examined for the presence of KDB antigens. Only one trout which was negative for IFAT demonstrated a positive CE while all other specimens were positive by both IFAT and CE (Table 8). As already stated, the pricklyback sculpin was negative.

SUMMARY

1. The causal agent of BKD is demonstrable in the Quillayute River System.

2. KDB are also found in fish from an area which has not received enhancement.

3. KDB is demonstrable in at least one museum specimen indicating the organism was present prior to completion of the Soleduck Hatchery.

4. There is a suggestion that a cross reacting bacterium may be found in non-salmonids.

5. Counterimmunoelectrophoresis may be a more sensitive screening technique that FAT.

Table 8. Comparison of IFAT and counterimmunoelectrophoresis analysis of samples taken from Ellen Creek, September, 1979.

Specimen	No. Fish	Kidney IFAT[a] Anterior	Kidney IFAT[a] Posterior	Electrophoresis[b] Liver	Electrophoresis[b] Kidney
Coho	6	0	0	0	-
Trout	1	0	0	0	-
Trout	1	0	0	+	-
Trout	2	0	0	-	-
Trout	1	0	2	+	+
Trout	1	0	2	+	+
Trout	1	2	12	+	+
Trout	1	21	18	+	+
Trout	1	500	8	+	+
Trout	1	10	ND	+	ND
Trout	1	2	ND	+	ND
Trout	1	0	25	+	+
Trout	1	5	0	+	+
Prickly sculpin	1	161	28	-	-

(ND) Not Done

[a]Bacteria per 150 microscope fields

AN EPIZOOTIC OF ATYPICAL BACTERIAL KIDNEY DISEASE IN ADULT MIGRANT COHO

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Bacterial kidney disease (BKD) is a major cause of losses among cultured salmonids in British Columbia. The disease has a wide distribution within the Province and, with the exception of the Kitimat River, it has been found in every coastal stream sampled. It is a problem to both saltwater and freshwater culturists. The mortality rate can be high and there is no completely effective chemotherapeutic agent or vaccine. In this region the most common clinical signs encountered are: (1) external - dark skin, popeyes, hemorrhaging at the base of the paired fins, and pale gills, (2) internal - swollen kidneys accompanied by grey purulent lesions, usually in the posterior half of the kidney. Only rarely are external lesions or swellings observed. In most cases the disease can be classified as a chronic nephritis which may involve other internal organs. There is some evidence, most of it circumstantial, to suggest that the main mode of transmission is vertical, i.e. parent-egg/sperm-offspring.

In this presentation we will describe an outbreak of the disease which occurred this fall among migrant adult coho returning to the Capilano River Hatchery. This particular epizootic is interesting for three reasons: (1) an unusually high infection rate, (2) occurrence of prespawning losses, and (3) unusual external disease signs.

Migrant Capilano coho arrive in Burrard Inlet in June and provide a substantial sports fishery. Starting near the beginning of July, they enter the river and can be separated into early, mid and late run fish. Approximately 85% of the early run, or those fish which entered during July,

became infected. Prespawning losses associated with atypical BKD signs began in mid-September (Figure 1) and were limited to this group. Later segments of the run also were infected but to a much lesser extent. The percentage of infected fish in the late run was estimated at 27%. A total of 350 first run coho were lost compared to 25% for the same group and period last year.

The health status of coho returns to the Capilano River has been monitored since 1974 (Table 1). BKD encountered in the past in adults has usually been in the carrier state; rarely have active cases with gross disease signs been found. The highest carrier level, 31% (Table 1), occurred in 1974, the first year of sampling, but no gross clinical signs were recorded and no prespawning losses reported. Among the hatchery's juvenile production fish, losses from BKD have always been low and the clinical signs have generally been those described above. When disease signs have been found in hatchery smolts, they have usually been limited to kidney lesions and popeyes.

High carrier levels for infectious diseases are fairly common in B.C. salmon, especially in the case of furunculosis. Figures as high as 38% have been recorded in migrant chum on the Queen Charlotte Islands for this disease.

In view of the sharp increase in the number of acute BKD infected coho returns and the occurrence of prespawning losses, we undertook a detailed examination of both Capilano chinook and coho. On three occasions, ripe or spawned out fish were sampled (Table 2). Although the causative agent for furunculosis, Aeromonas salmonicida, could be isolated from 26% of the chinook adults, no gross disease signs were noted and apart from a few fungus infected abrasions the fish were judged to be in generally good condition, almost free of BKD. In contrast to the chinook,

many coho had external pustules or blebs, usually on the sides above the lateral line but all surfaces except the head were involved to some extent. The lesions were similar in appearance to those caused by Myxosoma squamalis, a protozoan which infects the scale pockets of saltwater salmon. Initially the disease was confused with this parasite.

The pustules contained a thick, white fluid that under microscopic examination revealed numerous Gram-positive diplobacilli, later confirmed as the causative agent for BKD by use of the direct fluorescent antibody and immunodiffusion techniques. The bacterium could be readily cultured on Evelyn's kidney disease medium from the pustules.

In most cases histological examination of excised pustules showed the lesions to be superficial with little or no penetration of the underlying muscle. In addition, approximately 10% of the early run coho had massive external swellings, 1/2 to 3 inches in diameter, alone or in combination with the blebs, usually located dorsally between the head and dorsal fin. These swellings contained numerous Gram-positive diplobacilli and covered large areas of necrotic flesh with deeply penetrating channels into the muscle. In several cases sufficient muscle tissue was destroyed to make survival questionable. Yet in almost all cases no involvement of the internal organs was found.

Many of the coho were also carriers of furunculosis (Table 2) but the causative bacterium of this disease did not appear to play a role in the formation of the external disease signs. Diagnosis was based solely on the isolation of non-motile, brown pigment producing bacteria from kidney tissue and confirmed using slide agglutination techniques.

The disease signs described are not new. Other investigators, in the United States and elsewhere, have reported similar gross BKD pathology but mainly in Atlantic salmon and trout. The superficial nature of most of the pustules and blebs suggest that the fish contracted the disease after entering fresh water. No unusual fish were reported in the sports catch. In the present case, the mode of transmission would probably have been horizontal (fish to fish or fish to water to fish). Hatchery effluent drains directly into the river and so the facility's juvenile production stock may have been the primary source of infection, but resident, wild fish cannot be discounted as a source. The greater severity of the disease among the early coho may reflect longer exposure to infected fresh water. It is interesting to note that 100% of the early run was infected with the freshwater copepod, Salmincola, compared to 83% of the late run.

At the present time it is impossible to make any general statements regarding the importance of this epizootic on future runs or on hatchery operation. Nor is it possible to say what caused the mortalities, only that they were associated with atypical BKD. However, the situation demands that the adult returns be monitored each season. Action to deal with a similar problem next fall, should it occur, could include:

1. Water hardening of the eggs in Erythromycin;
2. Injection of the early run with antibiotics;
3. Prophylactic feeding of antibiotics to juvenile hatchery stock;
4. Screening of the adults for disease agents;
5. Modification of handling and sorting techniques;
6. More rigid disinfection of hatchery equipment and facilities.

Why bacterial kidney disease has shown such a sharp increase in severity is not known but several mechanisms may be involved:

1. A change in the environment - i.e. increased level of some pollutant;
2. A change in the causative organism - i.e. increased pathogenicity.
3. A change in the host - i.e. increased susceptibility of early run fish to BKD;
4. A combination of the above.

Table 1. Fish health survey results for bacterial kidney disease (BKD) and furunculosis since 1974.

Date Sampled	Number of Fish Examined	Percent BKD Positive	Percent Furunculosis Positive
Oct. 21, 1974	50	22.0	0
Dec. 12, 1974	110	31.0	18.0
Dec. 19, 1974	86	22.3	18.6
Nov. 16, 1976	86	7.0	14.0
Dec. 12, 1977	41	26.8	2.4
Nov. 22, 1978	100	5.0	21.0
Oct. 23, 1979	120	2.5	10.0

Table 2. 1980 fish health survey results for bacterial kidney disease (BKD) and furunculosis.

Date Sampled	Species	Number of Fish Examined	Percent Infected	
			BKD	Furunculosis
Oct. 22, 1980	Chinook	50	2.0	26.0
Nov. 13, 1980	Coho	35	85.0	28.6
Nov. 18, 1980	Coho	30	27.0	6.7

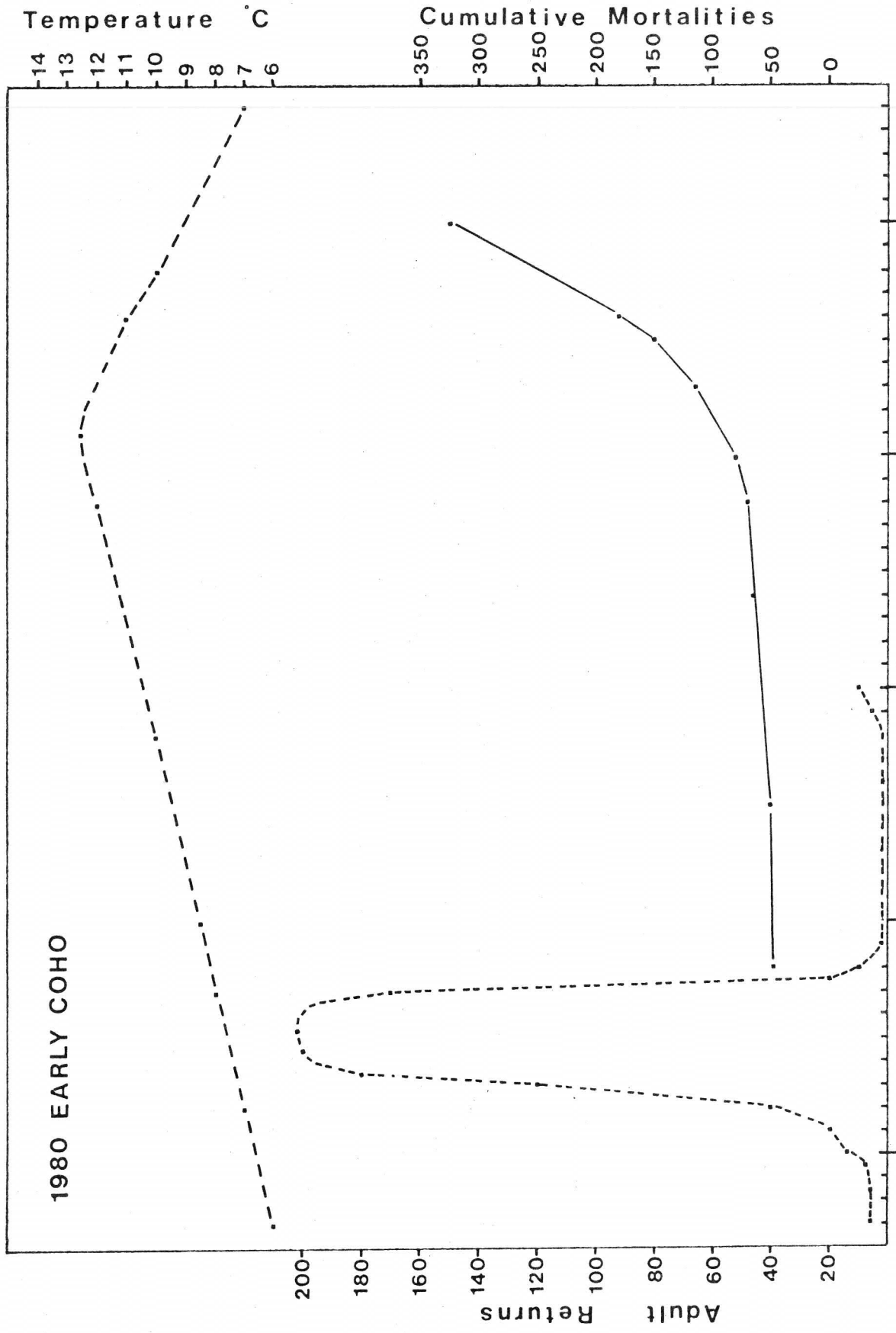

Fig.1 1980 early run coho returns, cumulative prespawning mortalities and river water temperatures for the Capilano Hatchery during the period of mid-June to mid-November.

RINSING UNFERTILIZED STEELHEAD EGGS AND IHN VIRUS

by

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Round Butte Hatchery has been plagued with epizootics of the virus disease Infectious Hematopoietic Necrosis in fry of Deschutes River stock summer steelhead four of the last six brood years (1975, 76, 78, 80). What triggers an epizootic is completely unknown. With most epizootics, there has been a portion of the same group which did not become diseased, even though from the same parents and held under identical conditions in a different container. IHN has been diagnosed in adult spawners most years; however, there has been no consistency between diagnosis in adults and epizootics in fry. Epizootics are typically disastrous, with over 90% mortality in three weeks. We now destroy all fry in the rearing container as soon as IHN is diagnosed.

To maintain production while experiencing epizootics, we now take three times the number of eggs needed to meet our goal of 162,000 yearling smolts. The adult run is divided into three segments by time: early (before December 10), middle (December 10 - January 31), and late (after January 31). We take 250,000 eggs from adults of each segment. Other physical measures to work around IHN include dividing our incubator stacks (some epizootics have occurred prior to ponding) and increasing our starting tanks from three large ovals to twenty-four 1.8 m circulars.

In 1979, an experiment was designed to determine if rinsing away ovarian fluid prior to fertilization would decrease the incidence of IHN in resulting fry. The hypothesis was that, by removing ovarian fluid, the

numbers of virus particles entering the eggs during fertilization and water-hardening would be reduced.

Methods

After a pilot test using four females yielded satisfactory fertilization, the experiment was conducted (3 replicates) using the late egg-take group in 1979. Procedures used were: A small mesh net was secured over the top of a bucket containing the pooled eggs from 20 females spawned by incision. Ovarian fluid was then drained into a graduate cylinder. Approximately one-half of the drained eggs were poured carefully into another bucket and one-half of the ovarian fluid poured back over these eggs. Eggs without ovarian fluid were then rinsed three times using 23 L of 1% saline solution (10 g table salt/L) each time. One-half of the pooled semen from 20 males was then added to each bucket (rinsed and unrinsed). Water was added to stimulate fertilization. After washing, eggs were allowed to water-harden in the buckets for 1 hour prior to disinfection in Wescodyne (1:150 for 10 minutes) and transportation to the hatchery. Each group was placed in a separate Heath-incubator stack. Loss of eggs and fry were recorded for each group. All adults used in 1979 were sampled (ovarian fluid and semen) for IHN by ODFW pathologists and none was found.

Encouraging results in 1979 (satisfactory egg survival and no IHN) led us to repeat the experiment in 1980 using all three adult run segments. Samples of ovarian fluid from females of the middle egg-take groups (the only spawning period sampled) showed 44% positive for IHN. Samples from the rinsed and unrinsed pools showed two of the three replicates, both rinsed and unrinsed groups, positive for IHN. In samples from the two posi-

tive rinsed groups, the pathologist reported that "cytopathic effect appeared late and was more diffuse with the saline rinse, suggesting the presence of fewer virus particles".

By spawning time for the late group, it was apparent that egg survival for the early and middle groups was much poorer than in 1979, especially in the rinsed groups. To determine if experimental procedures were at fault, two replicates of the experiment were conducted with the late egg-take and survival compared to two past methods used, hand-stripping and incision (one trial each).

Results

No epizootics occurred in rinsed or unrinsed groups in 1979, and survival to ponding was higher in the rinsed groups (Table I). In 1980, five of the eight rinsed groups developed IHN and were destroyed (Tables 2, 3, 4). None of the unrinsed groups became diseased. These results were opposite of what we expected, and we have no explanation for the high incidence of IHN in the groups rinsed with the saline solution.

Survival to ponding was lower in most rinsed groups than unrinsed groups in 1980. These results were opposite those seen in 1979, and we have no explanation for the lack of consistency. Survival in the groups spawned by hand-stripping and incision methods was comparable to that of past years and better than most, but not all of the rinsed and unrinsed groups in 1980 (Tables 2, 3, 4).

Table 1.

LATE EGG TAKE 1979 BROOD

Group	No. Eggs	% Survival to Ponding	Date Ponded	IHN Diagnosed Date Destroyed
A-Rinsed	50,840	82.2	4/19/79	None
A-Unrinsed	48,952	53.5	All groups	None
B-Rinsed	54,438	85.8		None
B-Unrinsed	50,007	74.2		None
C-Rinsed	60,135	77.7		None
C-Unrinsed	57,603	71.5		None

Table 2.

EARLY EGG TAKE 1980 BROOD

Group	No. Eggs	% Survival to Ponding	Date Ponded	IHN Diagnosed Date Destroyed
A-Rinsed	48,000	67.5	3/18/80	4/1/80
A-Unrinsed	47,280	63.2	All groups	None
B-Rinsed	47,520	54.5		None
B-Unrinsed	47,520	56.3		None
C-Rinsed	51,360	63.6		4/1/80
C-Unrinsed	46,560	67.0		None

Table 3.

MIDDLE EGG TAKE 1980 BROOD

Group	No. Eggs	% Survival to Ponding	Date Ponded	IHN Diagnosed Date Destroyed
A-Rinsed	46,144	64.0	3/25/80	5/5/80
A-Unrinsed	43,424	74.9	All groups	None
B-Rinsed	46,020	58.8		None
B-Unrinsed	38,940	81.5		None
C-Rinsed	35,872	36.1		5/27/80
C Unrinsed	25,016	55.4		None

Table 4.

LATE EGG TAKE 1980 BROOD

Group	No. Eggs	% Survival to Ponding	Date Ponded	IHN Diagnosed Date Destroyed
Hand-stripped	47,000	79.4	4/22/80	None
Incision	42,000	80.8	All groups	None
A-Rinsed	44,000	61.7		None
A-Unrinsed	45,000	64.5		None
B-Rinsed	40,584	87.6		5/12/80
B-Unrinsed	47,424	73.5		None

CERATOMYXA SHASTA: INITIAL TIMING, LONGEVITY, AND ABUNDANCE OF THE INFECTIVE STAGE IN THE DESHUTES RIVER OF OREGON

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Initial Timing

To describe the initiation of the infective period for Ceratomyxa shasta, susceptible, fingerling rainbow trout were exposed to the Deschutes River for 7-day periods at two locations (km 1 and km 161) during the Springs of 1978 and 1979. In 1978, the infective stage was present when the first groups (N = 75) were exposed March 31 - April 7 (Fig. 1). River temperature was 7.0 C during the exposure at km 161. In 1979, the infective stage was first detected at both sites during exposures (N = 50) from April 3-10 when the water temperature was 7.5 C at km 161 (Fig. 2). Meantime until death showed a significant negative correlation with percentage mortality in the different groups, probably due to the effect of multiple infections in individuals of the high-mortality groups.

Longevity

Water containing the infective stage was held in plastic aquaria partially immersed in flowing Deschutes River water to control temperature. A standard aquaria air pump and stone was used to aerate the water in each aquaria. By exposing highly susceptible, fingerling rainbow trout to water held for different intervals of time, it was found that no fish became infected after exposure to water held 10 or more days (Table 1). This indicates the mean longevity of the infective stage is less than 10 days and that it does not reproduce itself in the aquatic environment.

The process of infection seems quite efficient as 4-day exposures of 40 test fish to 96 L of Deschutes River water removed all infectious units (Table 1). No infections were found in subsequent exposures to the same water even

though exposures to water held 4 days with no fish did produce infections. Since this is far more water than consumed by these fish during this time interval, the infective stage must enter the fish externally through the skin or gills.

Number of Infectious Units per Infection

Starting with five fish in the first aquaria, the numbers of test fish exposed to water containing the infective stage in six, 96 L aquaria, were progressively doubled. Since the number of C. shasta-positive deaths experienced by groups comprised of 20 or more individuals remained similar in both trials (Table 2), one infectious unit must be capable of establishing infection and causing death in highly susceptible rainbow trout. These infections were characterized by a much longer time until death (60 to 90 days at 10 C) and low numbers of spores, many of which were malformed.

Abundance of the Infective Stage

By exposing 40 fingerling rainbow trout to 96 L of Deschutes River water for 4 days, every 3 weeks throughout the infective period in 1979, I was able to determine changes in abundance of infectious units. C. shasta was first detected April 3 at a concentration of about 30 infectious units per m^3 (Fig. 3). This was approximately one month later than when first detected using the more sensitive 7-day exposures to the River itself (See Initial Timing). Abundance of infectious units increased from April to a peak concentration of 150 per m^3 June 4. The concentration then generally decreased to near 0 at the end of November. Abundance of infectious units did not appear to be correlated with water temperature or volume of flow.

Figure 1

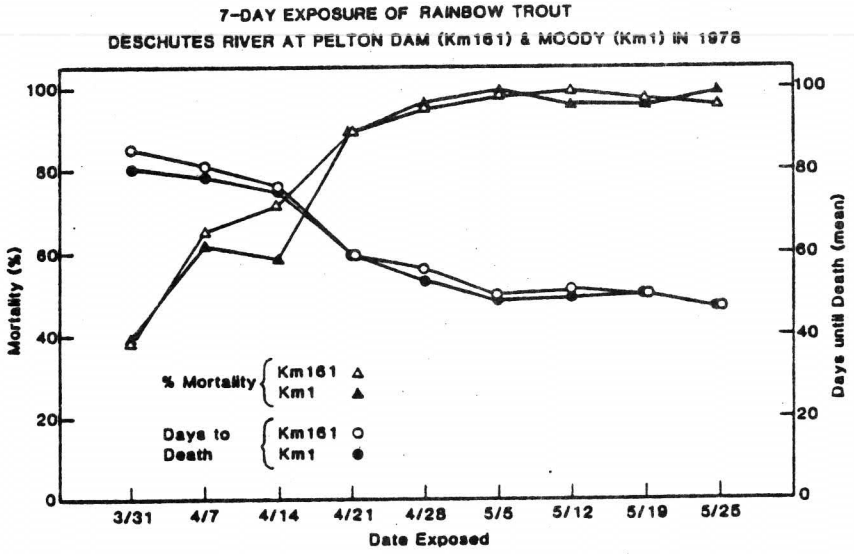


Figure 2

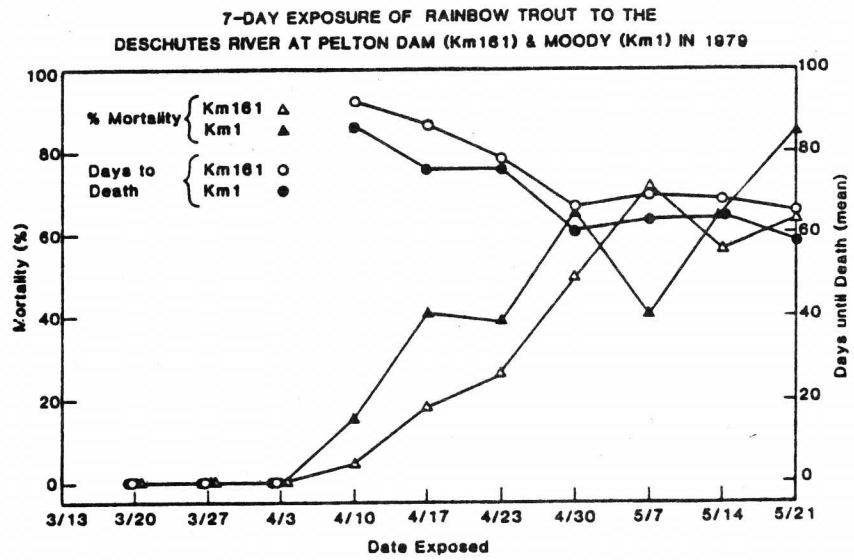


Table 1

LONGEVITY OF THE INFECTIVE STAGE

R.R.Rb at 2.4g, 5/25-29/79

Days Held	Positive/Negative	Survivors	Infection Rate (%)
0	20/1	19	51
1	13/1	26	33
2	4/1	35	10
3	8/1	31	20
4	5/1	17a	23
0-4	0/0	22a	0
5	9/0	30	23
6	3/0	37	8
7	1/0	38	3
10	0/0	40	0
14	0/0	40	0

a. Some died during transfer

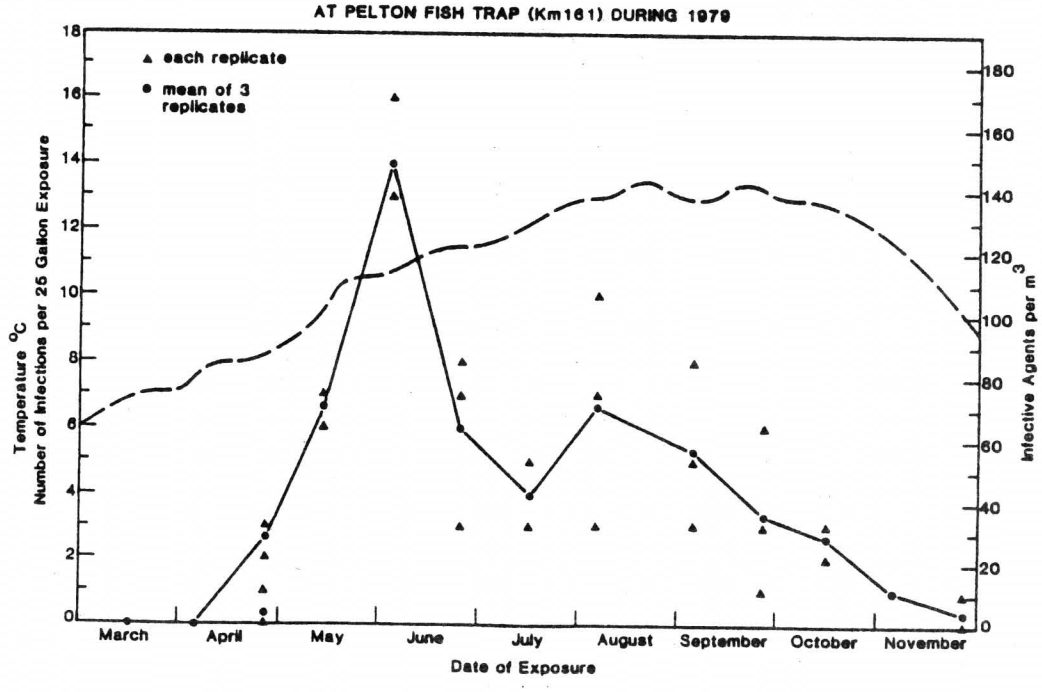
Table 2

EXPOSURE TO 94.6ℓ (25 gal.) OF DESCHUTES RIVER WATER

Number of Fish	Trial 1, 5/25-29/79 R.R.Rb at 2.3g Positive/Negative	Trial 1, 5/25-29/79 R.R.Rb at 2.3g Infection Rate (%)	Trial 2, 9/26-30/79 Diamond Lake Rb at 1.6g Positive/Negative	Trial 2, 9/26-30/79 Diamond Lake Rb at 1.6g Infection Rate (%)
5	3/0	60	0/0	0
10	7/0	70	3/0	30
20	10/2	50	3/0	15
40	9/2	23	3-6-1/0-1-0	8
80	10/2	13	4/0	6
160	11/1	7	4/0	3

Figure 3

RELATIVE INFECTIVITY OVER TIME FOR DESCHUTES RIVER AT PELTON FISH TRAP (Km161) DURING 1979



Histopathological Effects of River Ashfall Suspension on Chinook Salmon Fingerlings

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As a result of the eruption of Mt. St. Helens, substantial amounts of volcanic ash and mud were deposited in the Toutle, Cowlitz, and Columbia rivers. This material not only eliminated rearing areas, it also posed a threat to migrating smolts as they passed down the Cowlitz and Columbia rivers on their way to the ocean.

To determine the effects of suspended river ash on migrating fall chinook, live-box bioassays were conducted at three strategic locations: 1) Cowlitz River at Kelso, 2) the confluence of the Cowlitz and Columbia rivers, and 3) the Columbia River at Stella, approximately 10 river miles downstream from the confluence of the Cowlitz and the Columbia. Juvenile fall chinook, with an average weight of four to five grams, were placed in live boxes and sampled on a regular basis. They were examined grossly and microscopically for lesions, then placed in Bouin's fixative, sectioned, and stained. At the time the fish were sampled, the following water parameters were measured: dissolved oxygen, pH, temperature, and suspended solids.

Tissues most extensively affected were the gills and the skin. Typical histopathology of the gills included abrasion by silica particles, hypertrophy,

hyperplasia, aneurysm, hemorrhaging, and epithelial separation from the lamellar pilaster cells. Externally, severe abrasions of the mucoid and epithelial cells occurred, giving the fish a "sandpaper like" texture.

Below is a table of water parameters measured in mid-June. Samples of fish tissue shown in this presentation were taken at this time.

Site	% Mortality (48 hours)	Temp.	pH	Settleable Solids(1 hr)	D.O.
Cowlitz R.-Kelso	100 (after 6 hrs)	11°C	7.0	1000 + ppm	9.8ppm
Confluence Cowlitz-Columbia	0	14°C	7.0	100	9.8ppm
Columbia R.-Stella	0	14°C	7.3	>10	9.8ppm
Toutle River		11°C	7.3	10,000 + ppm	

STRAYING AND HOMING OF TRANSPLANTED DISAPPEARANCE CREEK, ALASKA CHUM SALMON TO BEAVER FALLS HATCHERY, ALASKA

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SUMMARY

Beaver Falls Hatchery, near Ketchikan, Alaska, has released marked chum salmon fry since 1975. Various marks have been used to identify experimentally differing groups (see Figure 1). Among the experimental groups, some were designed to test, through imprinting studies, if mixed zones or estuary conditions of a bay complex can produce satisfactory homing effect on returning salmon.

The results of the experimental groups of 1974 brood Disappearance Creek chum salmon are discussed in this paper because during the adult return, a large straying study was conducted in conjunction with a mark tag recovery program.

Figure 2 is a flow chart describing the experimental design of the 1974 brood chum salmon. Eggs were taken from adults returning to Disappearance Creek in late September, 1974 and flown 30 miles to the Deer Mountain Hatchery in Ketchikan. They were eyed at that facility, and then the major portion of those eggs were taken approximately 13 miles to the Beaver Falls Hatchery. The eggs that remained at Deer Mountain Hatchery were then taken back to Disappearance Creek as fry and released in that system to test their homing. The eggs taken to Beaver Falls Hatchery were divided into two groups, one released as unfed fry directly into salt water and the other as fed fry that were reared to about 2 grams in salwater rearing pens. All groups were differentially marked for evaluation.

Recovery of marks for evaluation of the 1974 brood was conducted primarily in 1978 when this brood returned as 4 year old adults. During the 1978 fishing season, a recovery program was initiated that examined 73% of the entire commercial catch of adult chum salmon in the Ketchikan area.

To determine straying of adult returns, stream escapement records (provided by the Division of Commercial Fisheries) of all streams located in George Inlet, Carroll Inlet, Thorne Arm, and Cholmondeley Sound were examined for historic chum salmon escapements (see Figures 3 and 4). Those chum salmon streams were assumed to be likely candidates for straying Beaver Falls chum salmon. An attempt was made to survey each one of these streams at least once and generally every ten days during the estimated peak of the adult return. If marked fish were found, they were sampled for length and weight. Scales were taken for age determination.

In total, 130 surveys were made and included the inspection of 66 streams, with the major chum salmon stream surveyed at least every ten days, weather permitting. Of all the streams walked, only three fin-clipped chum salmon were recovered and verified from eight seen. Six were seen on Mahoney River (45-16), one on White River (45-24), and one on the Carroll River (45-78). Two of the recovered chum salmon were found on Mahoney and the other was recovered on White River. No fin-clipped chum salmon were recovered in any of the streams walked in Cholmondeley Sound except Disappearance Creek itself. Three Beaver Falls Hatchery imprinted adults were recovered at Disappearance Creek. These results indicate approximately 4% straying of those fish imprinted back to the Hatchery and no detectable straying of those fish taken back to the parent stream for release.

Recovery programs conducted in 1979 and 1980 support the 1978 findings of a small percentage of straying to Mahoney River from Beaver Falls Hatchery.

In conclusion, findings suggest a reasonably good homing response to the transplanting of Disappearance Creek chum salmon to Beaver Falls Hatchery.

FIGURE 1.

SUMMARY
MARK-TAG PROGRAM RELEASES OF DISAPPEARANCE CREEK CHUM
BEAVER FALLS CHUM SALMON INCUBATION FACILITY

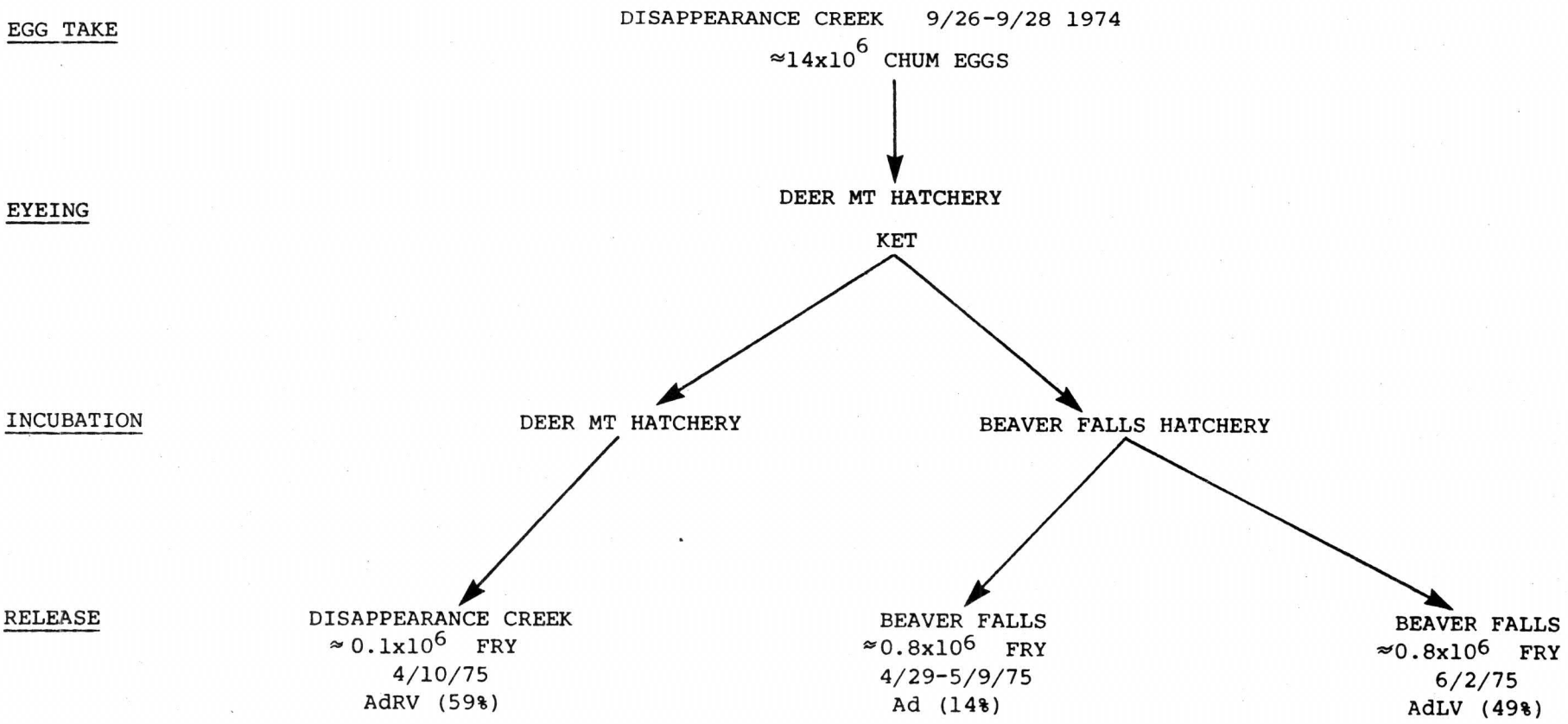
YEAR OF RELEASE	TREATMENT	MARK	NUMBER OF FISH RELEASED # VALID	TOTAL
1975	Imprinting Study	AdRV	74,124	125,206
1975	Short-Term Rearing	AdLV	45,887	93,994
1975	Unfed, Direct Release	Ad	103,849	747,564
1976	Imprinting Study	AdRVLV	35,176	44,945
1976	Unfed, Early Release	AdRV	31,084	535,162
1976	Unfed, Late Release	AdLV	30,662	292,834
1976	Short-Term Reared, Early Release	Ad CWT_1	24,492	698,145
1976	Short-Term Reared, Late Release	Ad CWT_2	31,084	729,358
1977	Unfed, Early Release	RV	33,191	612,845
1977	Unfed, Late Release	LV	32,301	759,782
1977	Short-Term Reared, Early Release	Ad CWT_3	28,729	939,187
1977	Short-Term Reared, Late Release	Ad CWT_4	3,334	63,182
1978	Unfed, Early Release	AdRV	52,313	1,241,760
1978	Unfed, Late Release	AdLV	53,777	54,348
1978	Short-Term Reared, Early Release	Ad CWT_5	31,161	989,090
1978	Short-Term Reared, Late Release	Ad CWT_6	57,051	149,906

Tag Codes Used:

Ad CWT_1: 15-15-5
Ad CWT_2: 15-15-15
Ad CWT_3: 4-1-1
Ad CWT_4: 4-1-2
Ad CWT_5: 4-1-4; 4-1-5; 4-1-6; 4-2-2; 4-2-3; 4-2-4
Ad CWT_6: 4-3-3; 4-3-1; 4-3-2; 4-3-4

FIGURE 2.

1974 BROOD DISAPPEARANCE CREEK CHUM SALMON



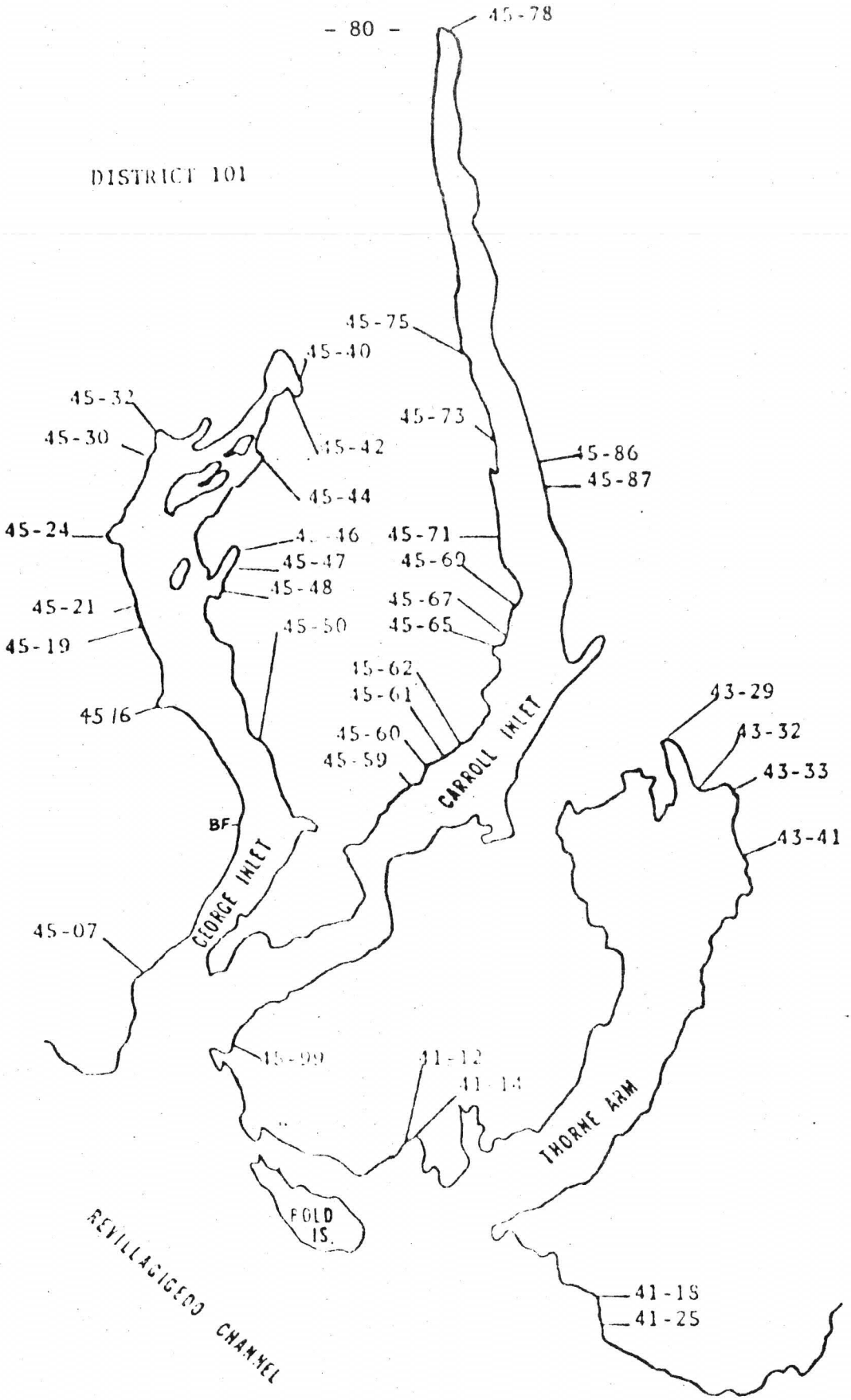
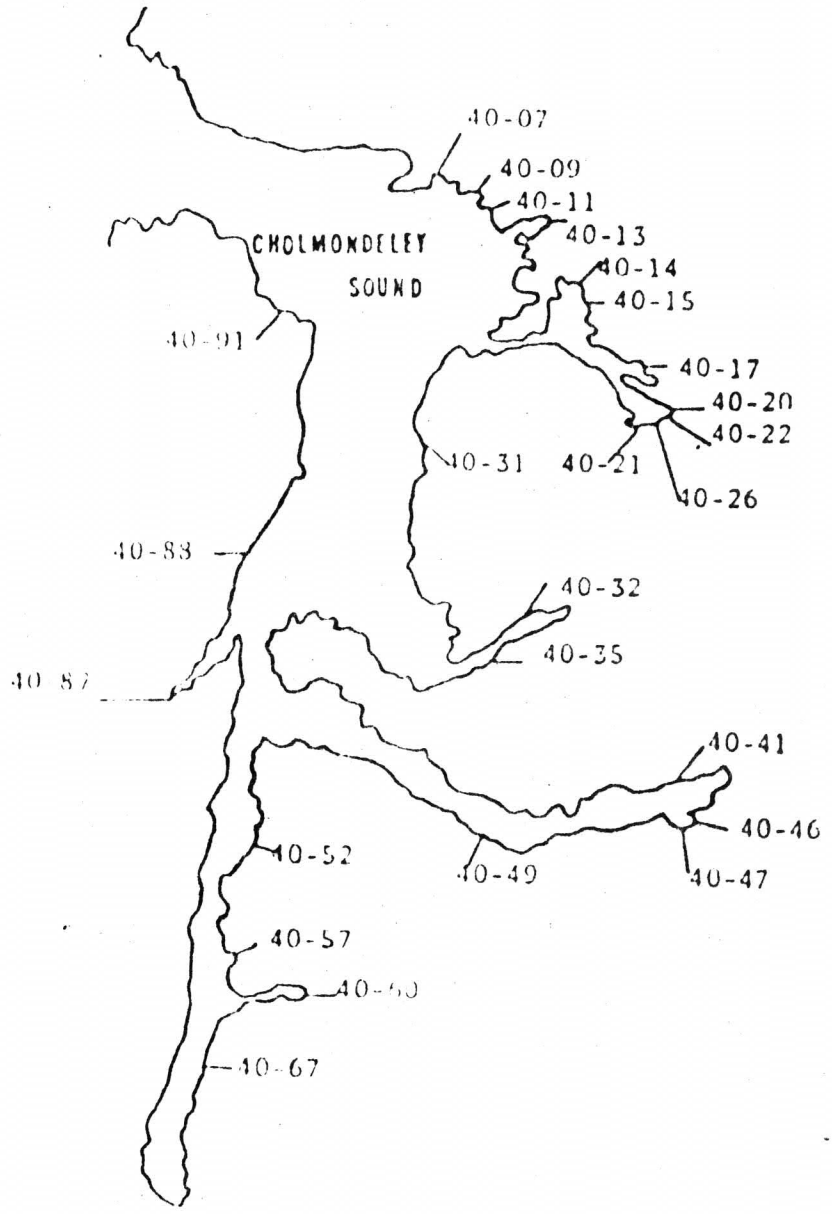


Figure 3. Map of streams surveyed in District 1 for marked chum salmon.



DISTRICT 102

Figure 4, Map of streams surveyed in District 2 for marked chum salmon.

MARINE SURVIVAL OF COHO SALMON SMOLTS RELEASED DIRECTLY FROM TRANSPORT VEHICLES INTO ESTUARIES

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INTRODUCTION

The Alaska Department of Fish and Game has released age 1 coho salmon smolts into creeks and estuaries for many years. These smolts are released either directly into the wild or into net pens for short term rearing prior to final release. The latter strategy allows the fish to recover from any transport stress and should enhance the homing of resultant adults. Direct smolt release into the wild may be a viable option at a particular release site.

In this paper, the marine survivals (and other interesting data) of coho smolts directly released at three locations in Southcentral Alaska in 1979 are presented. A history of coho smolt releases (1968-1979) and marine survivals is also presented for smolts released directly into Seward Lagoon, a small estuary at Seward, Alaska.

Data in this paper are not intended to prove that direct smolt releases are better than short term rearing prior to final release since these data are not based on comparisons of direct releases vs. short term reared smolt releases at the same time and place.

1979 COHO SMOLT

Incubation, Rearing, and Transport History

Green, fertilized coho salmon eggs were obtained from Bear Lake (near Seward) and Halibut Cove Lagoon (near Homer) stocks during fall 1977 (Figure 1). The Halibut Cove Lagoon stock was derived from Bear Lake

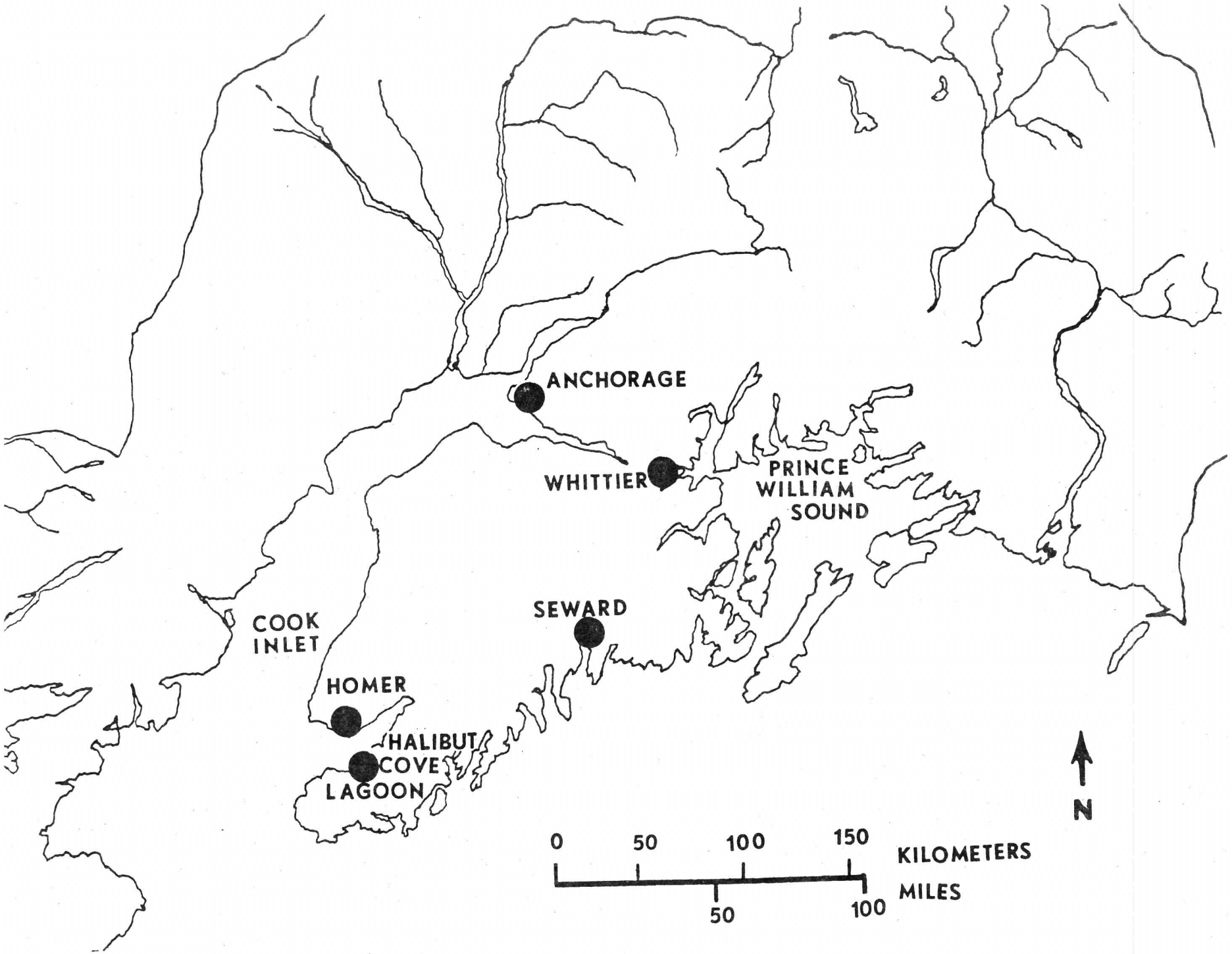

Figure 1. Coho Salmon Rearing and Smolt Release Sites in Southcentral Alaska.

coho smolts planted in 1976. The eggs and alevins were incubated in Heath trays at Fire Lake Hatchery (near Anchorage). After some rearing, fingerlings were transferred between May 22 and July 7, 1978 to the Elmendorf Facility, Ship Creek Hatchery Complex, at Anchorage for rearing to the smolt stage.

Average rearing temperatures during the final 1979 rearing period (January to May, June) ranged from 5.0° to 8.4°C (41° to 47°F).

All juvenile coho had a history of furunculosis. Two-10 day treatments with Sulmet controlled this disease. The bacteria causing furunculosis at Elmendorf is terramycin-resistant.

All smolts were transported in 1,893 liter (500 gal) Edo-Western fiberglass tanks on trucks. Spray bars or Fresh-flo units provided aeration. Each tank was filled with ≈1,324 liters (350 gal) of water. Prior to loading the smolts, Dow Corning antifoam AF emulsion [31g (1oz) of 10% dilution per 379 liters (100 gal) of water] and salt (3‰ salinity) were added to each tank. Fish were loaded via a Neilsen 15.2 cm (6 inch) diameter fish pump. Fish and tanks were inspected once each hour during transport.

Release Sites

Bear Lake stock coho smolts were released directly into Seward Lagoon and Whittier Creek, and the Halibut Cove Lagoon stock was released directly into a small unnamed creek which flows into Halibut Cove Lagoon (Figure 1). Transport distances (road) and times from Anchorage are:

Seward Lagoon - 209 km (130 miles); 3 hours

Whittier Creek - 80 km (50 miles); 4 hours

Halibut Cove Lagoon - 402 km (250 miles); 7 hours

The Seward Lagoon, Whittier Creek, and Halibut Cove Lagoon smolt release sites are all small estuaries. Seward Lagoon and Whittier Creek are primarily low salinity ($\leq$15%) estuaries, while Halibut Cove Lagoon is a high salinity ($\geq$25%) estuary.

Smolt Release

Numbers, sizes, and release dates of smolts at each of the three release sites are depicted in Table 1.

Marine Survival and Adult Size

Returns of jack (age 1.0) coho to each site were minimal (<10 per site). Marine survivals of the age 1.1 adults and their mean sizes are listed in Table 1.

The low survival of coho smolts at Halibut Cove Lagoon is not unusual and may be partially due to ineffective homing by the transplanted stock and the lack of smolt holding time in the small freshwater creek. The marine survival of smolts reared at the lagoon in the past has been as low as ≈0.1% (1978 adult return). Interestingly, coho smolts directly released (1979) into Fritz Creek, located ≈30 km (18.6 miles) north of Halibut Cove Lagoon, had a 1.3% marine survival; smolts were released

Table 1. Summary of Coho Salmon Smolts Directly Released from Transport Vehicles During Spring 1979 into Seward Lagoon, Whittier Creek, and Halibut Cove Lagoon.

Release site	Smolt data[a/]				Adult data[b/]					
	Release date	Number	Mean weight (fish/lb) g		Sample number	Fork Length mm	(inches)	Weight kg	(lb)	% Marine survival
Seward Lagoon	14,15 May	97,836	15.7	(29.0)	874	658	(25.9)	3.45	(7.60)	4.04
Whittier Creek	16,18,19 May	81,241	16.3	(27.9)	121	681	(26.8)	4.09	(9.00)	5.00
Halibut Cove	16 June	47,810	17.8	(25.5)	8	485	(19.1)	1.63	(3.58)	0.84

a/ A percentage of smolts released at each site was marked AD+CWT.
b/ Sexes were combined and only age 1.1 adults were measured.

3.2 km (2 miles) upstream of any saltwater influence. Also, coho smolts directly released (1979) into salt water at Homer Spit, located ≈23 km (14.3 miles) north of Halibut Cove Lagoon, survived at <0.01%!

The relatively high survival of coho smolts at Whittier indicated that the transplanted coho stock had an excellent homing response and/or perhaps predation on coho smolts was very low while coho prey were abundant. Interestingly, the marine survival of smolts short term reared at Whittier in 1978 was also relatively high at 5.7%.

The extremely small size of coho adults at Halibut Cove Lagoon in 1980 is unexplainable. In past years at this site, average adult sizes have ranged from 3.45 kg (7.6 lb) to 5.26 kg (11.6 lb)!

A comparison between sizes of the Whittier and Seward Lagoon 1980 adults shows that the former obtained adequate food! In fact, the largest 1980 sport caught coho at Whittier weighed 8.18 kg (18 lb).

Adult Straying of Transplants

Straying of returning coho adults was assessed only in the Halibut Cove Lagoon and Whittier areas. Adults generally moved from creek to creek at the respective areas of smolt release, so straying was "local" as far as we know.

SEWARD LAGOON DIRECT RELEASES OF
COHO SMOLTS DURING 1968 TO 1979

Smolt and adult data are listed in Table 2. All coho fingerlings were

Table 2. History of Coho Salmon Smolts Directly Released from Transport Vehicles into Seward Lagoon.

Brood Stock	Year	Smolt Data: Mark	Release date	Number	Mean Weight g	Mean Weight (fish/lb)	Adult Data: Sample number	Mean Size[a/] Fork Length mm	Fork Length (inches)	Weight kg	Weight (lb)	% Marine Survival "Jacks" Age 1.0	Age 1.1	Total
Oregon[b/]	1966	Ad	18,22 Apr. 1968	42,200	24.9	(18.2)	7	594	(23.4)	-	-	0.00	0.04	0.04
Oregon[c/]	1967	Ad	6,7 May 69	27,100	31.1	(14.6)	3	692	(27.2)	-	-	0.00	0.02	0.03
Bear Lake	1968	Ad	19,27 May 70	39,750	42.0	(10.8)	-	-	-	-	-	2.39	12.87	15.26
Bear Lake	1969	Ad	17 May 71	10,900	32.0	(14.2)	113	618	(24.3)	-	-	0.03	13.94	13.96
Kodiak	1970	Ad	31 May 72	66,500	27.0	(16.8)	199	719	(28.3)	-	-	1.38	4.46	5.83
Seward Lagoon	1971	AdLV	7,9 May 73	30,200	51.0	(8.9)	831	617	(24.3)	-	-	0.46	0.41	0.88
Kodiak	1972	AdRV	6,11 May 74	100,000	48.3	(9.4)	492	665	(26.2)	-	-	4.76	3.89	8.65
Seward Lagoon	1973	AdLV	15,19 May 75	100,700	49.9	(9.1)	237	692	(27.2)	-	-	2.59	1.96	4.55
Bear Lake	1974	LV	4,10 May 76	100,600	35.5	(12.8)	1,085	638	(25.1)	3.29	(7.2)	0.60	4.49	5.08
Bear Lake	1975	RV	6,13 May 77	100,450	44.1	(10.3)	687	661	(26.0)	3.57	(7.9)	1.61	7.68	9.29
Seward Lagoon	1976	Ad+CWT	1, 5 June 78	125,979	45.9	(9.9)	328	669	(26.3)	3.81	(8.4)	0.12	0.86	0.98
Bear Lake	1977	Ad+CWT	14,15 May 79	97,836	15.7	(29.0)	874	658	(25.9)	3.45	(7.6)	0.00	4.04	4.04

a/ Sexes were combined and only age 1.1 adults were measured. All samples were taken at Bear Creek weir, located 12.9 km (8 miles) upstream from the mouth of Salmon Creek. Seward Lagoon is only 2.8 km (1.8 miles) from the mouth of Salmon Creek. This table was based on data of McHenry (1980).

b/ Big Creek Salmon Hatchery.

c/ Eagle Creek Salmon Hatchery.

reared to the smolt stage at the Ship Creek Hatchery Complex, Anchorage. All smolts were trucked to and directly released into Seward Lagoon.

The poor returns of the Oregon coho transplants probably resulted from the long distance transplant and/or the early smolt release times (Table 2). The closer Kodiak stock transplants [distance ≈418 km (260 miles)] had much better survivals than the Oregon transplants.

The jack to adult ratios were generally higher when individual smolt size was larger.

OVERVIEW

The direct release of coho salmon smolts, particularly transplants, is considered experimental at this time, even though marine survivals appear promising. Short term rearing of smolts prior to final release is the safest policy for enhancing marine survival.

ACKNOWLEDGEMENTS

Nick Dudiak provided all the smolt and adult data from the Halibut Cove Lagoon, Homer Spit, and Fritz Creek sites. Stan Kubik provided these data for the Whittier site. Ted McHenry provided all the Seward Lagoon data.

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THE INITIAL PHASES OF AN OPERATING CENTRAL INCUBATION FACILITY IN SOUTHEAST ALASKA

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SUMMARY

Southern Southeast Regional Aquaculture Association (SSRAA) started construction of a hatchery facility during the summer of 1978. The facility was designed to accomodate and segregate different stocks of salmon. The hatchery has a capacity to incubate 28.5 million eggs and rear 24 million fry and smolts of various species and sizes. The objective of the hatchery program is to produce a large scale enhancement effort in specially designated areas while minimizing harvest pressures on the wild native stocks. To achieve this objective with a reasonable cost/benefit ratio, SSRAA's operational plan called for a central incubation facility (C.I.F.) located on the road system. This C.I.F. would support several remote release sites, which once returns are established, could become an independent hatchery and allow the C.I.F. to supply other remote release sites.

The C.I.F. operating plan calls for establishing brood stocks from two different races of chum salmon and one stock of coho salmon at two remote sites. The program goals include collecting 11 million summer chum eggs, 15.8 to 19.4 million fall chum eggs depending on the success of the summer chum egg take and 1.2 million coho eggs.

The summer chum donor site is in Carroll River on Revillagigedo Island,

approximately 40 kilometers from Whitman Lake Hatchery. The fall chum donor site is in Disappearance Creek and Lagoon Creek on Prince of Wales Island, approximately 61 kilometers from the Hatchery. The coho donor site is in Indian Creek on the mainland, approximately 104 kilometers from the Hatchery.

All the brood stock collection sites are remote and accessable only by plane, boat or helicopter. The capture of the chum salmon involves seining the fish up in the estuary and holding them in saltwater net pens to rippen. A weir is used in the lower portion of the river to enumerate the run size and capture adult fish. The coho are seined out of holes in the upper portions of the river and transported down the river to holding pens in the river near the camp. All the eggs and milt are kept separate and flown back to the Hatchery where fertilization takes place. The fertilized eggs are water hardened in a processing room and are disinfected with a wescodyne bath before entering the incubation room. The different stocks of salmon are kept separate through the use of different rows and stacks of heath trays.

The Hatchery maximizes its rearing space through the different timings of the chum stocks. The summer chum swim up and are ponded in raceways in December through January. They are reared in fresh water until March when the conditions are suitable at the remote site for operating a saltwater net pen facility. The summer chum are approaching 1 gram in size at this time.

The fall chum will swim up in late February through early April and be ponded in the space the summer chum were occupying. The yearling coho will be moved out to the remote site in early April allowing more room for the fall chum.

The salmon fry and smolts are transported to the remote sites through the use of fiberglass tanks mounted on a trailer, which is placed on a barge and towed to the rearing site. The chum salmon were loaded at a maximum of .5 pounds per U.S. gallon and the coho were loaded at a maximum of .75 pounds per U.S. gallon.

The transportation system consisted of micro-pore tubing laced in the bottom of the tanks and oxygen bubbled through the water column. The longest period of transportation was 16 hours with less than .5 percent mortality. The fry and smolts are acclimated through pumping salt water through the tank prior to being gravity fed into the saltwater net pens.

The remote release sites are designed to accomodate large releases, target returning hatchery fish through an existing commercial fishery and allow the surplus of hatchery fish to be harvested at the terminal area.

The fall chum and coho are being released in Neets Bay, located on Revillagigedo Island, approximately 64 kilometers from the Whitman Lake Hatchery. The summer chum are being released in Nakat Bay, located on the mainland, approximately 96 kilometers from the Hatchery.

In 1980, SSRAA transported, net pen reared for imprinting, and released 1,330,000 fall chum in Neets Bay, 278,000 coho in Neets Bay and 1,342,000 summer chum in Nakat Bay. The saltwater net pen rearing survivals for all three stocks was 99 percent (see Table 1.).

SSRAA's 1981 operational plans call for the transportation and net pen rearing for release of 14,355,000 fall chum, 530,000 coho and 3,280,000 summer chum.

TABLE 1. SUMMARY OF REMOTE REARING AND RELEASE, 1980

BROOD YEAR & SPECIES	NUMBER EGGS TAKEN	NUMBER * FISH PONDED	RELEASE SITE	AVERAGE DAYS REARED	AVERAGE WEIGHT RELEASE	DATE OF RELEASE	% SALTWATER REARING SURVIVAL	% SURVIVAL EGGTAKE TO RELEASE
1978 Coho	776,000	279,000	Neets Bay	39	24.5g	5/21/80	99.6	70.7
1979 Summer Chum	4,374,000	1,348,000	Nakat Bay	42	2.7g	5/7/80	99.5	30.7
1979 Fall Chum	1,519,000	1,332,000	Neets Bay	14	1.9g	6/14/80	99.8	87.5

*Number of fish ponded in saltwater net pens at remote sites

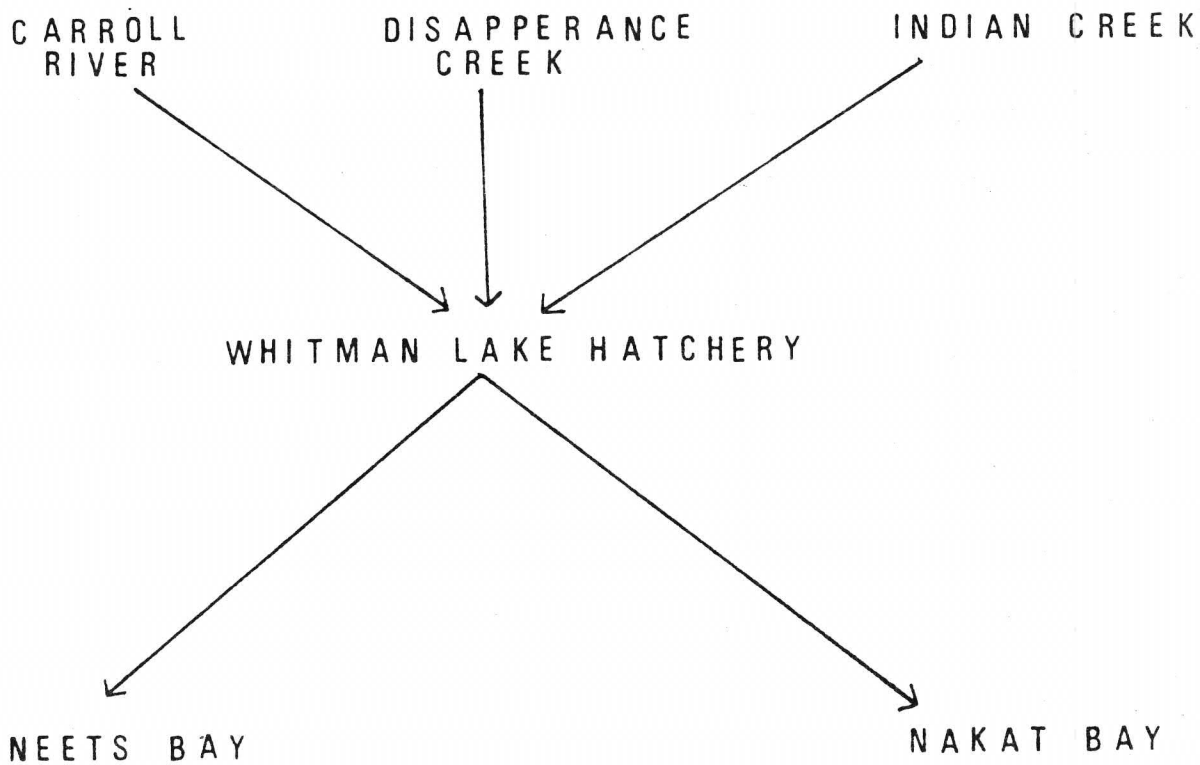
SSRAA

CENTRAL INCUBATION FACILITY

EGG TAKE

INCUBATION & REARING

IMPRINTING & RELEASE



OBSERVATIONS ON HOMING OF COHO SALMON FROM SHORT DISTANCE TRANSPLANTS

by

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Coho salmon of the 1972, 1974, and 1977 broods were cultured to age 1 smolt stage at Little Port Walter on Baronof Island, southeastern Alaska. Some broods were cultured partly in intermediate saline and estuarine water, others were cultured only in freshwater. Marked lots from each brood were held for varying lengths of time, ranging from 1-to 45-days, in net pens in a small bay, Toledo Harbor, 2 Km distant. A fishless stream, due to an impassable falls just at the head of tide, flows into Toledo Harbor. Marked control lots were released at Little Port Walter along with the treatment groups at Toledo Harbor from each brood on 31 May, a date approximating the peak of volitional coho salmon smolt emigration in the area.

Subsequent returns of adults were studied regarding where they schooled and milled in estuaries near streams and where they migrated into streams. Related observations were also made on other broods of adult coho salmon returning from fry plants made into nearby lakes that had no natural salmon runs. Coho salmon in all of these studies came either from the original Sashin Creek stock or the first generation progeny of that stock. Sashin Creek flows into Little Port Walter and has a natural anadromous run of coho salmon.

Some tentative conclusions of these observations are:

1. A definitive end-point of homing or straying can be difficult to quantify.

2. Imprinting of cultured coho salmon at Little Port Walter appears mostly fixed before 15 April.

3. Without suitable stream habitat homing is short-lived and straying quickly follows.

4. Partial imprinting to more than one stream (water source, location, situation) within a specific area or region may occur.

5. Larger numbers of precisely homing fish may "decoy" smaller numbers of weakly imprinted fish.

6. At Little Port Walter there is no apparent difference in the imprinting of coho salmon cultured in estuarine or freshwater environments.

EVALUATION OF FISH GROWTH AND NITROGENOUS WASTE HANDLING IN A RECIRCULATING SALMON REARING FACILITY WITH A CLINOPTILOLITE FILTER

by

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At the 1979 meeting of the Northwest Fish Cultural Conference, The Seattle Aquarium described a salmon rearing system featuring a physical-chemical water reuse system (Bruin et al., 1979). The system, consisting of a 9500 gallon raceway placed at the head of a fish ladder which empties into Elliot Bay on the central Seattle waterfront, was designed in the early 1970s by Kramer, Chin and Mayo. The physical-chemical reuse filter utilizes the natural zeolite clinoptilolite and at the time, was an experimental system for conserving water through water reuse. The water conservation through recirculation was necessitated because the only fresh water supply available to The Aquarium is a limited supply from the City of Seattle municipal supply.

Fresh water for the raceway rearing facility is obtained from the City water system, passed through a sand filter to remove particulates and subsequently dechlorinated by passing through activated carbon filters. Water reuse is accomplished by pumping approximately 120 gallons per minute from the lower end of the raceway, filtering it through pressure sand filter, passing up to one-half through the clinoptilolite filters for removal of ammonia (Figure 1, Table 1 and 2). The remainder of the recirculating water is reaerated by passing through a Venturi-type sparging unit as it re-enters the raceway. Makeup water is added continuously, with the excess being discharged at the end of the raceway. Flow rates can be measured at the sites shown by triangles. When the clinoptilolite filter is saturated with ammonia, it can be recharged by passing natural

seawater through in the reverse direction. The sodium ions in the sea water displace the bound ammonium ions. By sampling this recharging solution, the ammonia content can be measured quantitatively. This will be discussed in more detail later. The trials described in the 1979 paper marked the first tests designed to quantify the performance of the physical-chemical ammonia removal process. Those tests were continued and expanded during 1980 and it is the 1980 trials that will be reported on here.

The results obtained from the 1979 trials provided basic criteria describing the engineering performance of the system. The purpose of the first 1980 trial was to take the criteria developed in 1979 and to refine and substantiate them. To do that, we tested the predictive value of previously developed and commonly available biological and engineering criteria. Coho salmon were used for the first 1980 trial, chinook for the second.

In a normal hatchery design process, engineers would work from a desired production or poundage of fish, through first biological rearing and then engineering criteria, and would size the facility accordingly. In the predictive tests carried out at The Seattle Aquarium in 1980, because the facility already existed, it was necessary to work backwards through the criteria and reach a poundage which could be raised in the existing facility. Table 3 shows the predicted rearing schedule for the facility based upon established biological and engineering criteria.

As can be seen from Table 3, it was possible to predict the anticipated growth rates, mortality, total poundage standing inventory, pounds of food required, production of ammonia, and the time between recharges of the clinoptilolite filters. The starting point for the prediction was the

number and size of the coho salmon which were provided by the Washington Department of Fisheries.

Evaluations carried out after the first month of the trial revealed that the performance of the fish and the predicted program did not match. Several factors caused deviations from the predicted program. First, when the fish arrived they were not of the size listed at the start of the rearing program. Secondarily, the temperatures in 1980 did not follow the temperature reading of 1979. Due to the changes in fish size resulting both from the initial difference and from the change in growth rate caused by temperature deviations, the overall rearing program for 1980 only loosely fit the prediction.

Although the trial was to have gone on longer, due to an inability to keep dissolved oxygen levels above 4 mg/l, the trial was terminated on May 10. At that time, in order to evaluate the predictive program, it was recomputed using the actual temperature regime and actual fish weight at the beginning (Table 4). As the table shows, taking into account the fact that substantial ammonia-N is removed in the overflow, the predicted ammonia levels and recharge intervals varied from the actual observed values by 1 to 2 days out of a 10-12 day cycle, or by approximately 4-16%.

As already mentioned, 26,000 coho weighing 364 kg. were reared in the raceway from March 1 to May 6. This was almost three times the weight of any lots of fish reared previously. Table 5 shows the water parameters during this rearing period. The data are arbitrarily grouped into time periods corresponding to the times when the clinoptilolite filters were recharged. Even with this greater amount of fish, the clinoptilolite filters efficiently removed ammonia, keeping the raceway levels well below the established limits (.005 mg/l NH_3) for this waste substance. Toward

the end of the rearing period, it became difficult to maintain adequate dissolved oxygen in the water. During the last seven days it was necessary to aerate with compressed oxygen to keep the level above 3.0 mg/l.

To give a more quantitative assessment of ammonia handling during this rearing period, the ammonia that could be accounted for by analytical procedures was compared to the theoretical amount of ammonia produced by the fish. The two measurable quantities of ammonia were 1) that which is reovered in the recharge solution from the clinoptilolite filter and 2) that discharged in the overflow from the raceway. Typically, ammonia elution from the clinoptilolite followed the pattern shown in Figure 2. Since the flow rate of the recharge solution was known, integration of the area under the curve gave the amount of ammonia removed. These amounts for the six recharges are shown in Table 6. Similarly, the ammonia lost in the overflow was obtained by multiplying the flow rate times the average daily ammonia level. The two quantities, when added, gave the total amount of ammonia accounted for during each period. The theoretical amount of ammonia excreted by the fish was calculated from the amount of food eaten. For OMP II the conversion factor used was 0.0203 kg N/kg food. It can be seen from the ratios presented in the last column that the theoretical amount of ammonia produced is very close to that actually recovered.

Using the numbers given for the ammonia nitrogen recovered from the clinoptilolite filter, the capacity of the filter can be calculated as grams of ammonia nitrogen per kilogram of clinoptilolite (Table 7). This number was calculated from the average of six determinations and agrees well with the number obtained last year from a single determination. The capacity was also tested in a separate trial without fish using ammonium

chloride to saturate the filters. The chemical was added over a period of 36 hours. The average of two determinations is given and agrees with the capacity obtained with ammonia produced over a longer period of time by fish.

After the coho were released, a group of juvenile chinook were reared. The quantity and weight are given in Table 8. These fish were kept in the fresh water system for 45 days. A summary of water conditions is given in Table 9. The water temperature was higher than for the coho, and with the lower mass of fish, adequate dissolved oxygen levels were maintained with the sparging units.

Apparently at this warmer temperature, the growth of nitrifying bacteria became significant. Both ammonia and nitrite nitrogen were measured in the raceway and in the effluents from the sand filter and clinoptilolite filter. The raceway levels are shown in Figure 3. The ammonia level rose steadily as the clinoptilolite filters became saturated. Upon recharging the filter, the ammonia level dropped again with a subsequent gradual rise. By the fifth day of operation, a significant amount of nitrite could be detected in the raceway. By the twenty-sixth day, the nitrite level had reached 0.1 mg/l causing considerable concern. From the analyses of the filter effluents, it was apparent that the nitrite was being produced in the clinoptilolite filter, where presumably the nitrifying bacteria were growing on this substrate. Therefore, the flow through this filter was reduced by two-thirds, on the basis that a slightly higher ammonia level could be tolerated more readily than 0.1 mg/l nitrite nitrogen. This manuever did bring about a substantial decrease in the nitrite level. The gradual rise in nitrite at the end of the run can be attributed to bacterial activity in the sand filter.

These events are shown more clearly in Figure 4. The effluent from the clinoptilolite filter contained more nitrite than the influent for thirty days. Even after the flow rate was reduced, the filter was producing nitrite until the thirty-fifth day, when apparently the nitrite oxidizers became sufficiently active to remove this material. A similar curve for the sand filter is shown in Figure 5. As already mentioned, the nitrite produced in this filter brought a slight increase in the raceway level at the end of the rearing period. A nitrate analysis on the thirty-seventh day, shown in Table 10, confirms that much nitrate was being produced by bacteria in the clinoptilolite filer.

While in this case nitrite production by biological action in the system was not harmful, it is also not particularly desirable. In future designs for recirculating facilities using clinoptilolite, it may be necessary to allow for periodic sterilizing of the filter media. Finally, it appears that the next step in adaptation of clinoptilolite for physical-chemical water reuse might be the development of a large scale production unit based on the biological and engineering criteria obtained over the past two years. Such a system would permit further definition of criteria and more importantly, would allow the solution of the many operational problems which always occur with a new system.

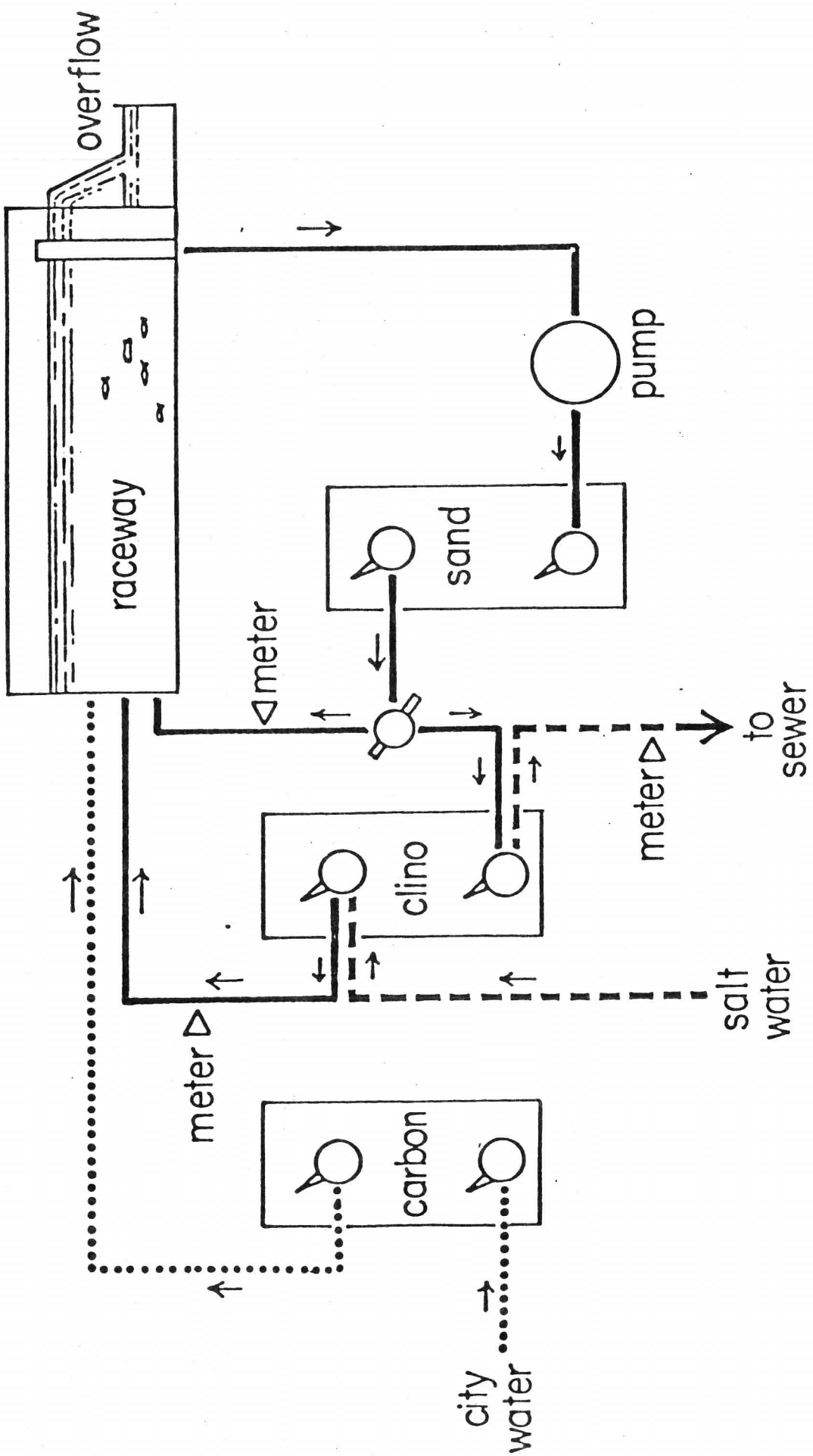

Fig. 1. Schematic drawing of raceway and water reuse system.

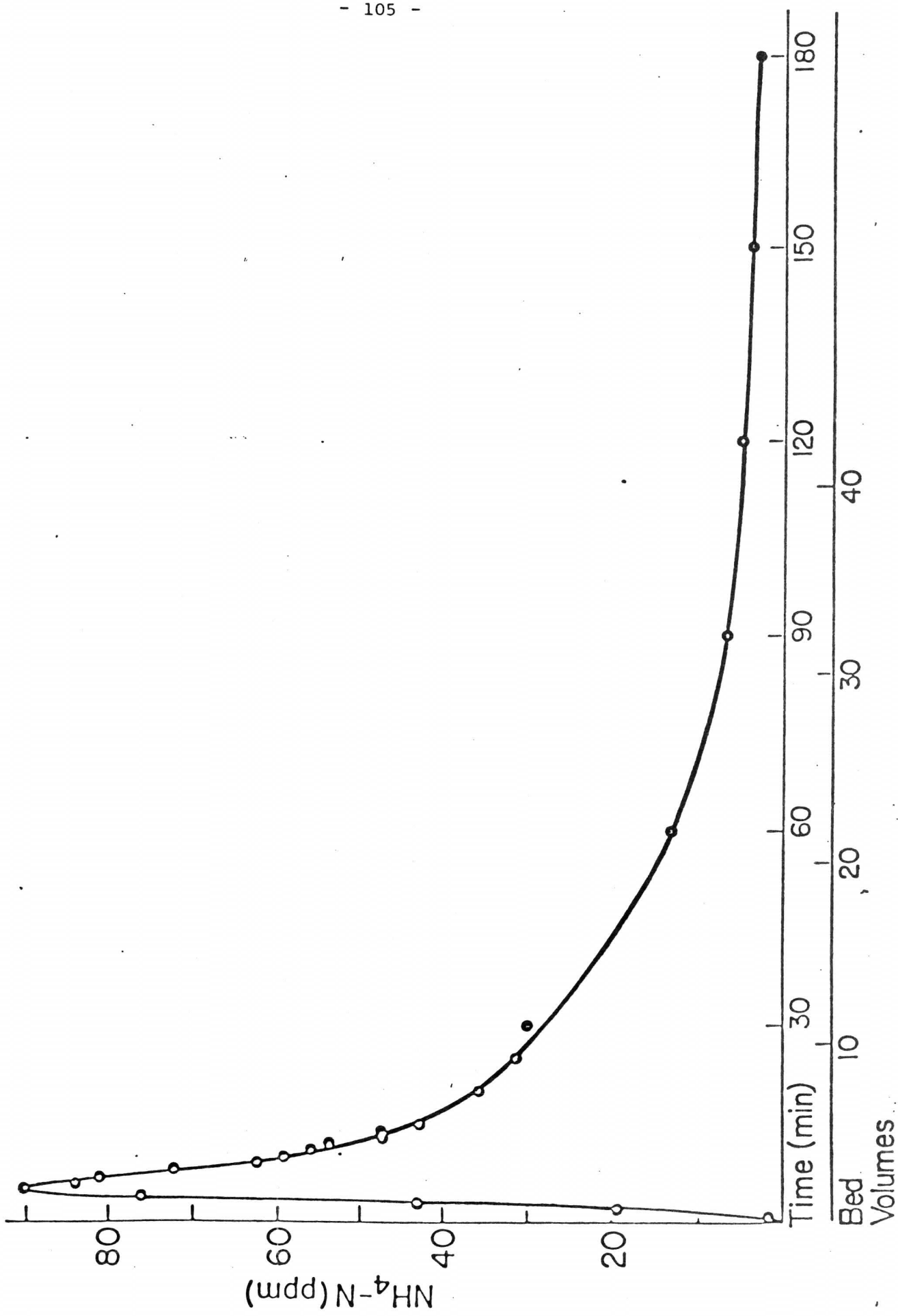

Fig. 2. Ammonia recovered in salt water recharge solution.

Fig. 3 Ammonia and Nitrite Levels in Raceway

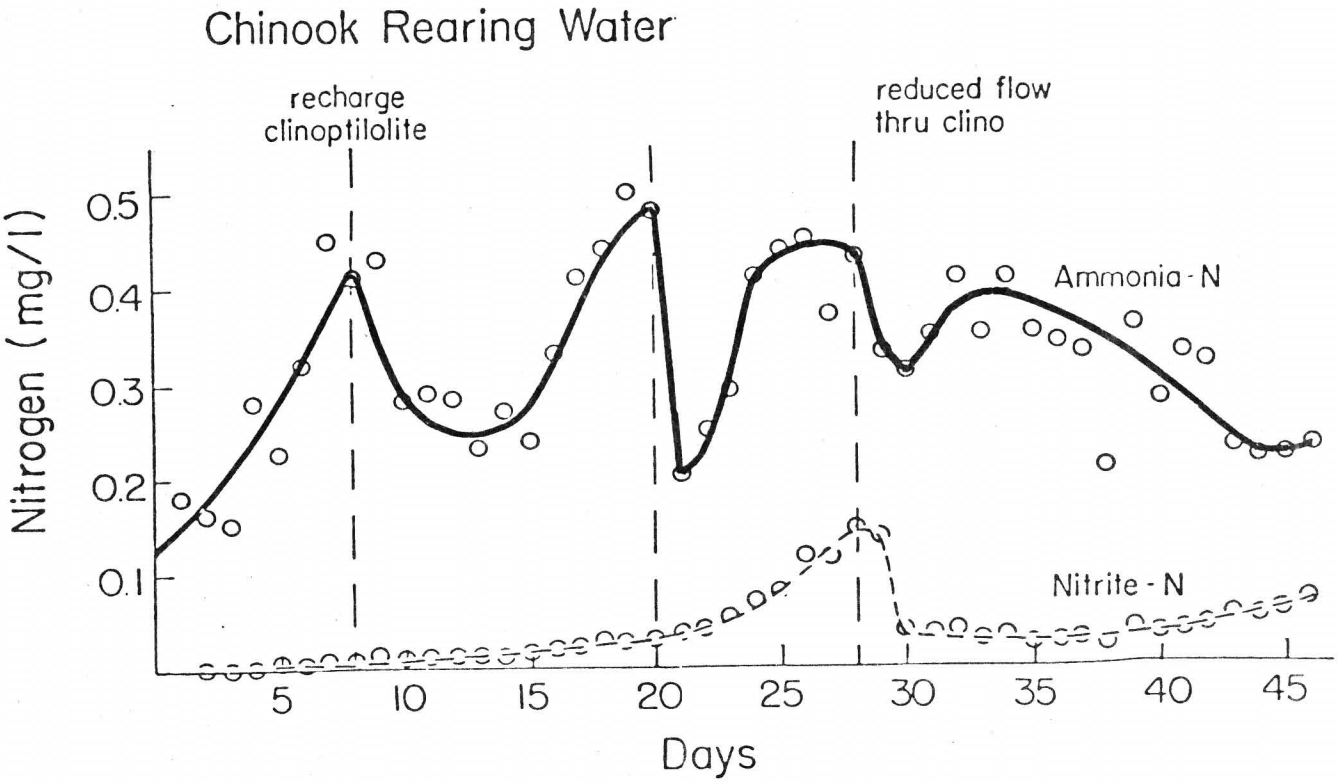

Fig. 4 Nitrite Production and Removal in the Clinoptilolite Filter

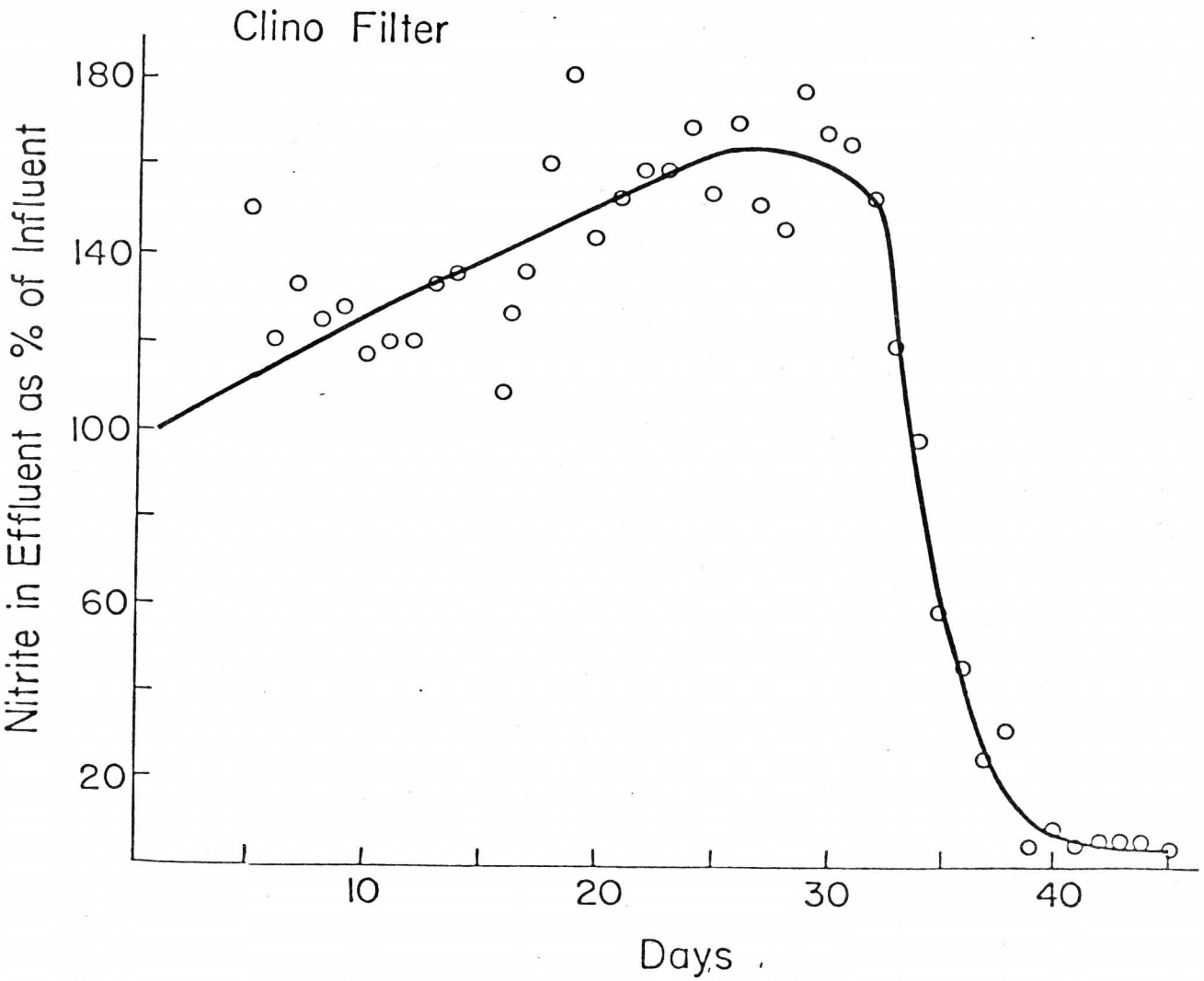

Fig. 5 Nitrite Production in the Sand Filter

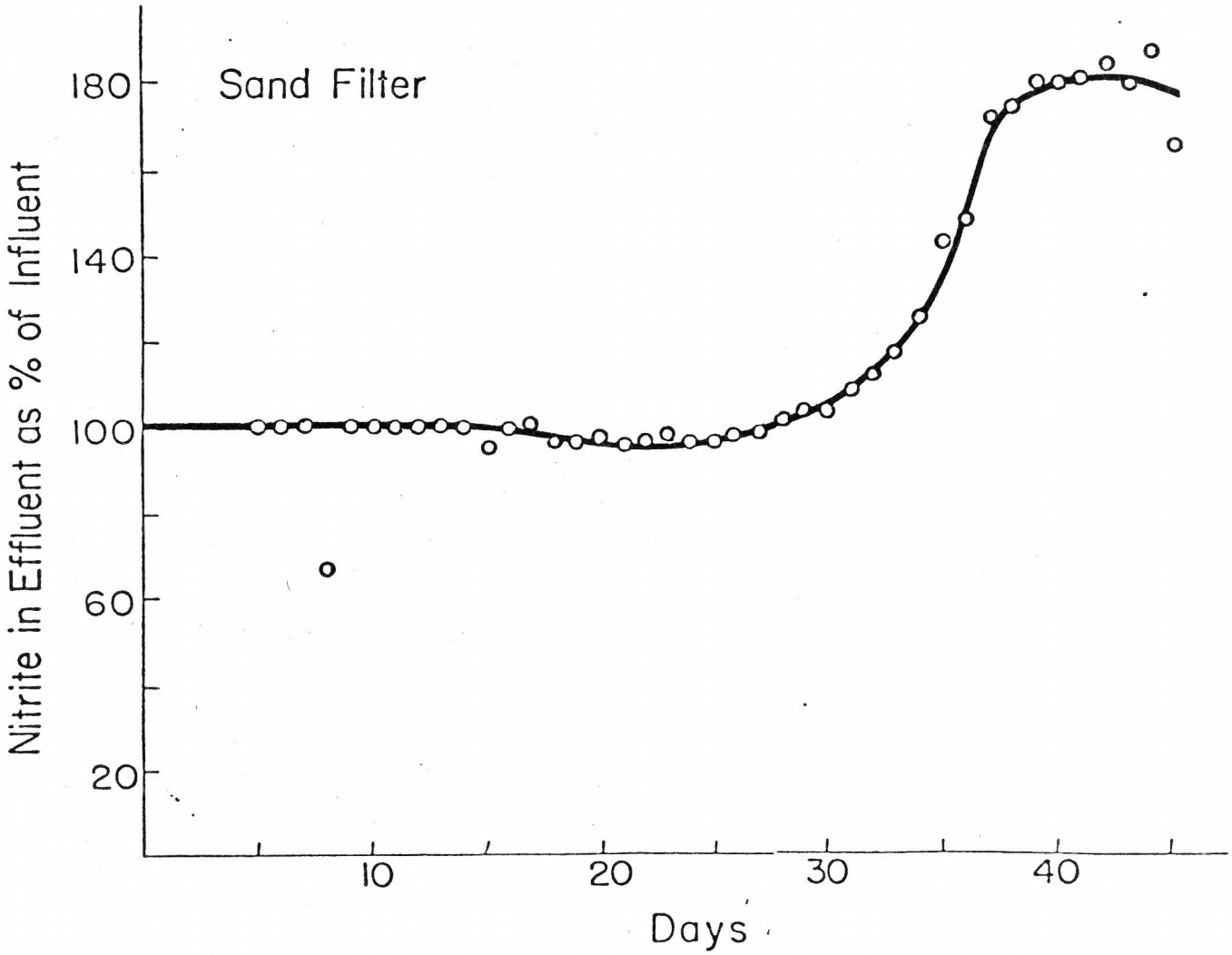

TABLE 1 FLOW RATES IN RACEWAY WATER SYSTEM

RACEWAY CAPACITY:	9500 gal. (35,950 l.)
OVERFLOW RATE:	13 gpm - 12 hr. turnover (49.21 l./min.)
TOTAL RECIRCULATING FLOW RATE:	120 gpm - 1 hr. turnover (454 l./min.)
CLINOPTILOLITE FILTER FLOW RATE:	50 gpm - 3 hr. turnover (189.25 l./min.)

TABLE 2 CLINOPTILOLITE FILTER CHARACTERISTICS (two in parallel)

SURFACE AREA:	9.8 sq. ft.
BED DEPTH:	42 in.
BED VOLUME:	34.3 cu. ft., 256 gal. (969 l.)
CLINOPTILOLITE WEIGHT:	848 kg.

TABLE 3

PREDICTED SALMON REARING PROGRAM
COHO SALMON, 1980

DATE	H_2O TEMP	TU =	IN. GAINED/ MONTH	FISH SIZE (IN)	FISH WGT. LB/G #/LB	FISH # (MONTHLY MORT)	TOT. WGT.	DIET %/DAY	x 1.5	TOT. FOOD DAY - LBS	NH_4N DAY-IN LBS.	TIMES BETWEEN RECHARGE
3/1	8.0°C 46.5°F	10.5	0.58	4.51	.027/12.3 37/LB	25,990 (1040)	701.7 LB 318.9 KG	1.1	1.65	11.6 LB 5.3 KG	.235	178 HR 7.4 DAY
4/1	11.0 51.8	14.1	0.78	5.09	.040/18.1 25/LB	24,950 (998)	998.0 453.6	1.0	1.50	14.9 6.8	.304	137 5.7
5/1	12.0 53.6	15.9	0.88	5.87	.060/27.2 17/LB	23,952 (958)	1437.1 653.2	1.3	1.95	28.0 12.7	.568	73 3.1
6/1	13.0 55.4	16.8	0.93	6.75	.091/41.3 11/LB	22,994 (920)	2092.5 951.1	1.4	2.10	43.9 19.9	.891	47 1.96
7/1	13.0 55.4			7.68	.134/60.8 7.5/LB	22,075	2958.1 1344.6	1.4	2.10	62.1 28.2	1.26	18 1.4

[1] Temperature based on 1979 profile

[2] TU = Temperature units = $1^{0}F$ above 38.6^{0} for one month

[3] Growth rate - 20 TU/inch assumed

[4] Length = 13.5104 Weight $^{.33}$

[5] 4% mortality/month assumed

[6] Diet from Moore-Clark Co., La Conner, WA

TABLE 4

REVISED PREDICTED SALMON REARING PROGRAM
COHO SALMON, 1980

DATE	H_2O TEMP	TU =	IN. GAINED/ MONTH	FISH SIZE (IN)	FISH WGT.	FISH # (MONTHLY MORT)	TOT. WGT.	DIET %/DAY	x 1.5	TOT. FOOD DAY - LBS	NH_4N DAY-IN LBS	TIMES BETWEEN RECHARGE
3/1	7.5°C 45.5°F	8.3	.4	4.3	.0309 LB	25,990	803.1 LBS	1.1	1.65	13.3 LB 6.0 KG	.270- 169.8	132-5.5-7.5
4/1	9.0 48.2	12.9	.6	4.7 (4.6)	.0421 (.0395)	25,250	1063.0	1.2	1.80	19.1	176.0	127-5.3-7.1
5/1	12.6 54.7	6.0	.3	5.3 (5.1)	.0604 (.0538)	24,510	1480.4	1.3	1.95	28.9	266.3	84-3.5-4.5
5/10	13.7 56.7			5.6 (5.2)	.0712 (.0570)	24,320	1731.6	1.4	2.10	36.4	335.2	67-2.8

[1] Temperature = 1980 Actual Temperatures

[2] TU = Temperature units = 1°F above 38.6°F for one month

[3] Growth rate - 20 TU/inch assumed

[4] Length = 13.5104 Weight $^{.33}$

[5] Actual 1980 Mortalities

[6] Diet from Moore-Clark Co., La Conner, WA

[7] Times between recharge - Hours/days based on filter adjustment for ammonia lost in overflow

TABLE 5 WATER QUALITY FOR COHO (3/1/80 - 5/6/80)

Time Period	Days	Temperature, ^{o}C	pH	NH_4-N (mg/l)	DO (mg/l)
I	14	7.8 ± 0.2	6.7 ± 0.1	0.22 ± 0.09	8.2 ± 0.5
II	10	7.8 ± 0.2	6.7 ± 0.2	0.30 ± 0.07	7.6 ± 0.6
III	10	8.5 ± 0.4	6.5 ± 0.1	0.31 ± 0.07	6.4 ± 1.0
IV	13	10.0 ± 0.7	6.5 ± 0.1	0.35 ± 0.09	6.1 ± 0.9
V	9	11.3 ± 0.3	6.5 ± 0.2	0.39 ± 0.10	5.0 ± 0.4
VI	11	13.1 ± 0.7	6.6 ± 0.2	0.48 ± 0.14	4.7 ± 1.2

TABLE 6 AMMONIA PRODUCTION AND RECOVERY

Time Period	NH_4-N Recovered (g)	NH_4-N Discharged (g)	Sum	Theoretical NH_4-N Produced	Ratio Actual/Theoretic
I	784	420	1204	1176	1.02
II	792	409	1201	1225	0.98
III	962	422	1384	1299	1.06
IV	1030	620	1650	1688	0.98
V	827	478	1305	1304	1.00
VI	926	719	1645	1769	0.93

TABLE 7 CLINOPTILOLITE CAPACITY

	NH_4-N (g)	g NH_4-N/kg clino
Biological (6)	890	1.0
Chemical (2)	840	1.0

TABLE 8 CHINOOK BIOMASS

	Number	Individual Weight (g)	Total Weight (kg)
On Arrival	40,000	2.4	100
At Conversion	35,000	8.2	290

TABLE 9 CHINOOK WATER QUALITY

	Temperature, ^{o}C	pH	DO mg/l
Initial	14.6 ± 0.2	6.9 ± 0.2	8.1 ± 0.4
Final	15.3 ± 0.3	6.7 ± 0.2	6.5 ± 0.4

TABLE 10 NITRATE ANALYSIS ON DAY 37

	NO_3-N (mg/l)
Sand Filter Inf.	1.28
Clino Inf.	1.30
Clino Eff.	2.01
Make-Up Water	0.09

AERATION OF HATCHERY WATER SUPPLIES

by

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Introduction:

Many B. C. hatcheries rely on groundwater for their water supply. Although groundwater offers many advantages, it tends to be low in oxygen and high in nitrogen. For example, a typical well at the new Nitinat hatchery on the West Coast of Vancouver Island has an oxygen level of 47% and a nitrogen level of 113%. Aeration facilities are necessary to bring these gases to near equilibrium.

It should be cautioned that some surface waters can also be high in nitrogen at certain times of the year. For example, over the spring of 1980 nitrogen levels at the Puntledge and Robertson Creek hatcheries reached 113% and 110% respectively. Obviously, some surface water supplies also require aeration.

For efficient hatchery operation, it is recommended that aerators should be designed to achieve an oxygen level of not less than 95% and a nitrogen level of not more than 103% of saturation. In light of these objectives the Department of Fisheries and Oceans has been engaged in programs to both measure the performance of existing aerators and to design new aeration facilities.

Rather than attempt to outline all the aeration devices tested, this presentation focuses on our general approach to the problem of assessing and designing aerators.

Theory

Consider a water droplet at $10^{o}C$ with an oxygen concentration of "C" mg/l. The equilibrium oxygen concentration (or saturation value, C_s) for water at $10^{o}C$ is about 11 mg/l. The rate of oxygen uptake is directly proportional to the deficit "C_s - C" (or distance from equilibrium). Mathematically, this can be expressed by the differential equation

$$\frac{dc}{dt} = k(C_s - C) \quad . \tag{1}$$

"k" is just the proportionality constant; it is usually termed the aeration co-efficient. "k" depends on temperature, the interfacial transfer area per unit volume of solution and the particular gas under consideration.

The aeration co-efficient increases if the temperature or the interfacial transfer area per unit volume increases. Also, "k" is greater for oxygen than for nitrogen. It should be remembered that the aeration co-efficient is an indicator of aerator effectiveness.

Equation (1) very concisely summarizes our experience about how aeration works; however, it is not very useful. The mathematical solution of equation (1) is much more important to aeration design and assessment. The solution is given by

$$C = C_s - (C_s - C_o)e^{-kt} \tag{2}$$

where: C_s = saturation concentration (mg/l)
C_o = initial concentration (mg/l)
t = time (seconds)
k = aeration co-efficient
e = 2.718...
C = concentration after time "t".

Equation (2) predicts the oxygen concentration "C" after a "t"

second exposure to air for a system characterized by an aeration co-efficient "k".

It is well known that "C_s" depends on temperature and on the partial pressure of oxygen in the gas phase. The 11 mg/l stated in the previous example referred to atmospheric conditions where the partial pressure of oxygen is about 0.2 atmospheres. In pressurized-type aeration systems "C_s" is altered and equation (2) is not necessarily correct. This is the case for aspirator systems or for unventilated aeration towers. In this presentation ventilated aeration towers will be assumed.

Application

For convenience, equation (2) can be expressed in terms of percent saturation "x" instead of concentration units:

$$x = 100 - (100-x_o)e^{-kt} \qquad (3)$$

where: x_o = initial % oxygen
x = final % oxygen
k = aeration co-efficient
t = time.

At first glance the theory expressed by equation (3) seems difficult to apply to the assessment to existing aerators. However, note that for a particular aeration device operated at a particular flow, the time for air/water contact and the aeration co-efficient "k" are constant. This allows us to use equation (3) to predict the performance of a particular aeration system given any initial combination of dissolved oxygen and nitrogen levels.

For example, if a hypothetical tower increased oxygen from an initial level of x_o = 20% to a final level of x = 70%, then the constant "kt" can be found by substituting these values into

equation (3), kt = 0.98. If we installed the identical aeration system on a water supply with an initial oxygen level of 70%, the system would have enough aeration capacity to increase the oxygen in the water supply to:

$$x = 100 - (100-70)e^{-0.98}$$

or $$x = 88.7\%.$$

We can use data collected on one water supply to predict the effects of the aerator on a different water supply.

This simple model can also be used in the design of aeration towers. In this presentation we will examine two cases: the first is a tower with horizontal screens and the second is a segmented packed column (Figure 1).

Case 1: Consider a column with "n" horizontal screens of expanded aluminium. The screens are spaced 8 inches apart. Water is introduced onto the top screen: droplets fall from screen to screen. The total travel time is directly proportional to the number of screens "n". Therefore, we can replace time "t" in equation (3) with the number of screens "n" to get:

$$x = 100 - (100-x_o)e^{-kn} \quad . \tag{4}$$

This simple model describes the performance of a real tower fairly well. Figure 2 shows plots of percent oxygen and percent nitrogen against the number of aluminium screens spaced 8 inches apart (the screening was 3/16 inch by 20-gauge expanded aluminium). The theoretical curve agrees fairly well with measured values. This trial was carried out at 18 USGMP/ft^2. We can predict with some

confidence that 14 screens are required to increase oxygen from 62% to 95%. In this case, oxygen is the parameter that dictates tower design: if we achieve oxygen levels of 95%, we automatically drop nitrogen levels to below 103% (see Figure 2).

Case 2: The second tower considered in this presentation is what we have referred to as a segmented packed column. This tower design evolved out of discussions with Dave Owsley of Dworshak National Fish Hatchery. A diagram of the 12-inch diameter segmented packed column is shown in Figure 1.

This is similar to a screen-type tower except that the discrete screens have been replaced with 12-inch diameter P.V.C. cylinders packed with 1.5-inch diameter flexi-rings. Four-inch air spaces between each 1-foot segment were designed to keep the column ventilated.

The travel time of water films or droplets was simply proportional to the number of segments "s". So theoretically:

$$x = 100 - (100-x_o)e^{-ks} \quad . \tag{5}$$

Figure 3 shows plots of predicted performance (equation (5) versus measured performance. Agreement between theory and practice was encouraging both for oxygen and nitrogen.

The packed columns have given us some promising results. This system has a very high flow capacity (the results shown in Figure 3 were generated at 226 USGPM/ft^2). Packed columns also have a low head requirement. This is important in lowering pumping costs. Also, performance is predictable so a tower can be custom designed to meet the needs of an individual water supply.

However, further work is required. In the near future we hope to investigate:

- the performance of the column over a wide range of flow rates

- the effects of different sized packing

- the effects of reductions in ventilation.

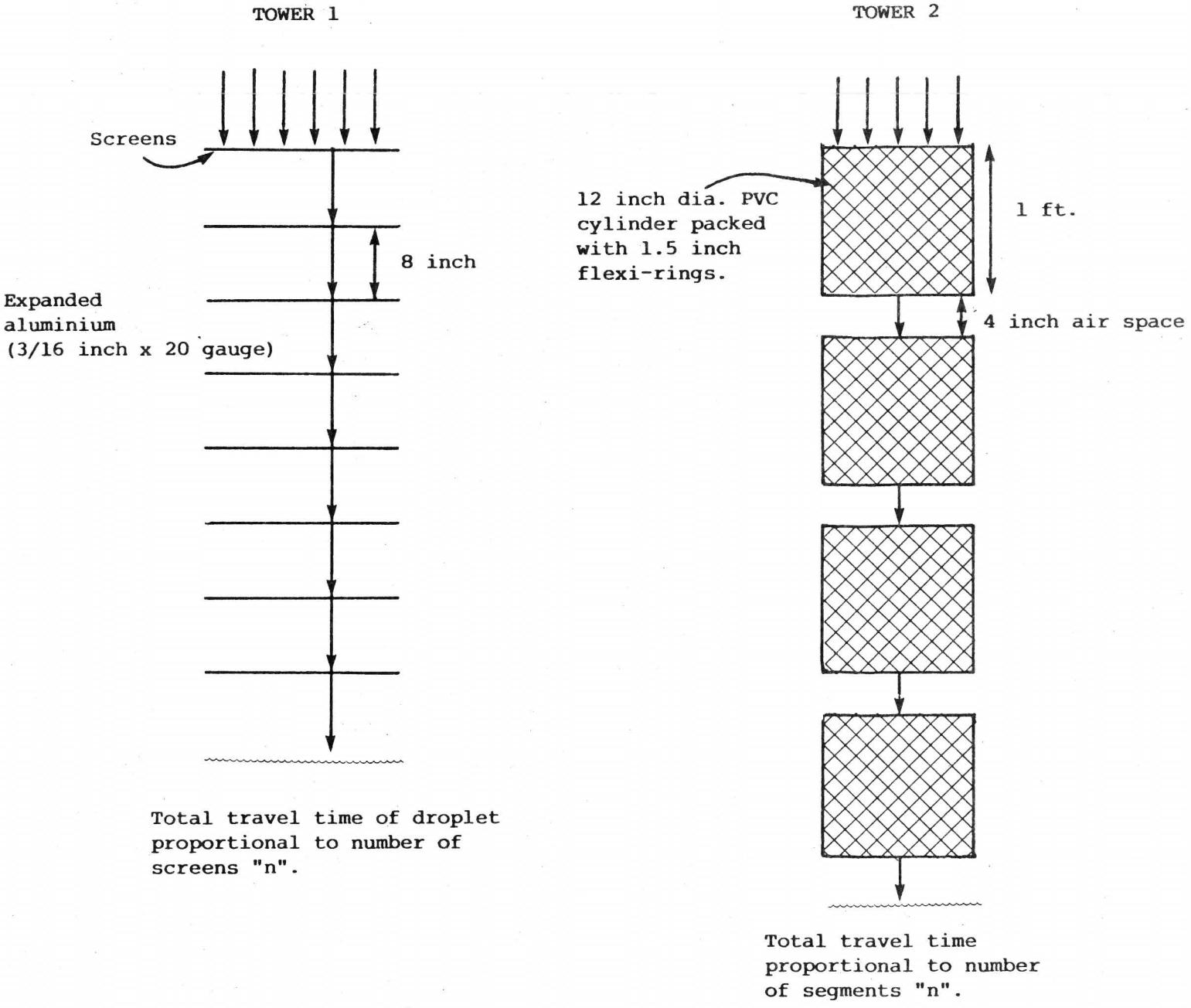

FIGURE 1. Schematic representation of two different towers tested during the aeration study.

Tower 1 used expanded aluminium (3/16 inch by 20 gauge) screening, while case 2 utilized 1 foot segments packed with 1.5 inch flexi-rings.

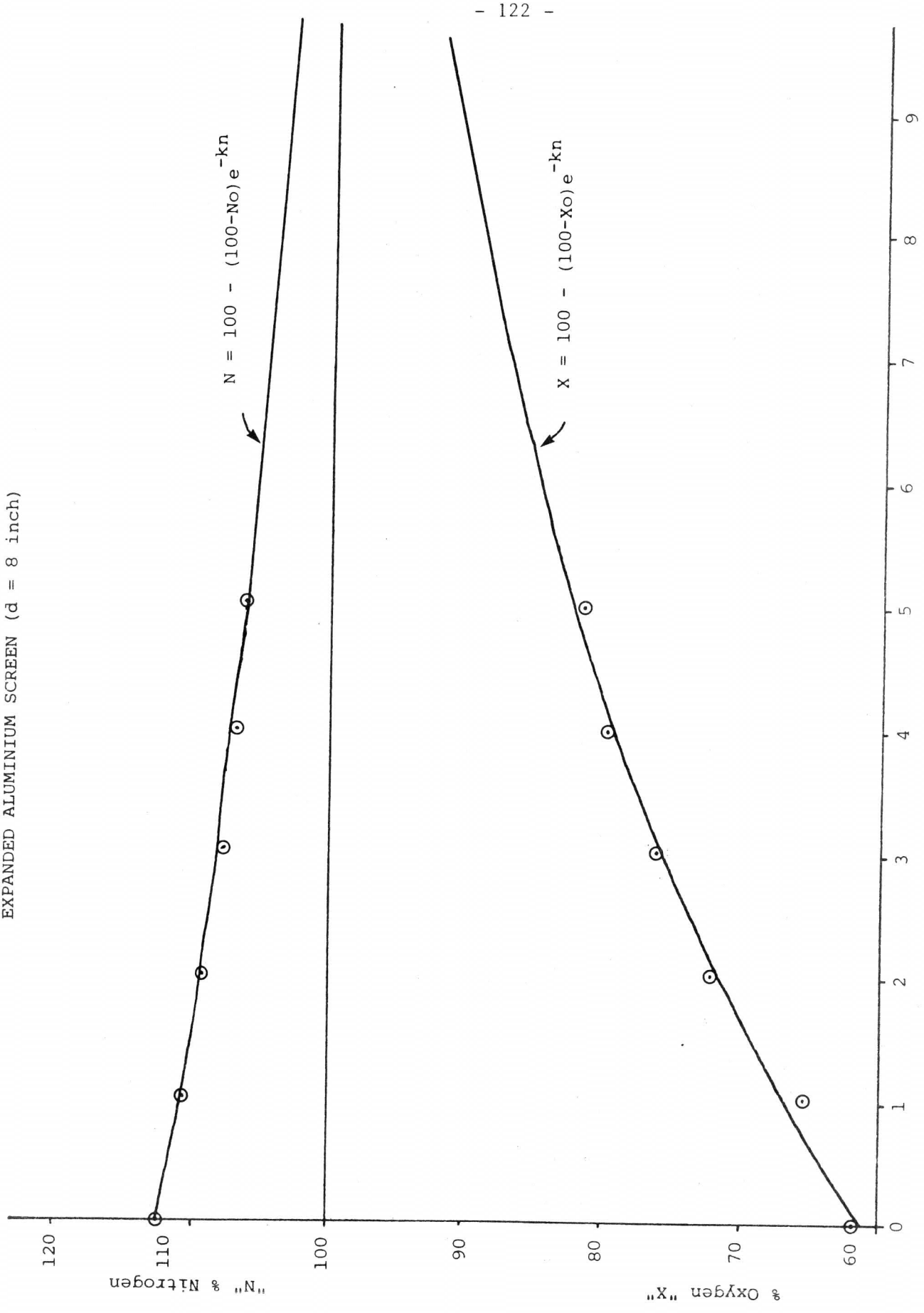

FIGURE 2. Percent oxygen "X" and percent nitrogen "N" as a function of the number of expanded aluminium screens "n". Solid lines are relationships predicted by theory, while circled points represent measured values.

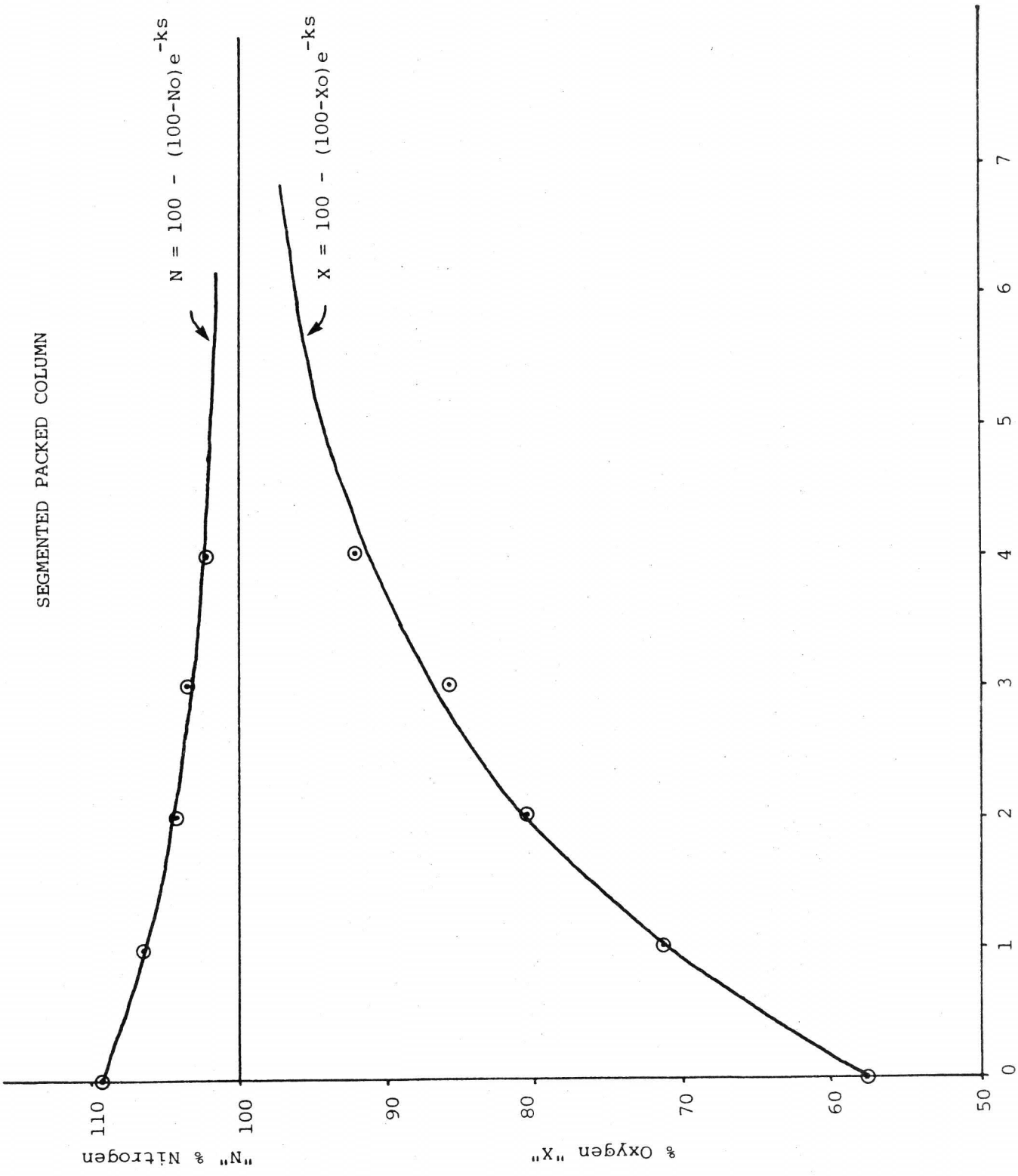

FIGURE 3. Percent oxygen "X" and percent nitrogen "N" as a function of the number segments packed with 1.5 inch flexi-rings "s". Solid lines are relationships predicted by theory, while circled points represent measured values.

EFFECTS OF SIZE AND TIME OF JUVENILE RELEASE ON ADULT COHO RETURNS

by

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Nanaimo, British Columbia V9R 5K6

Coho salmon yearlings were raised in six ponds at Rosewall Creek, Vancouver Island, British Columbia, from which releases were made at four times (14 April, 12 May, 10 June, 8 July 1975) (Bilton 1978, 1980). Prior to each release a portion of the juveniles in each pond were graded into three size groups (small, medium, large) on the basis of size distributions in each pond (Fig. 1). These were nose-tagged according to size group, pond and release date, and marked by adipose fin removal. Fifty-seven groups were released in all. Returns of adults and precocious males (jacks) to the weir and to the fishery (commercial, sport) were analyzed. Total adult returns (catch plus escapement) from each of the four releases were 7% April, 16% May, 37% June, and 15% July. For April release fish there was an inverse relationship between smolt size and percent adult return; for May release fish a slightly negative relationship; for June release fish a curvilinear relationship, with highest returns from smolts weighing 19-24 g; and for July release fish also a curvilinear relationship with highest

returns from smolts weighing 25-27 g (Fig. 2). Larger smolts produced more jacks, while at the same time later releases of fish of a given size produced fewer jacks.

A more sophisticated analysis of the data was completed in which the data was subjected to response surface analysis (Bilton et al. 1980; Bilton et al. MS). Based on maximum likelihood estimates of the coefficients and parameters of the second-order nonlinear polynomial used as a model, response surface analysis of the data for all 57 releases generates the surfaces shown in Figs. 3, 4. These surfaces show regression contours for predicted returns of adults (Fig. 3) and jacks (Fig. 4) in relation to time of release and mean juvenile weight at release.

For adult returns (Fig. 3), the predicted maximum at the centre of the surface (Ys) is 43.5%, corresponding to release on day 173.2 (22 June 1975) at a mean juvenile weight of 25.1 g. For the adults the standard deviation of Y over the surface is ± 2.98%. Hence the contours are known with a precision of about ± 6% ($\underline{P}$ = 0.05). The surface also shows an interaction between time of release and juvenile size with respect to adult returns. That is, maximum returns occur with early release of smaller juveniles and later release of larger juveniles. This can be illustrated as follows (Fig. 3). A curve drawn to connect the points at which tangents to the surface contours are parallel to the axis of mean weight ($\partial Y/\partial x_2=0$)

provides estimates of release weights for which percent return of adults is maximized at given release times. For the four Julian days of Table 1 (days 104, 132, 161, 189) these weights are, respectively, 16-17, 18-19, 22-23 and 27-28 g. The surface also indicates that returns from releases made after approximately day 180 (29 June 1975) can be expected to drop sharply whatever the mean size at release may be.

For returns of jacks (Fig. 4) the predicted maximum at the centre of the surface is remote from the factor space examined. The standard deviation of Y (percent return of jacks) over the surface is ± 0.59%. Hence the contours of the surface are known with a precision of about 1.2% ($\underline{P}$ = 0.05). For both surfaces (Fig. 3, 4) the estimates of precision refer, of course, to the factor space (time of release, weight at release) encompassing the 57 data points involved. Most significant in Fig. 4 is the indication that greater returns of jacks may be expected from early releases of larger juveniles, an outcome that most salmonid culturists would wish to avoid.

Figure 5 represents an overlay of three responses evaluated from the data. A central contour of the surface for percent return of adults (40%) (Fig. 3) is shown (upper right in figure). Several contours are also shown from Fig. 4 for percent return of jacks (0.01, 0.5, 5%). Also indicated are several central contours of the benefit-cost surface for adult returns (lower right in figure; contours 14, 16; Bilton et al. MS). Also shown is the path of joint optimality running from the centre of the surface

for adult returns toward the centre of the surface for benefit-costs of adult returns. The centre of the latter surface is outside the release time-release weight factor space considered, and benefit-cost estimates at low release weights (e.g. less that 6 g) presumably have doubtful value. Nevertheless, the path of joint optimality shows that maximum percent return of adults is achieved at less than maximum benefit-cost. Conversely, maximum or near-maximum benefit-costs are achieved at less than maximum return of adults. In general, as one moves upward on the path of joint optimality, adult and jack returns increase and benefit-cost ratios diminish. Comparison of British Columbia production hatchery adult returns with the Rosewall Creek model (Fig. 6) indicates that despite site specific and annual variability, the fit of the surface for adult returns to the hatchery returns appears to be quite reasonable.

In conclusion these data indicate the potential of doubling the present average return of 25% from B. C. production hatcheries by releasing coho juveniles at the optimum size and time. Because the model is based only on one series of releases from one site in one year further experiments are currently being carried out to estimate both annual and site variability.

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FIGURE CAPTIONS

Fig. 1. Experimental design. (From Bilton 1978).

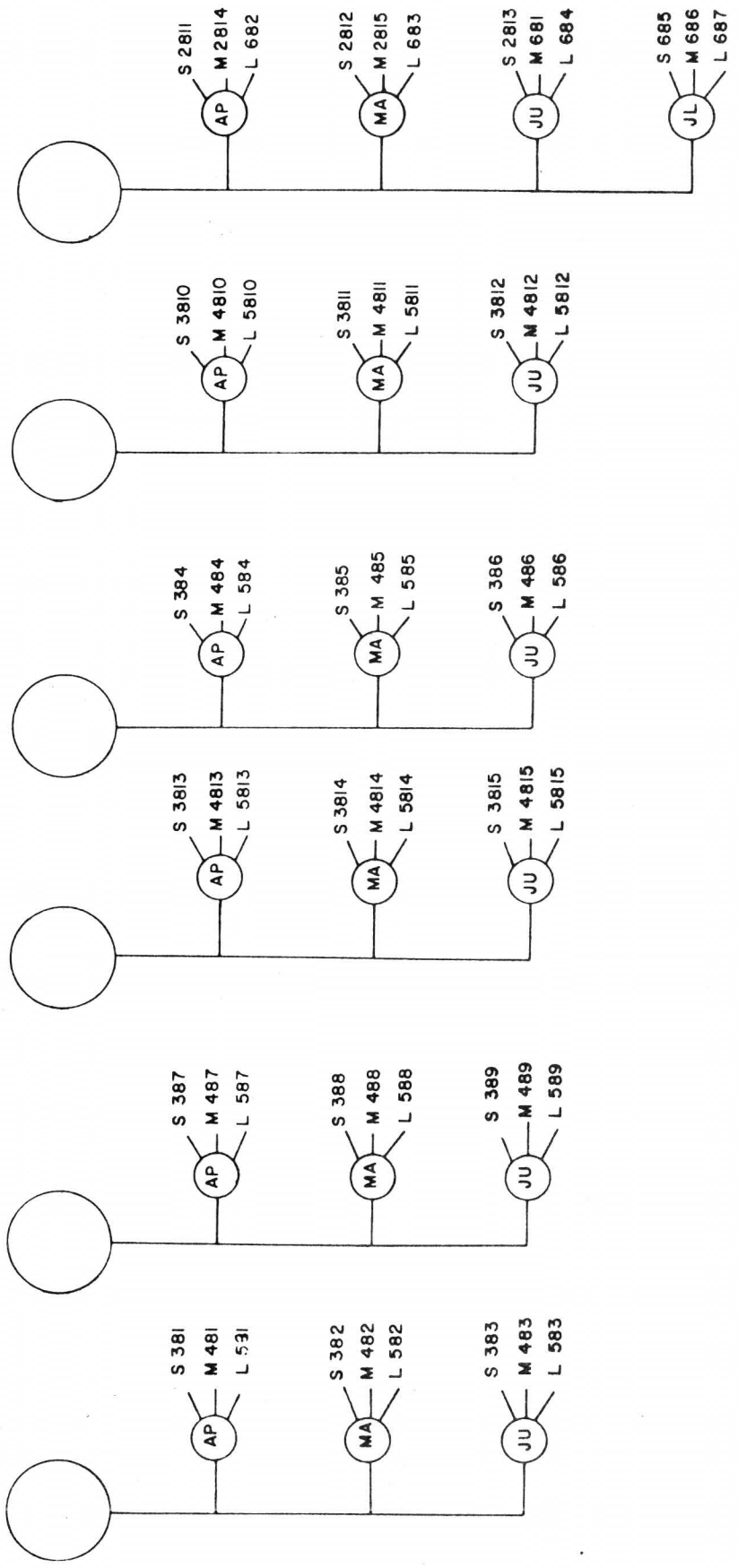
Fig. 2. A comparison of the percent return of adult coho minus jacks originating from smolts of different sizes released in April, May, June, and July. Open symbols indicate values for each of the 18 sub-groups. Closed symbols indicate values for each of the six populations. (From Bilton 1980).

Fig. 3. Influence of time of release (Julian days) and mean size at release (g) on total returns of adult coho salmon (to the weir and to the fishery). Contours are shown for 5, 10, 20, 30, and 40% return. Predicted maximum return at the centre of the surface (Ys) is 43.5%, for a release on day 173.2 (22 June 1975) at a mean juvenile release weight of 25.1 g.

Fig. 4. Influence of time of release (Julian days) and mean size at release (g) on total returns of jack coho salmon. Contours (% return) increase toward the upper left corner of the figure. The provisional surface indicates that increased returns of jacks can be expected from early release of larger juveniles.

Fig. 5. Overlay of computed response surfaces. Shown are 1) a central contour (40%) around the centre (Ys) of the surface for percent return of adult coho, 2) several contours (0.01, 0.5, 5%) of the surface for percent return of jack coho, and 3) central contours (14, 16) of the benefit-cost surface for adult returns. The coordinates of points on each surface are those of time (Julian days) and size (g) of juveniles at release. Also shown is a "path of joint optimality", running from the centre of the surface for adult returns toward that for benefit-cost of adult returns. Points on this path are optimized jointly between the two centres in terms of time and size at release.

Fig. 6. Available data for independent releases of coho juveniles from four British Columbia hatcheries (sites), in four brood years (1972-74), overlaid on the response surface for adult returns generated from the data for the 1975 Rosewall Cr. releases. Y_s--centre of the contours for the Rosewall data. Numbers beside each hatchery release--percentage of returning adults (fishery and escapement). (Six releases of zero-age smolts, subject to temperature manipulation, rapid growth, and release in the year prior to normal release, also are shown; these are judged not to be comparable with the remaining points on the surface). (From Bilton et al. MS).


S 381
M 481
L 531
AP
S 382
M 482
L 582
MA
S 383
M 483
L 583
JU
S 387
M 487
L 587
AP
S 388
M 488
L 588
MA
S 389
M 489
L 589
JU
S 384
M 484
L 584
AP
S 385
M 485
L 585
MA
S 386
M 486
L 586
JU
S 3813
M 4813
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M 4815
L 5815
JU
S 3810
M 4810
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AP
S 3811
M 4811
L 5811
MA
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M 4812
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JU
S 2811
M 2814
L 682
AP
S 2812
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M 686
L 687
JL

Figure 1.

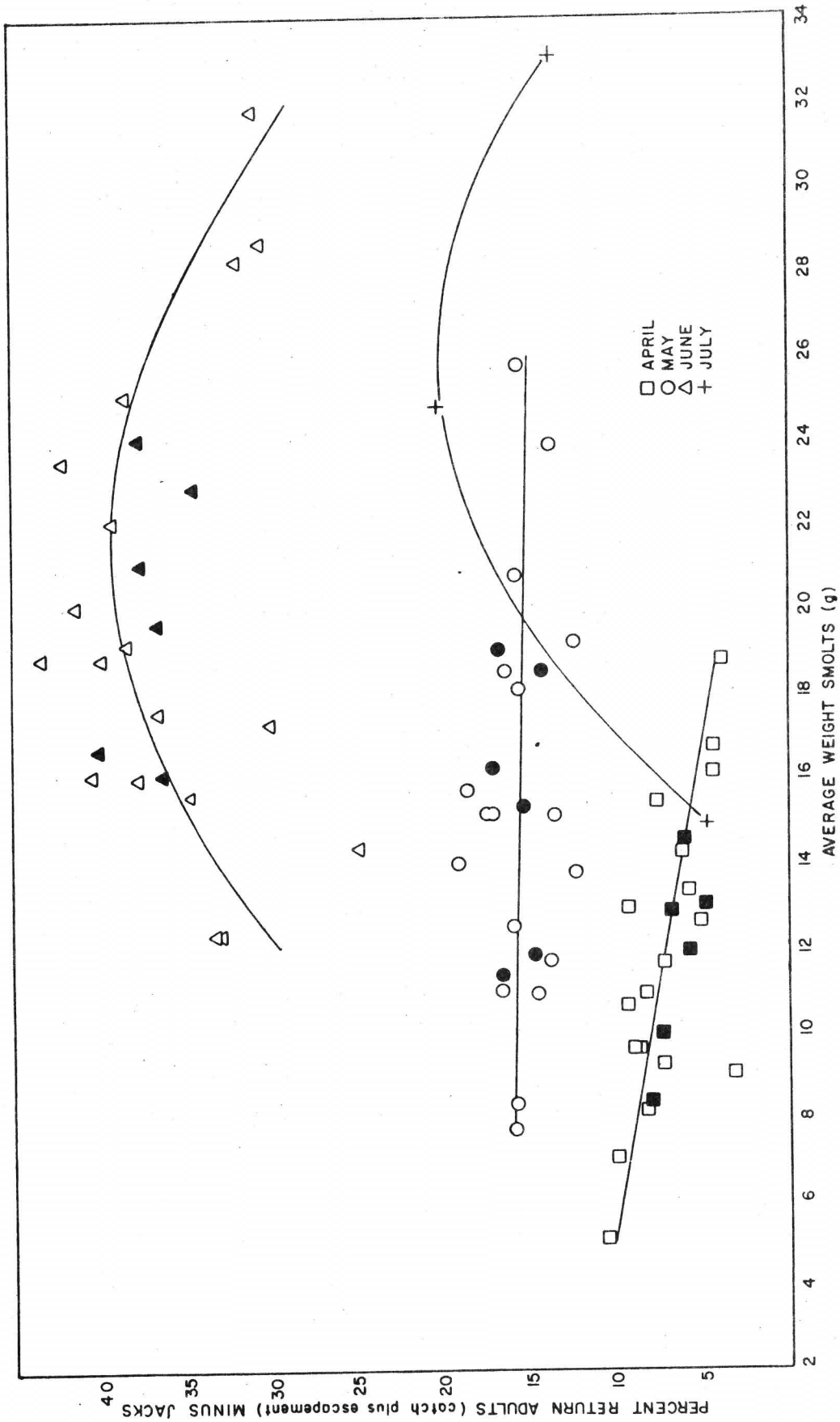
PERCENT RETURN ADULTS (catch plus escapement) MINUS JACKS
AVERAGE WEIGHT SMOLTS (g)
APRIL
MAY
JUNE
JULY

Figure 2

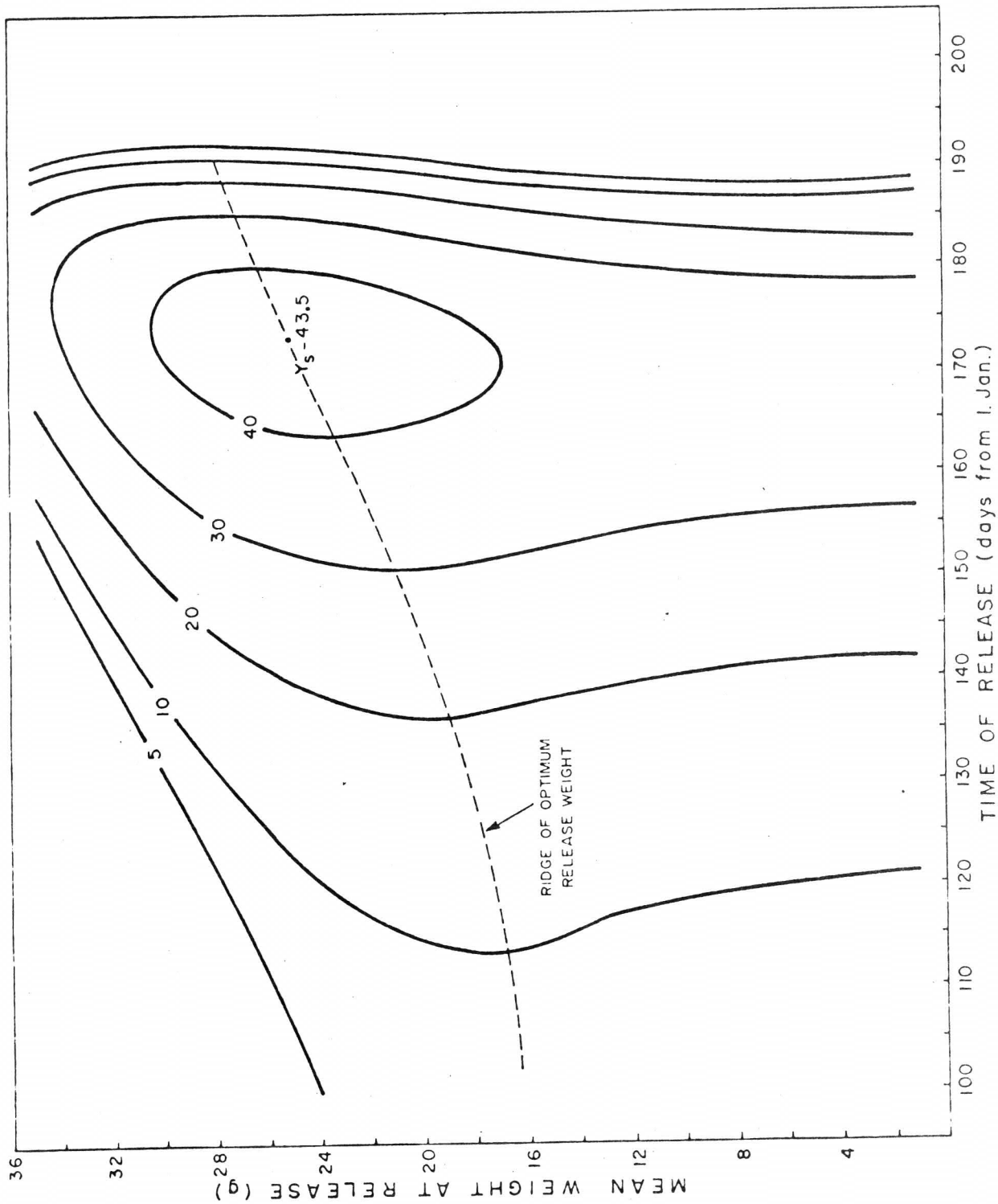
MEAN WEIGHT AT RELEASE (g)
TIME OF RELEASE (days from 1. Jan.)
RIDGE OF OPTIMUM RELEASE WEIGHT
Y_s - 43,5
5
10
20
30
40
36
32
28
24
20
16
12
8
4
100
110
120
130
140
150
160
170
180
190
200

Figure 3

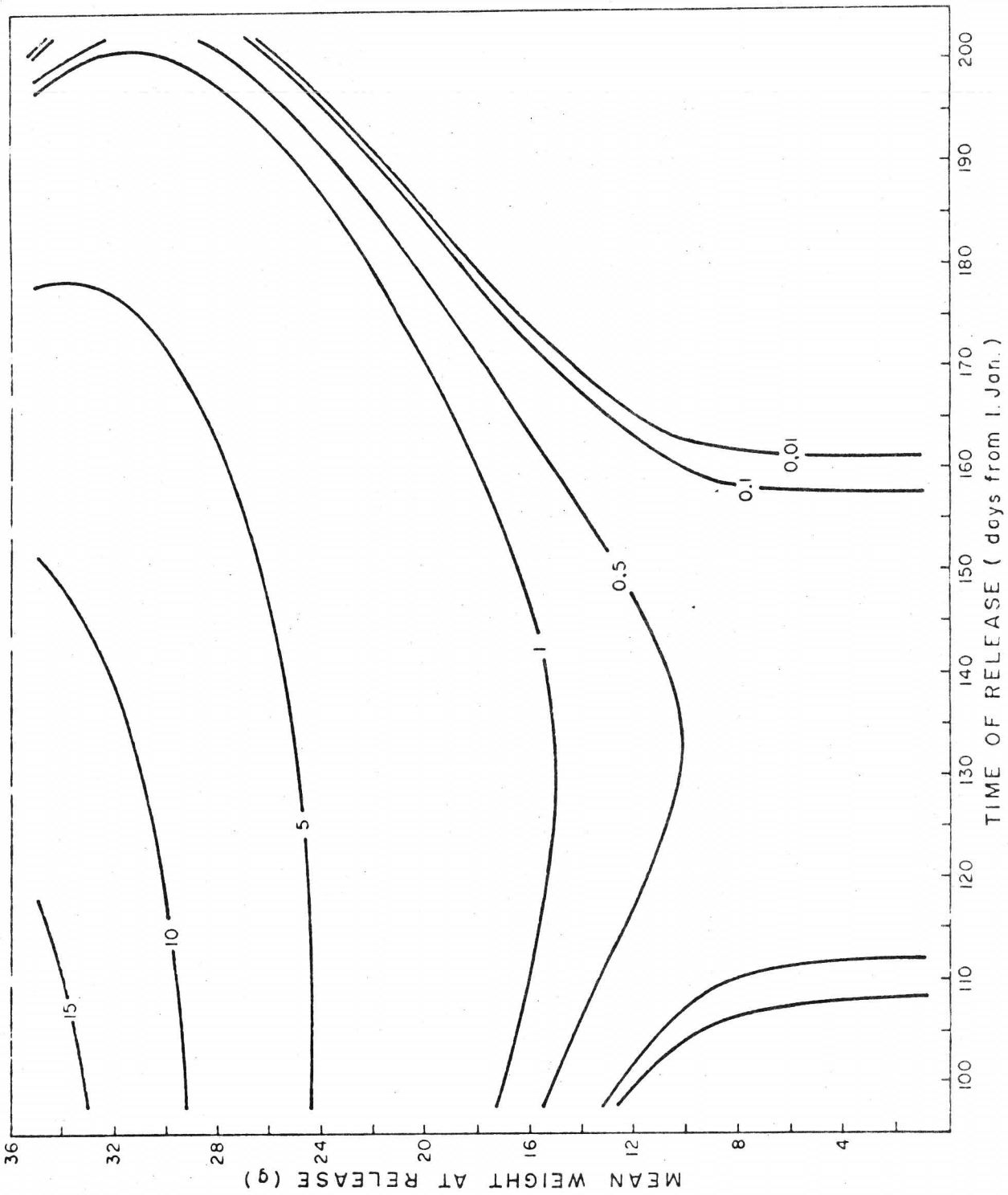
MEAN WEIGHT AT RELEASE (g)
36
32
28
24
20
16
12
8
4
TIME OF RELEASE (days from 1. Jan.)
100
110
120
130
140
150
160
170
180
190
200
15
10
5
1
0.5
0.1
0.01

Figure 4

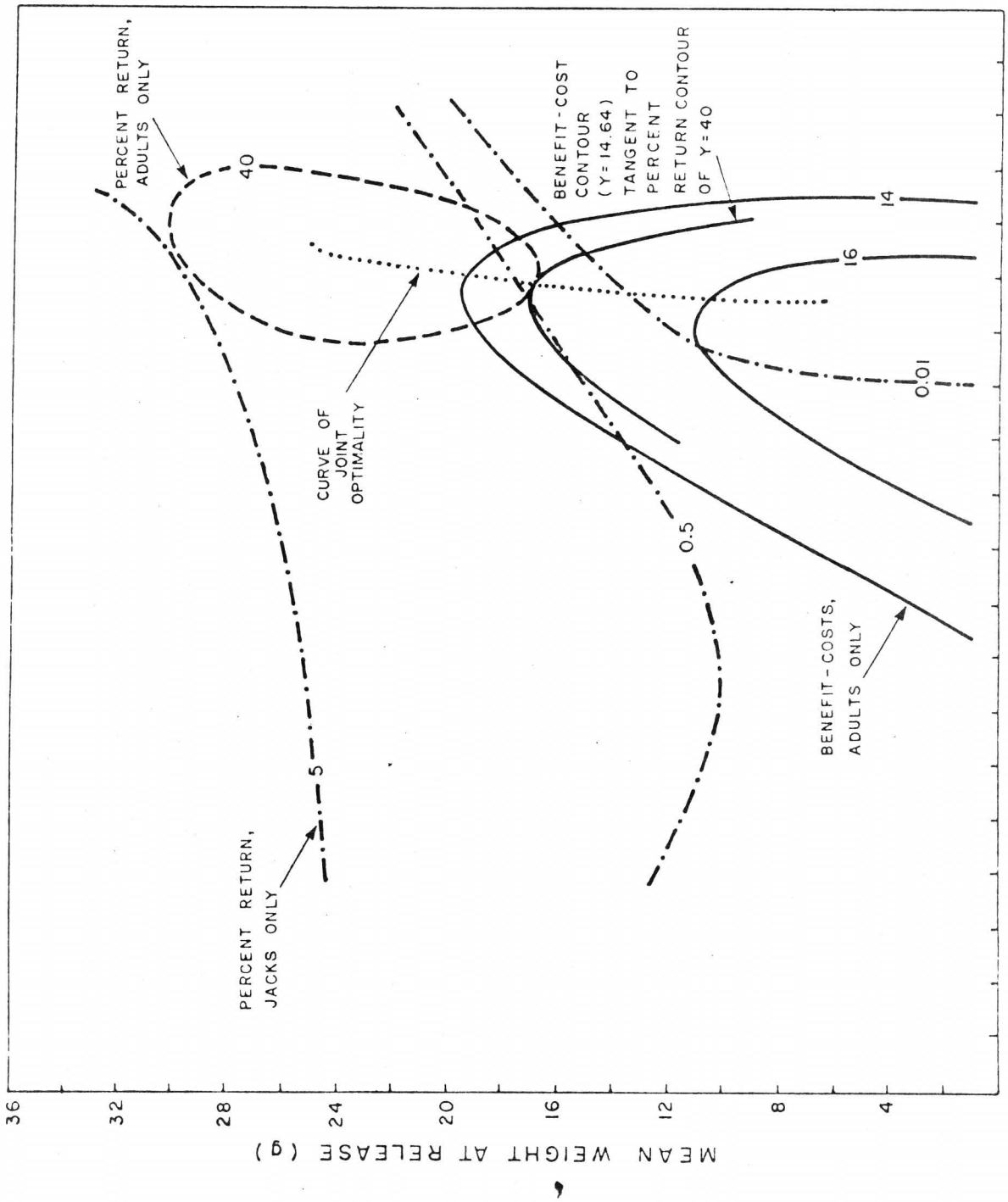
PERCENT RETURN, ADULTS ONLY
40
BENEFIT-COST CONTOUR (Y=14.64) TANGENT TO PERCENT RETURN CONTOUR OF Y=40
14
16
0.01
CURVE OF JOINT OPTIMALITY
0.5
BENEFIT-COSTS, ADULTS ONLY
PERCENT RETURN, JACKS ONLY
5
MEAN WEIGHT AT RELEASE (g)
36
32
28
24
20
16
12
8
4
100
110
120
130
140
150
160
170
180
190
TIME OF RELEASE (days from 1. Jan.)

Figure 5

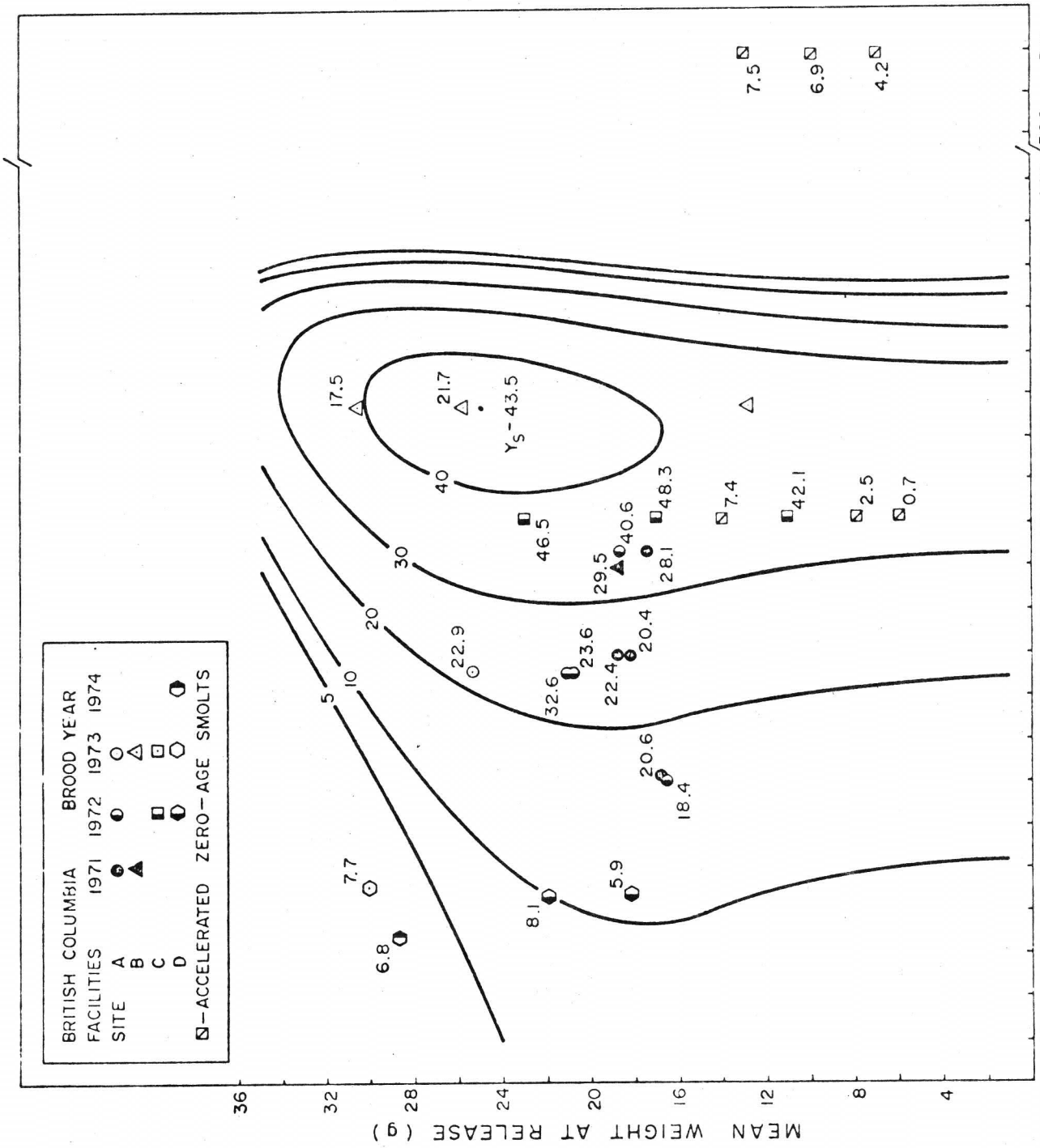
BRITISH COLUMBIA BROOD YEAR
FACILITIES 1971 1972 1973 1974
SITE A
B
C
D
⊠-ACCELERATED ZERO-AGE SMOLTS
MEAN WEIGHT AT RELEASE (g)
TIME OF RELEASE (days from 1 Jan.)
Y_S - 43.5
5
10
20
30
40
7.7
6.8
8.1
5.9
22.9
32.6
23.6
22.4
20.4
20.6
18.4
17.5
21.7
46.5
29.5
40.6
28.1
48.3
7.4
42.1
2.5
0.7
7.5
6.9
4.2

Figure 6

INFLUENCE OF TEMPERATURE ON TIME TO COMMENCE FEEDING OF CHINOOK SALMON ALEVINS

by

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The transition from yolk to active feeding in wild salmonid alevins presumably is associated with emergence from the gravel. Cultured salmonids, on the other hand, seldom experience emergence. More often, cultured fish are hatched and reared in gravel-free incubators where they remain until such a time as they are deemed ready to begin feeding. At that time, the alevins are ponded and feeding is begun. Initiating feeding at inappropriate stages of development, either too early or too late, has deleterious effects on alevin growth and survival (see Heming 1979 for references). The best time to begin feeding is therefore a major concern of fish culturists. This study examines the relationship between timing of first feeding and subsequent growth and survival of chinook salmon (Oncorhynchus tshawytscha), and documents the effects of temperature on that relationship.

Materials and Methods

Chinook eggs from fall-run Campbell River adults were reared from fertilization in Heath incubation trays. Trays were held at 6, 8, 10 and 12 °C. Four trays were used at each temperature, with approximately 3000 eggs per tray. Immediately after hatching was completed, resulting alevins were transferred to 6-L circular growth tanks held at the same temperatures as incubation trays. Twenty growth tanks were used at each temperature, with 345 alevins per tank. Alevins in each tank were assigned randomly to one of ten feeding treatments. These treatments differed only in the timing of initial food presentation. Feeding of alevins in the ten treatments was initiated in serial order from hatching (treatment 1) to complete yolk absorption (treatment 9). Alevins in treatment 10 remained unfed for the

duration of the study (1650 thermal units from fertilization). At regular intervals, 15 alevins from each tank were sampled, anaesthetized with MS-222, and preserved in 5% neutral formalin. After approximately 80 days of preservation, total alevin, tissue (body) and yolk (contents of yolk sac) weights (wet and dry) were determined.

To examine the relationship between emergence and first feeding, 345 alevins were transferred from incubation trays to a simulated redd held at the same temperature. Redds were constructed from 40-L acrylic tanks, filled with 1/2 - 1 inch graded gravel (see Heming 1979 for details). Alevins were introduced beneath the gravel surface of the redds through PVC pipes and were allowed to emerge spontaneously.

Results and Discussion

Contribution of Yolk to Growth and Development

A general model of growth and development of chinook alevins using yolk alone (Fig. 1) was constructed from data from unfed fish in growth tanks (treatment 10) and redds (Table 1). Chinook eggs contained 174 ± 15 mg (± 1 SE) of dry yolk at fertilization. At hatching, 81% of that yolk remained. Alevins buttoned-up with 26% yolk remaining. Yolk absorption was accompanied initially by positive growth, that is, by an increase in dry tissue weight. Dry tissue weight reached a maximum, however, with 6% yolk remaining. During absorption of that last 6% of yolk reserves, chinook began to catabolize their own tissues and dry tissue weight decreased. Changes in total alevin weight primarily reflected changes in total water content and therefore were a poor indicator of growth. In all cases, a maximum alevin wet weight (MAWW) was reached before the maximum tissue weight (MTW) occurred. The specific occurrence of MAWW, however, was temperature-dependent. MAWW occurred earlier in development at higher temperatures. Yolk reserves present at MAWW increased from 9% at 6 °C to

29% at 12 °C. Nevertheless, timing of 50% emergence from the simulated redds was closely related to attainment of MAWW in the growth tanks.

Importance of the Timing of Initial Feeding

Feeding had no effect on yolk absorption. Regardless of when or if fed, all alevins completed yolk absorption at the same time. Growth, on the other hand, was significantly affected by the timing of initial food presentation (Fig. 2). All fish initially fed before reaching MAWW attained the same final size, whereas fish fed at or after MAWW were smaller. The extent of this size reduction was related directly to the duration of food deprivation after MAWW. Timing of initial feeding also affected overall survival (Fig. 3). However, no significant effect was seen unless feeding was delayed until MTW. No evidence was found that early feeding reduces survival, as has been reported for other salmonids (Atkins 1905, Hurley and Brannon 1969).

In conclusion, chinook salmon must begin feeding before reaching MAWW and before emerging from the redd to ensure maximum growth and survival. The cut-off point, after which food deprivation reduces growth and survival, is temperature-dependent occurring earlier in development at higher temperatures. As such, the best time to begin feeding of cultured chinook is not related to any specific developmental stage, be it button-up, maximum tissue weight or complete yolk absorption. As well, swim-up activity is a poor indication of when to commence feeding because swim-up is influenced by light exposure (Kolgaev 1963) and presence of a gravel substrate (Heming 1979). Provisional estimates of this cut-off point for chinook salmon in this study were used to derive the following equation,

$$F = 1201.1 - 20.3T,$$

which relates F, the point after which food deprivation reduces growth and survival, in thermal units post-fertilization to T, water temperature, in

degrees Celsius. This equation probably is unique to the species and experimental circumstances. Nevertheless, reinterpretation of past studies (Palmer et al. 1951, Marr 1965, Harvey 1966) indicate that growth and survival of other salmonid species also is maximized when feeding begins before MAWW.

References

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Kolgaev, A.M. 1963. On the premature assumption of active swimming by young chum salmon, Oncorhynchus keta infraspecies autumnalis Berg, and the consequences of this phenomenon as studied under hatchery conditions. Voprosy Ikhtiologii, tom 3, vyp 3(28): 561-562. Fish. Res. Board Can., Transl. Series No. 545.

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Palmer, D.D., H.E. Johnson, L.A. Robinson, and R.E. Burrows. 1951. The effect of retardation of the initial feeding on the growth and survival of salmon fingerlings. Prog. Fish-Cult., 13: 55-62.

Table 1. Effects of temperature on growth and development of chinook alevins using yolk alone. MAWW-maximum alevin wet weight, MTW-maximum tissue weight, CYA-complete yolk absorption.

Temp (°C)	Days to 50% hatching	Days to 50% emergence*	MAWW			MTW			Days to CYA
			days	mg	% yolk remaining	days	mg	% yolk remaining	
6	95	192	186	687	9	196	112	5	247
8	71	136	138	673	10	146	105	5	183
10	55	104	106	656	15	120	98	6	147
12	44	85	82	600	29	95	91	6	119

*from simulated redd

Figure Captions:

Figure 1. General model of growth and development of chinook alevins using yolk alone. HT-hatching, MAWW-maximum alevin wet weight, MTW-maximum tissue weight, CYA-complete yolk absorption. Refer to Table 1 for details.

Figure 2. Final weight (1650 tu post-fertilization) in relation to time of initial feeding. (arrow indicates occurrence of MAWW)

Figure 3. Total mortality (1650 tu post-fertilization) in relation to time of initial feeding. (arrow indicates occurrence of MTW)

FIGURE 1

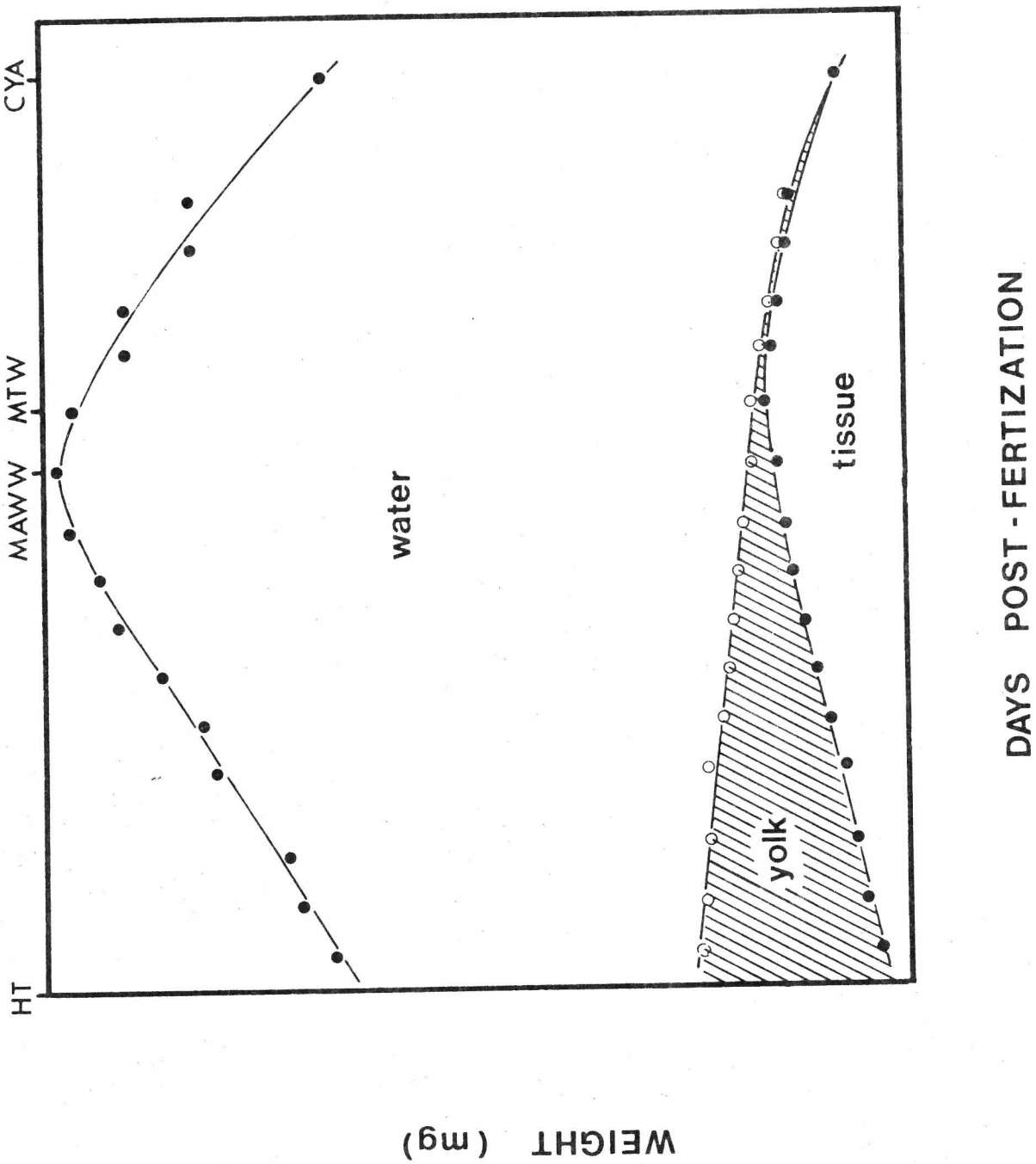

CYA
MTW
MAWW
HT
water
tissue
yolk
WEIGHT (mg)
DAYS POST-FERTIZATION

FIGURE 2

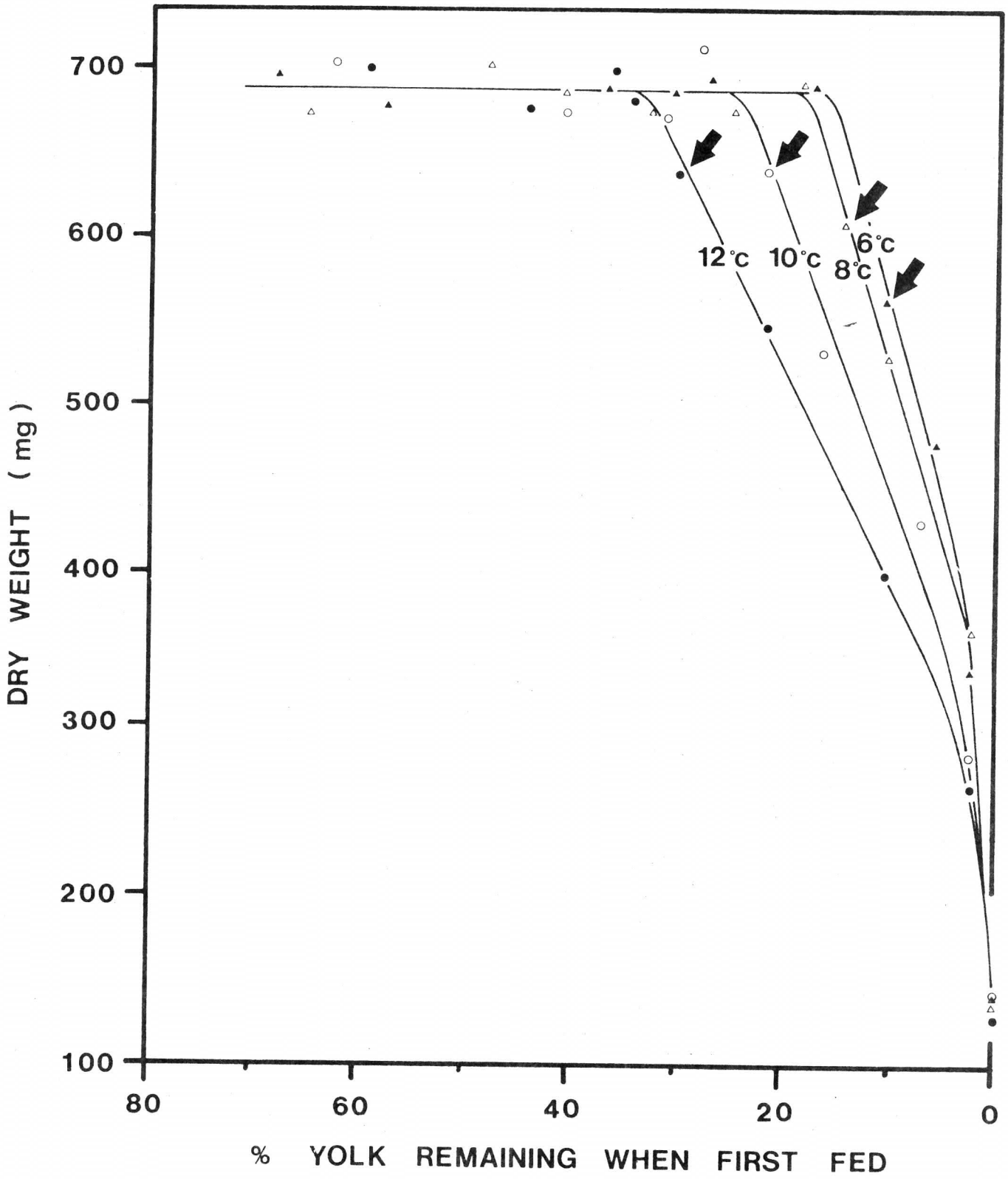
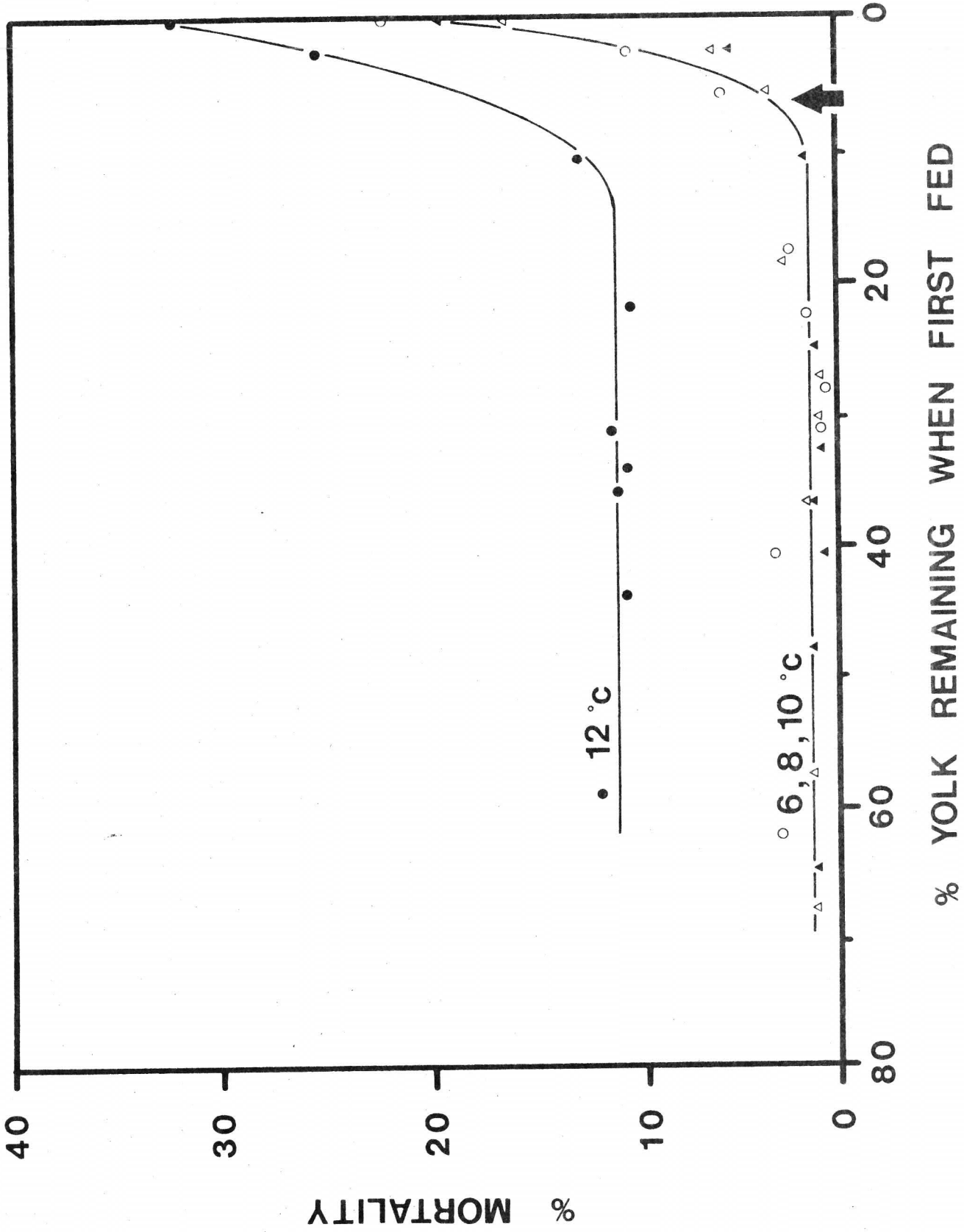

700
600
500
400
300
200
100
DRY WEIGHT (mg)
12°c
10°c
8°c
6°c
80
60
40
20
0
% YOLK REMAINING WHEN FIRST FED

FIGURE 3


% MORTALITY
40
30
20
10
0
0
20
40
60
80
% YOLK REMAINING WHEN FIRST FED
• 12 °c
○ 6, 8, 10 °c

EAGLE CREEK NATIONAL FISH HATCHERY DENSITY STUDY FOR COHO SALMON

by

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INTRODUCTION

Recent work on coho salmon conducted at the Capilano Salmon Hatchery in British Columbia indicates a correlation between rearing density and survival of returning adult coho salmon (Sandercock and Stone, 1979). They found a linear relationship in which the higher the rearing densities of pre-smolts the lower percentage of returning adults. Their work compliments and extends the growing awareness by all fish culturist of a critical need for space that dates back to early loading studies at Cortland, NY. The need for space is measured in many ways. At Eagle Creek we use density factor (D.F.) equalling lbs/ft^3/length. The Canadians use number/cubic meter and number per square meter.

This past year we set up two populations of cohos totaling 85,600 each matching the Canadian high and low densities and held them for five months at those levels prior to release. Table I shows a comparison between these loading levels. These groups were given a ventral fin clip and released in May 1980. Right ventral - low density, left ventral - high density. The Abernathy Salmon Culture Development Center is setting up elaborate tests on coho at Willard NFH to further test the Canadian findings and also to expand that work by including the basic requirement for flowing water (load factor).

PURPOSE

The purpose of this test is to continue the density study started in 1980. We have patterned a new study after the Canadian test, but this time controlling the densities from initial ponding. Eagle Creek's lack of space at initial spring ponding and limited water supply in the summer will prevent us from ever duplicating their exact procedure on a production

basis. They start with a very low density at initial ponding and gradually increase the density factor to maximum at release without splitting or handling the fish again. The procedure used at Eagle Creek will differ by utilizing the established hatchery procedure of reducing load levels three times before release. The maximum density will be reached four times instead of twice as in the Canadian procedure.

An additional variation to the Canadian tests and to the Eagle Creek procedure used in 1980 will be to include a 50% higher test level. This additional test level of density factor .45 will expand the overall test range as well as testing the traditional loading levels of many hatcheries. As an example Eagle Creek's normal loading level for the past two years has been D.F. .30, reduced from D.F. .40 by simply raising the water level in the raceways.

Eagle Creek will set up three different populations at initial ponding in February at density factors of .075, .1 5, and .225. The densities will be re-established when growth results in density factors of .15, .30, and .45. The final splin in August will establish a population that will reach the maximum density factor at release time and size in April. For the period, August thru April, or a full eight months the test duplicates more closely the Canadian test.

Table II shows the approximate sequence of splits, giving the dates, numbers, size, etc. The process will require three splits in order to reach the final density.

The test will be repeated for three consecutive years, to insure that any results are valid and repeatable.

CANADIAN PROCEDURES

The eggs are incubated in Heath trays at 7,500 per tray. The fry were held in fiber-glass troughs at approximately 35,000 fry/m^3, which converts to a

density factor of 2.46 (density factor is: lbs/ft^3/length). The fry were then moved to Burrows ponds for rearing at the number scheduled for release at smoltification.

EAGLE CREEK PROCEDURE

The eggs are hatched in Heath incubators at 8,000 per tray. The swim-up fry go directly into 8 x 80 raceways. As the fish grow from low D.F. and reach maximum densities they will be split back to the original starting densities. Half to continue on the test, the rest put back in the production population (density factor not to exceed .30). The final split in August will then match the Canadian procedure in that they will not be split again for the eight months until release.

1. Test begins at initial ponding
2. Three loading levels with two pond replicates each
3. 8 x 80 raceways
4. Set the flows at approximately 500 gallons per minute, and measure bi-weekly
5. Velocities will be constant at .06'/second
6. Volume - 1,600 cubic feet
7. First use water
8. K factor to be determined at each split
9. Sample counting will be performed bi-monthly until September, and monthly thereafter.
10. Growth projections will be matched to the production fish to reach a size of 15/lb by April 30. Maximum gain will be restricted during the summer months because the high temperature limits available oxygen
11. The fish will be fed OMP through 3/64 pellets, then Abernathy 4/64 to 8/64 for the summer and back to 1/8 OMP from October until release
12. The first year the population will be established by sample count, and

hand weighing, subsequent year's tests will be established by actual egg counts and splits will be done with a fish pump

13. Feed levels will match the normal hatchery levels and feeding will be done by hand
14. Load factor in the highest density will not exceed 1.5 in the summer. Load factor of 1.5 will approach maximum in 65^{0} temperatures and on peak temperature days feeding and cleaning may have to stop by noon to prevent low O_2 stress
15. Water chemistry will be recorded at each sampling period for O_2, NH_4, PH, and NH_3. Chemical tests will be done the afternoon before each sampling day
16. Fish will be wire coded tagged in September of each year by FAO Vancouver
17. Gill ATPase will be monitored prior to release by Wally Zaugg of NMFS
18. Tag Recovery will be performed by FAO Vancouver

Regular station fish cultural procedures will be followed in rearing all experimental groups. The same diet, feeding level, and feeding techniques will be used for all lots during each experiment. Daily water temperature, pond flow, mortality, and feeding records will be maintained by station personnel. Fish growth will be monitored bi-monthly through August and monthly thereafter. Management charts will be maintained to record all pertinent growth data.

Table I

Canadian VS Eagle Creek Loading Data

	#/M2	#/ft2	#/M3	#/ft3	lb/ cu ft	Density Factor	Flow	lbs.	lbs/gal	Load Factor
CANADIAN TEST LEVELS										
Low 59,200 fish	500	47	666	19	.83	.16	600	2619	4.40	.87
Med/Low 78,618 fish	664	62	885	25	1.11	.22	600	2479	5.80	1.16
Med/High 86,550	731	68	975	28	1.24	.24	600	3830	6.38	1.27
High 106,678 fish	901	84	1201	34	1.50	.30	600	4720	7.87	1.57
EAGLE CREEK TEST LEVELS										
Low 4 ponds 21,400 fish	353	32.8	464	13	.94	.16	500	1500	3.15	.53
High 2 ponds 42,800 fish	720	66.9	945	27	1.91	.32	500	3057	6.41	1.09
Very High 62,100	1043	97.0	1371	39	2.59	.47	500	4436	9.30	1.58

Canadian Test
Fish Size:
5.0171
22.6/lb
Pond Size:
17'x75'x2.5'
90.3 M^3
3188 ft^3
118.4 M^2
1275 ft^2

Eagle Creek Test
Fish Size:
5.8868
14/lb
Pond Size:
8'x80'x2.5'
45.3 M^3
1600 ft^3
59.5 M^2
640 ft^2
K Factor:
.0003500

Table II

Eagle Creek

	Approx. Split Date	Size	D.F. Start/end	lbs/cu ft	lbs. Start/end	#/lb	Number	L.F. Start/end
Initial Ponding	Feb.	1.45"	.075/.15	.109	174/496	943	164,082	.25/.51
			.15/.30	.218	349/994	943	329,107	.50/1.02
			.22/.45	.326	523/1490	943	493,189	.75/1.52
First Split	April	2.05"	.075/.15	.154	246/679	331	81,426	.25/.50
			.15/.30	.308	492/1357	331	162,852	.50/1.0
			.225/.45	.462	738/2036	331	244,278	.75/1.50
Second Split	June	2.87"	.075/.15	.215	344/939	120	41,395	.25/.5
			.15/.30	.43	688/1878	120	82,790	.50/1.0
			.225/.45	.645	1032/2817	120	124,185	.75/1.5
Third Split	Sept.	3.92"	.075/start	.29	470/start	44	20,700	.25/start
			.15/start	.59	940/start	44	41,400	.50/start
			.255/start	.88	1411/start	44	62,100	.75/start
Release	April	5.75"	.15/end	.86	1380/end	15	20,700	.50/end
			.30/end	1.73	2760/end	15	41,400	1.00/end
			.45/end	2.59	4140/end	15	62,100	1.50/end

COWLITZ SPRING CHINOOK REARING DENSITY STUDY

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Spring chinook salmon production in Washington State Columbia River hatcheries has made up about 25% of total poundage produced by these hatcheries. Estimated total recoveries of micro-tagged study groups indicate, however, that spring chinook survival from those hatcheries studied averages only 1.09%, and the return per pound of fish liberated averages only .05. These rates are very minimal when compared with the generally used base line rate of one fish contributed to the ocean fishery per pound of fish liberated. These results indicate that the spring chinook rearing program, as it is now conducted, is not as economically productive as rearing of other species.

Aside from economics, the spring chinook has some very desirable sport fishery attributes and rearing programs must be maintained. In order to bring the economics of producing spring chinook into a more favorable realm, studies are being carried out to pinpoint present problems in hatchery techniques. It is apparent that spring chinook do not respond favorably to techniques generally suitable to fall chinook and coho salmon.

The problem area identified and studied herein is excessive loading density during rearing. Characteristically the fish are brought up to heavy loadings several times during rearing and then ponds are split by outplanting to decrease loading. This practice may stress the fish several times during rearing, particularly if the loading densities reached are too high for spring chinook salmon. Study groups representative of standard hatchery practice have been split up to three times during rearing and have been loaded at densities averaging 5.75 lbs./gpm, sometimes reaching as high as 10 lbs./gpm.

Methods and Materials

Two aspects are important to the study. First, all study groups were placed in ponds for rearing at the number desired for final loading densities. Second, the final loading densities were graduated through three levels; low, medium, and high. These levels represented densities lower than usually practiced, average densities, and higher than average in an attempt to bracket the relation between rearing density and overall performance as measured by contribution and survival (ultimately quality).

Specifically, six rearing ponds were used, each with a water flow of 2,000 gpm. Rearing ponds at Cowlitz Hatchery are Burrows type measuring 100' X 20' X 10' deep (water depth). Final loading densities were programmed at 3 lbs./gpm (2 ponds), 6 lbs./gpm (2 ponds) and 9 lbs./gpm (2 ponds). Final release size was programmed at about 5/fish/lbs. (90.8 g/fish). All study fish were adipose clipped and coded wire tagged. The study design and release data are shown in Table 1.

Analysis included comparison of contribution to the various fisheries, and adult returns to the Cowlitz Hatchery.

Results and Discussion

Mortalities during the rearing period averaged about 8% lower than during previous years because disease problems were essentially absent. This was due, at least in part, to decreased handling resulting from elimination of pond splits during rearing.

As one might anticipate, adult survival decreases with increased density (higher pond populations) and, as survival decreases, cost per adult recovered increases.

Simple examination of percent survival can be misleading and it is beneficial to examine the effects of loading density in terms of contribution derived from the use of a rearing pond and the costs incurred in providing that contribution. Certainly, as long as benefits (contribution) accumulate more rapidly than costs, then increased production (numbers) from a pond is acceptable. When increasing production from a pond decreases survival to the point that costs outstrip benefits, the production capacity of the pond has been exceeded and costs are incurred unnecessarily.

Assuming a constant cost of $1.50/lb. of fish released (not totally valid because of fixed costs associated with operating a pond), the average cost per pond of density study fish released was:

Density	1975 Brood	1976 Brood
Light	$12,500	$10,500
Medium	25,000	19,200
Heavy	34,400	26,900

The average cost per fish recovered was:

Density	1975 Brood	1976 Brood
Light	$25.50	$22.00
Medium	29.00	18.00
Heavy	42.50	24.00

In general, an increase from 30,000 fish released (3-4 lbs./gpm) to 60,000 fish released (6-8 lbs./gpm) greatly enhanced the contribution from use of a rearing pond (Tables 2 and 3). Increasing from 60,000 to 90,000 fish released (9-11 lbs/gpm) did little to improve contribution and resulted in appreciable additional cost.

Specifically, the increase from light to medium density in the 1975 brood resulted in a 74% increase in contribution at only a 14% increase in cost per fish contributed. The same comparison for the 1976 brood is even more dramatic, showing a 119% increase in contribution with an 18% decrease in cost per fish contributed. Clearly ponds used to rear 30,000 spring chinook yearlings were underutilized and an appreciable increase in contribution was gained by rearing 60,000 fish with little or no impact on cost per fish contributed.

The increase from medium density to heavy density demonstrated an overloaded condition for these particular ponds. For the 1975 brood, increasing the release to 90,000 fish actually decreased contribution by 7% when compared to a release of 60,000 fish with a 47% increase in cost per fish contributed. The 1976 brood heavy density situation was little better when compared to the medium density and contributed only 6% more fish with a 44% increase in cost per fish contributed.

As an alternative view one might also be interested in the cost per additional fish contributed by increasing numbers released from a rearing pond. For 1975 brood chinook, releases from medium density ponds cost $12,500 more than those from light density ponds ($25,000-$12,500) and produced 367 more

adult fish than did the light density releases. The cost per additional fish is, therefore, about $34.00. The cost difference between a medium density and heavy density pond was $9,400 to contribute 57 fewer fish. The same exercise applied to 1976 brood chinook shows the additional 578 adults produced from medium density ponds over those produced from light density ponds cost about $15.00 each, a cost actually lower than that for fish from the light density ponds. The additional 69 adult fish produced from heavy density ponds over medium density ponds cost about $111.00 each. This demonstrates again that, for the rearing ponds at Cowlitz Hatchery, light loading of 30,000 yearling chinook per pond does not take full advantage of available capacity. Doubling populations to 60,000 fish per pond results in appreciable increased adult contribution at little increase in cost per additional fish contributed. Rearing 90,000 fish produces very little in contribution and the cost per each added fish contributed is extreme.

These results are, of course, specific to the particular pond design and water characteristics at Cowlitz Hatchery. The loading densities should not be used as a rule for rearing of spring chinook yearlings in other systems. What should be noted is that all hatcheries have system-specific limitations that should be determined experimentally. These limitations can be subtle enough not to be apparent before release as was the case for this study at Cowlitz Hatchery. Rearing in the heavy density situation appeared equally successful to that in the lighter densities and the lack of added benefits could only have been discovered with a tagging experiment. Based upon the results of this study, spring chinook yearlings at Cowlitz Hatchery are now reared without pond splits and at flow densities not to exceed 6-7 lbs./gpm final loading at release.

Table 1. Design criteria and actual release information for Cowlitz spring chinook density study; 1975 and 1976 broods.

	No. Ponds	Population	Density (lbs/gpm)	Size (fish/lb)
Design	2	30,000	3	5
	2	60,000	6	5
	2	90,000	9	5
Achieved 1975*	2	28,357	4.1	3.4
	2	61,720	8.4	3.7
	2	88,051	11.4	3.8
Achieved 1976*	2	28,000	3.5	5.0
	2	57,613	6.4	4.5
	2	88,700	9.0	4.0

* Mean of two ponds

Table 2. Performance statistics for 1975 brood Cowlitz spring chinook density study.

Number released	Number recovered	Percent survival	Ave. survival/ density	Fish/lb released	Cost($)/ recovery	Ave. fish contributed/ pond used
28,746	499	1.56		.055	28.00	
27,967	548	1.96	1.76	.067	23.00	499
61,782	905	1.46		.054	28.00	
61,658	827	1.34	1.40	.050	30.00	866
88,051	738	.84		.033	45.00	
88,691	879	.99	.91	.037	40.00	809

Table 3. Performance statistics for 1976 brood Cowlitz spring chinook density study.

Number released	Number recovered	Percent survival	Ave. survival/ density	Fish /lb released	Cost ($)/ recovery	Ave. fish contributed/ pond used
28,227	468	1.66		.064	24.00	
27,776	504	1.81	1.74	.076	20.00	486
56,964	1,092	1.92		.082	18.00	
58,262	1,036	1.78	1.85	.076	18.00	1,064
87,966	1,435	1.63		.084	18.00	
89,433	831	.93	1.28	.045	34.00	1,133

RECENT TRENDS IN THE PACIFIC COAST ANADROMOUS FISH PROGRAM OF THE FISH AND WILDLIFE SERVICE

by

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I would like to introduce myself as part of the administrative overhead of a large federal fishery program. I am confident there are many other administrative people here with us who may be interested in some non-technical program management issues related to fish culture.

I will describe the fishery resources program of the U.S. Fish and Wildlife Service. This is a national program but I will focus on the Pacific Coast administrative region of the agency, which includes the states of Washington, Idaho, Oregon, Nevada and California. In that region, the Fish and Wildlife Service operates 19 fish culture facilities releasing about million salmon and trout annually, plus several research and technical assistance stations which contribute to fish culture. The mission of the agency is to conserve fish and wildlife resources for the public benefit.

Our fishery program is not directed by a simple, clear mandate of federal law. Rather, the program has grown over about 100 years through various Congressional and administrative directives. These directives have gotten our agency into a variety of fishery activities, some more productive than others. In recent years, there has been a sincere effort in the agency to improve program management and to focus effort on attaining a limited number of resource-related objectives.

For example, our fishery program on the west coast has been subjected to a "zero based" evaluation. That is, we have evaluated all our activities - on-going, established ones as well as new projects - against several criteria. These criteria have included:

1) The resource benefit to be expected, such as stabilizing a depressed and declining stock;

2) The public use benefit, for example, restoration of a historically important but now depleted fishery;

3) The appropriateness of federal government involvement.

One outcome of this evaluating and prioritizing has been a significant shift from the rearing of catchable trout for stocking on federal and Indian lands to salmon and steelhead trout propagation. We have gotten plenty of criticism for reducing our production of catchable trout but we feel the reallocation of effort to anadromous fish has made our program more effective, especially in contributing to resource restoration objectives, and in keeping to a proper federal role in fish culture.

Another change that has recently taken place in our fish culture program is increased emphasis on rearing salmonid stocks that have become severely reduced in numbers. We have several of those in the U.S. as you know. We are now rearing or planning soon to rear Puget Sound spring chinook, Snake River fall chinook, Sacramento River

winter chinook, and a non-anadromous species, the Lahontan cutthroat trout. The Lahontan trout is protected by our federal Endangered Species Act. If any Pacific salmon stocks are placed under the protection of that Act, their management will become more complicated and the Fish and Wildlife Service may be required to devote a lot more hatchery capability to rearing those stocks.

A third area of new emphasis in our fish culture program is improved planning and evaluation of hatchery operations and cultural techniques. Fish culture is such an important part of our agency's fishery program that we want to redirect the efforts of some of our biologists away from technical assistance to outside agencies and toward helping our hatcheries operate more effectively in meeting program objectives. Fish culture objectives would include increased survival from smolt to adult, and reduction of adverse effects of hatchery releases on wild populations.

These trends in our fish culture program have come about through a rather informal planning process. In the last few months, we have initiated a more structured process which involves writing strategies for meeting our fisheries objectives over a 10-15 year period in each of four key basins: Columbia-Snake, Puget Sound, Sacramento-San Joaquin, and Klamath. Operational plans will identify the specific actions proposed to carry out our strategies. We will then submit these action proposals to our Washington, D.C. level for funding. This isn't much of a deviation from our past practices, just a little more systematic, objective-oriented, and forward-looking.

In closing, I emphasize that the fishery resource activity of Fish and Wildlife are intended to be consistent with the management objectives of other agencies. We encourage development of inter-agency fish management plans and will do our best to abide by them. Such a plan has been drafted for the Columbia Drainage, including long-range objectives for hatchery production. However, no inter-agency plans have been formally adopted for any of the key geographic areas I mentioned earlier. I calculate that a Columbia chinook salmon may pass through jurisdictions of about 12 entities having or claiming to have some fishery management authority, not to mention various agencies controlling flow and other habitat components. The outlook for agreement on the touchy management issues like harvest allocation may not be good, but we are hopeful that basinwide and coastwide objectives for hatchery propagation of anadromous fish can be agreed to.

If anyone here would like to share experiences in planning and evaluating anadromous fish culture programs, I would be very happy to talk with you.

UTILIZATION OF "WASTE" HEAT FOR A FISH HATCHERY IN INTERIOR ALASKA

by

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In the early 1970's, the Alaska Dept. of Fish and Game began an intensive effort to develop a plan for the rebuilding and maintenance of Alaska's depleted fisheries. The goal being to achieve optimum sustainable yield (commercial, sport, and subsistence) from natural and artifically enhanced Alaska stocks, and to moderate the fluctuations in the fisheries from year to year. To achieve this goal, the Department looked into four separate programs: supplemental production through hatcheries, habitat alteration, habitat protection, and management.

In 1974, the voters of Alaska approved a bond fund to finance the selection of a hatchery site in Interior Alaska. The search for a site focused on geothermal areas and areas near power plants, where large amounts of water are used for cooling the plant's turbines. Some of the problems associated with the use of geothermal areas were the remoteness of these areas, thus increasing both developmental and operational costs; the insufficient water supplies (most of the springs produce less than 200 gpm);

presence of toxic compounds; and the fact that most of the geothermal areas that are accessible are already privately owned and utilized for purposes other than fish production.

The second source of warm water was steam power plants. There are five such plants in Interior Alaska (Clear Air Force Station, Fairbanks, Eielson Air Force Base, Healy, and Fort Wainwright) that are water cooled. A problem that can surface from time to time using water from these plants is that chemicals (some toxic to fish) are used to clean piping systems of the plant itself and are discharged with the cooling water. After looking at several different locations, it was decided that the hatchery should be located at Clear Air Force Station (AFS), not because of the waste heat available from the coal fired power plant located on base, but because of the availability of approximately 2500 gpm of water that is used only to cool electronic equipment. Clear AFS is a ballistic missile early warning site located at mile 298 on the Parks Highway, and is operated by the United States Air Force. The site is located about 50 miles north of Mt. McKinley Park and is typical of Interior Alaska, cold and dry with extreme temperature variations. The minimum temperature is -70°F (-57°C), the maximum temperature 98°F (37°C), and the average mean winter temperature is -3°F (-20°C).

In November 1976, the Alaska voters approved a $28 million bond sale to finance construction of several new incubation and rearing facilities. The money to construct Clear AFS Hatchery was a small part of this bond package. As with most hatchery programs our first problem was lack of sufficient funds because of the high cost of construction in Interior Alaska. The size, complexity, and future operating costs dictated an "economical" design with no frills. On

April 4, 1980, bid proposals for the construction of the Clear AFS Hatchery were opened, and as the low bid was within our allocated budget, the hatchery at long last was going to become a reality!

After having determined that the radar equipment cooling water effluent would be our source of warm water (2500 gpm at 51°F (107°C)), it was necessary to locate a source of cold water. To accomplish this, a well field contract was let in January 1979. It was readily apparent that there was an almost unlimited supply of 38°F (3.3°C) water to mix with the warm water after drilling an 8", a 10" and two 12" wells. Having eliminated the major stumbling block to all hatcheries, sufficient high quality water, design commenced on the hatchery proper. Knowing that any rearing at the site would have to be accomplished indoors because of extreme low winter temperatures (-70°F, -57°C), the Department decided to cover the rearing area as well as the incubation and other support areas of the hatchery with a pre-engineered metal building. The cost of the building was bad enough, but the cost of heating it with fossil fuel was a definate limiting factor. At this stage of the design, it was decided to once more utilize the "waste heat" made available to us in the form of warm water. A heating system was designed based on straight-pass water-to-air heat pumps and air-to-air heat exchangers. The warm water is only 51°F (10.7°C), and when 2500 cfm of -70°F (-57°C) make up air is added, and the high humidity in the hatchery is considered, the design becomes complicated. The system is designed to maintain the office area at 70°F (21°C), the shop at 65°F (18°C), the incubation area at 55°F (13°C), and the rearing area at 40°F (4.5°C) which is not very warm but much preferable to -70°F (-57°C). All major parts of the system have been duplicated and

there is an elaborate alarm system incorporated into the heating system for safety. In Interior Alaska a hatchery's heating system is every bit as important as its water supply system as a loss of heat would cause the loss of an entire years' egg takes. Our only back up, should we lose power, are two 140,000 BTU space heaters, but Clear AFS has only been without power for a total of 21 minutes in almost 20 years of operation.

Both the cold water and warm water had unacceptably high nitrogen supersaturation levels so a gas stabilization tower was incorporated into the design. To keep matters as simple as possible, we chose to use packed columns to handle our supersaturation probelms. Due to lack of sufficient head being available, all water had to be pumped anyway but this process added approximately 25 feet more head to be handled by our pumps. We do have an emergency gravity supply system that will provide warm water to the four raceways only, but the water will be supersaturated with nitrogen. The final process water design incorporates a separate gas stabilization tower, headbox, and supply piping for both the warm and cold water to each water use point. This will give the facility maximum flexibility to work with various species, and stocks within each species to be handled at Clear AFS Hatchery.

At this time, there is no housing on site at the hatchery because of its proximity to a high security area maintained by the U.S. Air Force. This created a major problem for hatchery operations in that the nearest town for the crew to live in was 7 miles from the hatchery site, yet alarms must be answered in a timely fashion or loss of fish may result. The problem then became two fold: 1) How to lessen the danger in not being able to respond as quickly to an alarm as you could, if you lived on site, and 2) How does a person living 7 miles

from the hatchery know that an alarm has gone off? The solution to the first problem was to incorporate an automatic pump start sequence into the alarm circuitry. If an alarm circuit that involves the process water supply is triggered in any way (low level, pump failure, etc.), the automatic pump start sequence will begin and all pumps that have been preset for standby operation will start at 10 second intervals. The alarm and automatic start systems are duplicated for both the warm and cold water process systems. This system should keep everything alive until someone has been able to respond to the alarm and evaluate the problem. The immediate answer to the second problem was to use a telephone alarm system to notify the person on standby of a problem at the hatchery. This solution had to be ruled out when it was discovered that not only was the local phone system subject to frequent breakdowns, but the only lines available were party lines which can tend to be very busy. A radio alarm was the only alternative left us. The system consists of a VHF-FM Base station with 12 volt standby, a paging encoder, a selective call monitor with a charger and amplifier, and the necessary antenna and feed lines. When a person is on standby he or she will carry the monitor with them and plug it into a charger/amplifier when at home. These monitor units are the same type that doctors use to enable them to respond to emergency calls.

With the exception of the heating system, the gas stabilization system, the alarm system, and the provisions taken to achieve control of the hatchery process water temperatures, the hatchery design was common to any other hatchery after making appropriate considerations for the Arctic climate.

The long range production goals of the Clear AFS facility are as follows:

Species	Green Eggs ($x10^3$)	# Released ($x10^3$)	Size at Release
chum	520.0	401.0	1.0 g (454/lb)
king	217.0	167.0	6.0 g (75/lb)
coho	325.0	250.0	6.0 g (75/lb)
rainbow trout	Number yet to be determined		2.3 g (200/lb)
grayling	1,250.0	Majority to be released as unfed fry,	
sheefish	1,500.0	balance for experimental studies.	

Chum salmon have been incubated in temporary incubators at the base of the radar tracker unit at Clear AFS every year since 1977. Last spring approximately 270,000 unfed fry were released into Clear Creek to help establish a local brood stock for future use by the hatchery. This fall we took about 400,000 eggs and expect to move them from their temporary incubators into the hatchery by late December. We expect our first returns of chum salmon released in 1977 back to Clear Creek next fall. King and coho salmon eggs will be taken for the first time next year. Egg takes for all three species of salmon will take place at remote locations with the water hardened eggs then transported some 15 to 150 miles back to the hatchery, depending on the species. The number and source of rainbow trout has not yet been decided upon but there has been some talk of maintaining our own brood stock eventually. All of the above species will be reared using existing technology with some minor modifications necessitated by our location. This year approximately 340,000 sheefish eggs were taken from the Koyukuk River and are now in temporary incubators awaiting completion of the hatchery. Grayling eggs will be taken next June from Interior stocks. The majority of both the

sheefish and grayling will be released as unfed fry, with the balance retained for experimental rearing studies. One of the tasks at Clear AFS Hatchery is to develop culture techniques to use with grayling and sheefish.

The growth and development of king and coho salmon in Interior Alaska is very slow, often causing the fish to remain in fresh water from two to three years before outmigration occurs. The main reason being the cold water and limited of food supply. If a hatchery were to use the same water supply, rearing would indeed be very difficult if not impossible, making the importance of the warm water supply readily apparent. Instead of taking two to three years to release an outmigrant, that fish will be released in less than one year. (The term smolt has not been used here since these fish must migrate almost 1500 miles before reaching salt water where smolting will occur.) Even more important is the flexibility to adjust the incubation and rearing temperatures so that the fish can be released at the optimum size and time.

In this day and age, when energy is becoming more and more valuable, we can no longer afford to waste "waste" heat. The concept behind Clear AFS Hatchery is to utilize some of this "waste" heat for production of fish flesh. Even though the hatchery is not yet functional, we believe that the concept is a good one and other hatcheries built in cold climates will eventually use the same technology wherever possible.

WASTE HEAT UTILIZATION IN FISH CULTURE FACILITIES

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INTRODUCTION

With 15% of the world's fresh, liquid surface waters and 23,000 km of Pacific and Atlantic coastline, Canada is in a unique position to utilize its natural water resources for Aquaculture.

However, because of the climatic variations in Canada, the optimum rearing temperatures for fin fish or shell fish are seldom achieved here.

The use of heat discharged in the effluent from power generation stations, industrial processes and produced within an aquaculture operation itself, provides a means of tempering cold water temperatures and improving the growth rate of many desirable species.

THERMAL EFFLUENT AQUACULTURE

Lennox Oil-Fired Generating Station Condenser Coolant Stream, Ontario

Completed in 1977, the oil-fired Lennox generating station on the shores of Lake Ontario near Kingston, Ontario, was built with features to prevent one of the major barriers to thermal effluent aquaculture, tapping into the heated water supply. Pipeline connections to the warm water discharge and cooling water intake lines were provided and the necessary pumping and control connections were built to accept future pumps and valving.

At peak operation the station is capable of producing 2,000 megawatts of electrical power and requires a cooling flow of 55 m^3/s. The peak daily temperature differential (ΔT) between the lake water and condenser coolant discharge is 13.5°C. The ΔT varies from 5.5°C to 13.5°C depending on the power demands on the plant.

In 1974, the Ontario Ministry of Natural Resources initiated a study to assess the fish hatchery production facilities required to rear a combined 91,000 kilograms of splake (M. Salvelinus fontinalis x F. Salvelinus namaycush) lake trout, (Salvelinus namaycush), brook trout (Salvelinus fontinalis) and rainbow trout (Salmo gairdneri) at the Lennox site. Individual fish size requirements varied between 58 grams and 227 grams.

A review was made of lake water and condenser discharge temperature data and the target temperatures needed to ensure fish growth were analyzed to achieve the various production sizes required.

Based on the combined needs of water temperature and flow it was decided that process demands in the hatchery should be provided by direct connection to the power plant discharge; a connection to the plant's 21-metre deep cooling water intake; and provision of a separate 36-metre deep intake to be built for the fish hatchery.

In addition to the water intakes, it was decided that separate provisions should be made for 4 hot and cold water blending systems, a

sulphur dioxide dechlorination system; and a 4-system aerator/degasser unit. The temperature supply systems were selected to ensure future flexibility in production scheduling while still meeting initial target objectives. When the fish hatchery was being planned, chlorination of the condenser water was not included as part of the power plant maintenance program, however, an allowance was made for a dechlorination system for the fish hatchery in the event this should change.

Outdoor production units for the fish hatchery were to be semi-enclosed concrete raceways. A public visitation centre, day use park, and fee fishing pond were also included in the overall hatchery development (Underwood, 1974).

At the time of planning for this facility, the cost was estimated at $10 million, in 1974 Canadian dollars. While connections to the heated water and power plant intake have been provided, the cost of operating the oil-fired station and consequent use of the power plant for peak loadings only has delayed the building of the fish hatchery. It is likely that the present cost of the complete project would now require a reduced scale of operation. Implementation of the project would be more likely if the power plant became a base-load station through conversion of the oil-fired units to coal.

Bruce CANDU Coolant Streams, Bruce Agripark, Ontario

The CANDU-PHW (Canadian Deuterium Uranium-Pressurized Heavy Water)

reactor uses natural uranium as fuel and heavy water (deuterium oxide) as a moderator and coolant. Heat produced by splitting uranium atoms is transferred to the heavy water coolant, which is pumped through pressurized tubes containing the hot fuel bundles and then to boilers where the heat is used to turn demineralized water into steam. Once through the generator turbines, steam is condensed in heat exchangers cooled by lake, ocean or river water.

In the case of one 3,000 MW_e CANDU power plant, the size of plants now being built, approximately 170 m^3/s of water is required to cool the condenser heat exchangers. Assuming all other factors were suitable, the theoretical salmonid production from one such plant could be in excess of 27,000 tonnes per year (Truch, 1975).

In 1979, The Bruce Agripark Joint Venture Group of private sector investors initiated a research and development project aimed at the combined agriculture/aquaculture use of the moderator coolant heat from Ontario Hydro's 3,000 MW_e Bruce "A" CANDU nuclear generating station near Kincardine, Ontario.

Of the heat generated by the 4 units of the generating station, approximately 30% is converted into electricity, about 64% is discharged into Lake Huron, the source and recipient of the plant's turbine condenser cooling water and the remaining 6% is discharged through the moderator cooling system. Unlike the condenser cooling flow, which has a fixed ΔT of 9.1°C,

(but it is dependent on the hourly ambient lake intake temperature for its final discharge temperature), the moderator coolant circuit has a constant daily discharge reading. During the winter months this later temperature is approximately 41°C.

With 1979 Ontario greenhouse fossil fuel heating costs of approximately $75,000 to $100,000/hectare and an increasing produce trade deficit for winter vegetables, it is proposed to utilize the available moderator coolant heat to substantially reduce heating costs and eventually heat 58 hectares of greenhouses near the power plant.

Heated lake water would be transported to the site by a 760 mm diameter reinforced concrete pressure pipe (Consumers, 1979).

The second phase of this project envisions using the approximately 2800 l/s/hectare, 23°C effluent from the greenhouses for commercial fish farming operations. Since continuous 23°C temperatures would be too warm for the rainbow trout operations initially envisioned at the fish farm, it is proposed to blend the heated supply with cold water from a surface intake near the site during the winter and with cool water from the lake intake of the power plant during the summer.

Water for the power plant cooling circuits is drawn from the lake at a depth of 12 m into a tunnel approximately 1.6 km offshore. Because of cold hypolimnetic upwellings, even at this distance offshore, temperature

fluctuations reach 4°C/h. On rare occasions temperature shifts exceed this amount. Rapid temperatures shifts would be dampened by the fish farm water distribution system and water volume of the rearing units.

Maximum water temperatures from the power plant intake tunnel have reached 24°C but normally exceed 21°C for only short periods in August (Underwood, 1980). No plant wastes are added to this circuit.

Lake water is heated in the moderator cooling circuit be means of a heat exchanger extracting controlled heat from the heavy water surrounding the reactor.

The final assessment of the potential for this co-operative development of agriculture and aquaculture is expected to be completed by mid-1981.

Grand Lake Coal-Fired Thermal Plant Condenser Coolant Stream, New Brunswick

The New Brunswick Department of Natural Resources is utilizing the thermal effluent from a 100 MW_e coal-fired generating station to rear brook trout and Atlantic salmon (Salmo salar) on the shores of Grand Lake, New Brunswick. This facility is currently the only operational salmonid power plant thermal effluent aquaculture project in Canada.

Using stock from a nearby hatchery, with groundwater at 6-14°C as its sole water supply, starter stock are introduced into two 60 m by 30 m by 1.2 metre water depth, "Hypalon" lined ponds created from abandoned fly ash ponds near the power plant (Aqua. achievements, 1980).

According to Gilbert (1980), the 57 gram brook trout stocked in the ponds have grown to a round weight of 283 grams within a three month rearing period. Feed for the program is prepared from gaspereau (Alosa pseudoharengus) and an added vitamin supplement. Based on current growth rates, it is expected that the Grand Lake facility will be able to produce three crops of 284 gm brook trout between September of the first year and June of the following year. Initially, one pond has supplied 80,000 trout per rearing cycle.

The second rearing pond is being employed to rear Atlantic salmon smolts. By using the thermal effluent the program hopes to produce 30,000 smolts within one year, instead of the usual 2-3 year period required in existing conventional Atlantic Canada hatcheries.

Water for the rearing ponds is supplied by two 30 kW pumps capable of supplying 212 l/s through a 183 m long, 410 mm diameter pipeline. The Δ T through the power plant is approximately 13°C (Hooper, 1980). At the present time normal summertime lake surface water temperatures exceed the upper rearing temperature preference for salmonids. Deep wells are being planned to allow summer operations at the site, (Gilbert, 1980).

Alberta Gas Trunk Line Company Compressor Station Heat, Alberta

The Province of Alberta conducted a 1977 study of the potential for combining its requirements for an expanded salmonid hatchery brood stock program for rainbow trout, brook trout, lake trout, brown trout (Salmo trutta) and cutthroat trout (Salmo clarki) with the use of waste heat from Alberta Gas Trunk Line's Compressor Stations.

Seven sites were assessed for their potential to provide waste heat and the 380 l/s water supply required for the brood stock needed to produce 6-10 million fall spawning rainbow trout eggs per year.

Typical operational features of the gas compressor station, used to compress natural gas for transmission in pipelines, included minimal potable water demands, usually satisfied by wells; available waste heat of 12 x 10^9 calories/h to 19 x 10^9 calories/h; either vertical or horizontal exhaust stacks; normal maintenance on only one or two units per station at any one time; large, open, gravelled areas with ample space between the buildings and the fenced perimeter; and a high performance standard for the station operation.

Only one site, the Clearwater station, offered the potential for water supply development of the flow required for the brood stock facility.

Air-to-water heat exchangers required for the facility were estimated as costing $310,000; a twin - 300 mm diameter closed-loop pipeline from the compressor to brood stock site - $150,000/km; and water-to-water heat exchangers at the brood stock site - $75,000. Standby boilers were estimated as requiring an investment of $200,000. All costs were calculated in 1977 Canadian dollars, (Underwood McLellan, 1977).

Estimated power requirements to run the heat exchanger and pipeline systems varied from 19 kW for a pipeline 1.6 km long, to 130 kW for a pipeline 9.6 km long.

Total amortized capital and operating costs for the Clearwater site in comparision to expanding an existing provincial brood stock facility, the Raven rearing station, showed an overall additional cost of $287,340 per annum for the Clearwater site, exclusive of any waste heat charges, (Underwood, 1977).

For this waste heat source, it was concluded that while a facility was feasible and the heat demand and the available supply closely coincided, the capital costs required to capture and utilize this waste heat would be $2 million more than developing the traditional Raven brood stock station.

Hills Lake Fish Hatchery Process Waste Heat, Ontario

The Ontario Ministry of Natural Resources' Hills Lake fish hatchery

near Englehart, Ontario is a brood stock and rearing station for lake trout and brook trout. In 1980, Underwood McLellan completed the detail design for a new facility to be erected on the existing site.

The water supply for the hatchery is a 378 l/s spring water source with an annual temperature variation of 4°C to 8.5°C.

The new facility will be provided with an early rearing auxillary heating and two pass re-use system, 48-8 tray Heath incubation units, 36-4.8 m early rearing troughs and 8-5.5 m mini-raceways. Semi-enclosed outdoor facilities include 36-18 m x 2.4 m x .76 m W.D. (water depth) raceways, 4-18 m x 1.2 m x .76 m W.D. raceways and 8 brood stock ponds.

In order to utilize the naturally available cool water temperatures during the summer, the air handling system in the hatchery is equipped with a stainless steel, water chilled, heat exchanger. Cool air from the system is supplied to the feed storage room, laboratory and administrative offices. With this system feed storage temperatures can be maintained at approximately 10°C without the use of refrigeration compressors. Water, warmed with the heat extracted from the feed storage and lab/office area, is passed through a packed column degasser/aerator (Dave Owles, Dworshak Hatchery) and piped to the mini-raceways in the early rearing area.

To minimize the effects of point sources of heat on the hatchery ventilation system during the summer months, the compressor refrigeration

systems installed for the walk in cooler and freezer are also water cooled. A ΔT of approximately 10°C is achieved across the nickel cooling coils and is directed, via the packed column degasser, to the flow in the mini-raceways. Using this system it is possible to raise the mini-raceway water temperature some 1°C.

The heat capture systems installed in the Hills Lake facility are to become operational when construction of the new $4.5 million dollar facility is completed in 1982. While the use of excess heat within the hatchery complex does not provide the same order of heated flows as available from traditional power station or industrial systems, this approach does provide a means of working towards an energy integration approach in fish hatchery design.

RECOMMENDATIONS

The assessment to date of thermal effluent aquaculture facilities has shown that success is possible but that capital and waste heat costs must be minimal for smaller, single purpose operations.

Development costs of new facilities are site specific and do not follow any one trend. There is, however, generally a need for an adjacent cold water supply to allow year-round operations for salmonid rearing.

Capital cost benefits are accrued by establishing in close proximity to the waste heat supply and utilizing heated water directly for process flows in the aquaculture facility.

Where practical waste heat available from the process systems within an aquaculture facility should be re-captured for use in the rearing systems.

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MECHANICAL SHOCK SENSITIVITY, WATER UPTAKE, AND DEVELOPMENT OF INTERNAL EGG PRESSURE IN COHO SALMON EGGS

by

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INTRODUCTION

Salmonid fish culturists generally are aware of the sensitivity of eggs to mechanical shock. Post et al. (1974) exposed rainbow trout (Salmo gairdneri) eggs to five quantifiable types of mechanical shock. Smirnov (1975) subjected Pacific salmon eggs to mechanical shock, but the forces involved in the method used are difficult to quantify in practical terms.

Recently, we designed and constructed a device by which groups of salmon eggs could be exposed to a wide range of shock intensities of known characteristics. This device is being used to investigate the shock sensitivity of coho salmon eggs. In addition, water uptake and internal egg pressures were measured to better

understand the changes that occur when salmon eggs are activated, that is, exposed to fresh water. This preliminary report presents data obtained for the first 96 hr after egg activation.

MATERIALS AND METHODS

Coho eggs and milt from four females and four males were obtained from the Quinsam hatchery, Vancouver Island, B.C., and transported to the Pacific Biological Station, Nanaimo. There the gametes were pooled, mixed, activated, and incubated at 10°C. Egg diameters of inactivated eggs averaged 7.9 mm. Activation times of small subgroups of eggs were staggered to allow enough time to perform the tests and measurements at the appropriate time intervals. The time intervals from activation were as follows

	Time from activation (hr)																
Test	0	.02	.08	.17	.25	.5	.75	1	1.5	2	4	8	12	24	48	72	96
Shock (drop height, cm)	-[a]	+[b]	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+
Egg weight (mg)	+	-	-	-	+	+	-	+	-	+	+	+	+	+	+	+	+
Egg pressure (atm)	+	-	-	-	-	-	+	-	+	-	+	+	+	+	+	+	+

[a] - no test or measurements at this time.

[b] + shock test or measurement performed.

Each shock test was conducted by placing a single layer of about 30 eggs, without water, in a 60-mm diam × 15-mm petri dish. The petri dish was placed in a chamber of a metal carrier held at heights ranging from 0-50 cm. At a given time from activation the chamber was released and allowed to fall freely, guided by metal wires inside Teflon sleeves. The carrier and chamber were designed to come to a sudden stop upon impact when dropped. This was accomplished in the design by partially filling a hollowed-out portion of the drop-chamber with lead shot. In addition a 2-mm thick plate of synthetic elastomer, with high impact strength and ability to absorb shock, was positioned below the chamber to prevent damage to the metal components of the device with repeated use. The shock (ergs) applied to an egg was calculated based on the drop height (cm), egg mass (g), and acceleration due to gravity (920 $cm \cdot s^{-2}$). At least three drop heights (from 5-50 cm) plus a control (0 cm) were tested and replicated three times at each time interval. After each shock test, the petri dish and its egg sample were placed in water at 10°C to allow the surviving eggs to develop for 7-8 days. Live and dead eggs then were counted and preserved in Stockard's solution for later examination.

Egg mortality from the shock tests was analyzed as follows. First, the threshold time was determined at which eggs in a sequence of tests following activation became significantly more sensitive to mechanical shock in comparison with their controls. This was achieved by analysis of variance of arcsin-transformed egg mortality resulting from shock intensities ranging from 0-13700 ergs. Secondly, the changes in shock sensitivity occurring after egg activation were

determined. Preliminary analysis of data from the first 96 hr was achieved by plotting mean mortality on log-probit paper, corrected for control mortality using Abbott's correction (Finney, 1952), and estimating the TLm (median tolerance limit or shock intensity causing 50% mortality) at each time interval. In instances where the maximum drop height (50 cm) was insufficient to cause 50% mortality the TLm values were estimated by extrapolation from the available data. The TLm estimates were transformed to a shock intensity index for easier interpretation and visualization of the changes that occur in coho egg sensitivity to mechanical shock. This transformation was achieved by taking the reciprocal of the ergs estimated to cause 50% mortality at each time interval from activation.

Individual egg weights were obtained from 10 eggs, each incubated in a separate chamber. At appropriate time intervals each egg was carefully damp-dried on tissue paper, weighed to within 0.1 mg, and returned to the incubation water. The activation times were staggered so each egg was weighed at identical time intervals. No mortalities resulted from the weighing procedure.

Internal egg pressures were measured mechanically using a method described by Eddy (1975). The method is based on the relationship $P = W/A$, where P is the internal pressure, W is the load applied via a flat surface to a spherical object, and A is the flattened area on the egg surface caused by the load W applied. Ten eggs were incubated, each in a separate chamber, and these were remeasured at appropriate time intervals. One egg died in association with the measurement procedures during the 96-hr period.

RESULTS

Shock test results indicated that significant (α = .05) egg mortality began one minute after activation, with egg mortalities (mean $\pm$ 1 standard deviation) of 6.0% (5.4-6.6) and 18.0% (6.5-29.4) resulting from a 30-cm drop (7306 ergs) and a 50-cm drop (12176 ergs), respectively. Shock sensitivity indices, when plotted at their respective times after activation (Fig. 1a), indicate a rapid increase in shock sensitivity to an initial maximum at 10-15 min, followed by a brief drop in sensitivity at 30-45 min. Egg sensitivity then gradually increased 72-96 hr after activation, with sensitivity rising sharply at 96 hr, indicated by the lowest measured drop height (8.4 cm) needed to cause a 50% egg mortality.

Internal egg pressures increased gradually and appeared to reach a plateau about 48 hr after activation (Fig. 1b). The variances associated with mean egg pressures were rather large. However, 96 hr after activation the internal egg pressures were significantly (α = .05) greater than egg pressures prior to and including 4 hr from activation. Changes in egg weights demonstrated that there was a rapid uptake of water within the first hour after activation, with no significant change occurring after that time (Fig. 1c).

DISCUSSION

The changes in coho egg sensitivity to mechanical shock observed for the 96-hr period (10°C) differ significantly from the changes noted by Smirnov (1975) for coho eggs at 8-9.6°C. Smirnov's data describe a rapid rise in sensitivity to an initial maximum 15 min after activation, followed by a reduction in sensitivity during the following period from hr 1 to hr 12. Sensitivity then increased to a second but lower peak 5 days after activation.

Our results indicate a rapid increase in sensitivity with significant egg mortality resulting from a 30-50 cm drop 1 min after activation. An initial peak in sensitivity occurred 10-15 min after activation, similar to but lower than the peak found in the initial period of egg sensitivity in Smirnov's (1975) results. Following this initial peak there was a moderate reduction in sensitivity for a period of about 30 min, compared with the 11-hr period indicated by Smirnov's (1975) data. Egg sensitivity then gradually increased until 72-96 hr after activation when a further rapid increase in sensitivity was observed, similar to that observed by Smirnov (1975) 5 days after activation. The differences between our results and those of Smirnov (1975) most likely reflect differences between the two procedures used for applying the mechanical shock.

Water hardening as a process is not well understood. Our measurements of egg weight and internal egg pressure indicated that two components of this process changed at significantly different rates.

Increase in egg weight, indicative of water uptake, was completed by 1 hr while internal egg pressure gradually rose and appeared to reach a plateau about 48 hr after activation.

A third component of water hardening has been demonstrated by Zotin (1958), who suggested that an enzyme is associated with the initiation of chain polymerization, or hardening, within the zona radiata (egg capsule). Capsule toughness for lake salmon (Salmo salar morpha sebago Girard) and lake trout (S. trutta morpha lacustris Linn) eggs was found to increase to a maximum 3-7 days after activation (Zotin, 1958). This phenomenon could cause a change in elasticity of the egg capsule, which in turn would result in an increase in egg pressures when measured mechanically, as was done in our experiment. Therefore, as water uptake was complete by 1 hr, the gradual increase in egg pressure observed is probably associated with the hardening of the egg capsule. This capsule hardening may also be associated with the rapid increase in egg sensitivity noted 96 hr after activation.

Other variables such as temperature and mineral content of the water also may affect shock sensitivity, since they are known to affect the rate of water hardening (Eddy, 1975; Khlebovich et al., 1977; and Zotin, 1958). In addition, egg size may also affect shock sensitivity since larger eggs develop lower internal egg pressures than smaller eggs (Eddy, 1975; Jensen, unpublished data). It is also likely that sensitivity of eggs to mechanical shock will be found to vary between species and stages of embryonic development. Our work is

aimed at seeking a better understanding of these processes and their possible inter-relationships.

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Fig. 1a. Mean shock sensitivity index ($ergs^{-1} \times 10^{-5}$) ■ and drop height (cm) estimated to cause 50% mortality.

b. Egg pressure (atmospheres $\times 10^{-3}$) means $\pm$ 95% confidence limits ⧗.

c. Egg weight (mg) means $\pm$ 95% confidence limits ⧗.

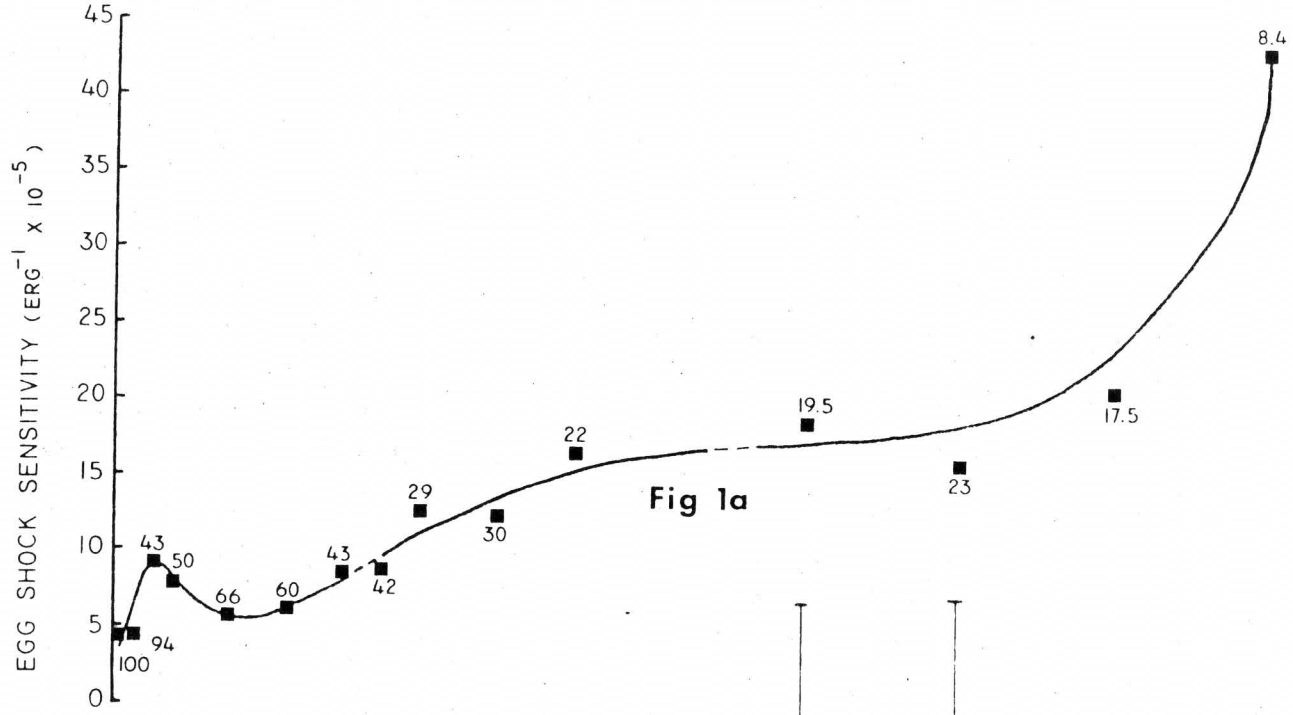

Fig 1a

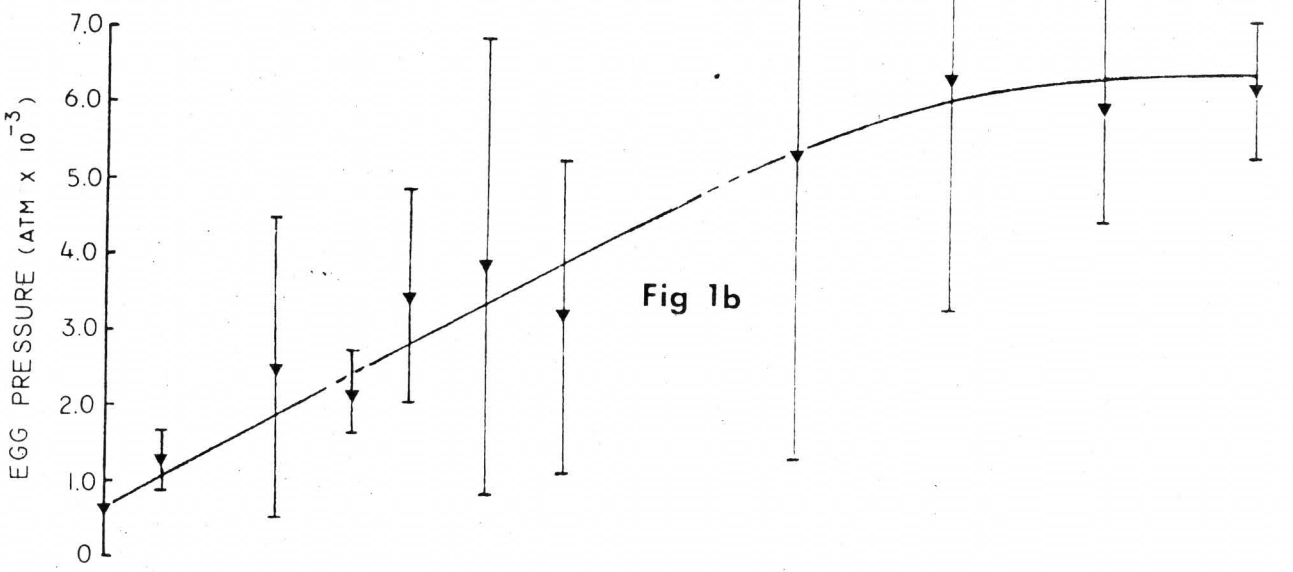

Fig 1b

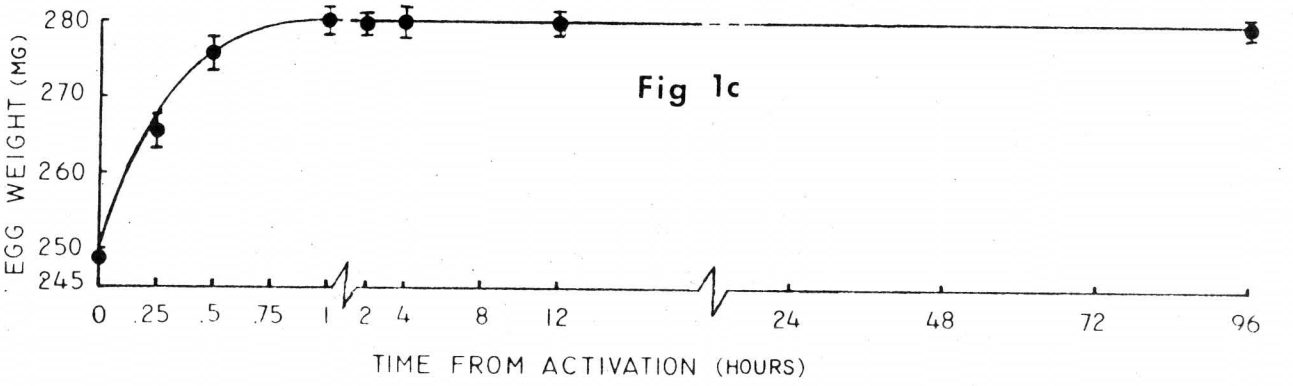

Fig 1c

EFFECTS OF SELECTED HERBICIDES ON SMOLTING IN COHO SALMON

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The 96-h LC50 values of several herbicides to yearling coho salmon Oncorhynchus kisutch were determined. All 96-h testswere conducted under static conditions at 10°C in freshwater of alkalinity and hardness ranging from 70-83 mg/L and 85-93 mg/L (as $CaCO_3$) respectively. The herbicides acrolein and dinoseb were the most toxic of the 12 water soluble herbicides tested, having 96-h LC50 values of 68 and 100 µg/L respectively. Atrazine, diquat and picloram were moderately toxic in freshwater with 96-h LC50 values ranging from 10-30 mg/L.

Fish exposed to Amitrole-T, diquat and paraquat in freshwater all exhibited dose - dependent effects in subsequent seawater entry tests. The other herbicides tested produced little or no dose - related mortality when fish were challenged with seawater. No apparent affects on the (Na,K) - stimulated ATPase activity of the gills were observed with any of the herbicides tested.

The effect of sublethal concentrations of Tordon 101, dinoseb and diquat on migratory disposition was tested by releasing herbicide - exposed salmon into a natural stream; only diquat produced a significant reduction in downstream migration.

Under normal (field) application acrolein and dinoseb could affect survival of all life stages of salmonids if water from treated irrigation ditches were released into the stream or river without sufficient holding or detoxifying time. The use of diquat at recommended treatment levels could reduce downstream migration of smolts and possibly affect their survival in seawater. All other herbicides formulations tested appeared to have no effect on smolting of yearling coho salmon; however, atrazine has been shown to affect growth of young salmonids and survival of invertebrates at very low concentrations. Effects of the herbicides on other life stages of coho salmon or different formulations of the herbicides might produce considerably different results.

Reference:

Lorz, H.W., S.W. Glenn, R.H. Williams, C.M. Kunkel, L.A. Norris and B.R. Loper. 1979. Effects of Selected Herbicides on Smolting of Coho Salmon. U.S. Environ. Prot. Agency. Ecol. Res. Ser. EPA 600/3-79-071. Corvallis, Oregon. 103 pp.

The Muddy Road Home or Who Put This Mountain in My River

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On the morning of May 18, 1980 a violent eruption of Mt. St. Helens took place. Immediately following the eruption a series of two large mud and debris flows occurred in the Toutle River. Total effects on the fishery resource are still undetermined but at the time, it was felt that a total loss of juveniles and adults in the Toutle and Cowlitz rivers, below their confluence, had occurred.

Toutle Salmon Hatchery, located close to the mountain on a tributary of the Toutle River, was damaged heavily by the second large mudflow of May 18. Ponds were buried by debris and the facility is currently closed. These flows occluded the Cowlitz River and a portion of the Columbia River. Water was still able to flow but turbidity and temperature were high and live box tests in the Cowlitz River showed mortality of juveniles to be 100%.

Of immediate concern to WDF Salmon Culture Division was the effect of this high turbidity on adult salmon returning to Cowlitz Salmon Hatchery. The spring chinook run had just begun.

As a means of determining the effects on adults it was decided to recycle some of the adults through the affected area.

Adults were continuing to arrive at Cowlitz Salmon Hatchery but in low numbers. The trapping facility was allowed to fill with fish so adequate numbers could be obtained on a single day for marking and trucking.

On June 4, 200 fish were selected from the trapping area separated into four groups and tagged differentially with Petersen disc tags and flags. Release data are shown in Table 1 and Figure 1.

Recoveries were obtained from the Cowlitz Salmon Hatchery, sport caught fish and fish found dead in the Cowlitz River. Recovery data by week are tabulated in Table 2 and Figure 2.

It appears the turbidity did not have a large adverse effect on adult migration. Subsequently, it was determined from the recovery of tag adults at Cowlitz and Kalama Falls hatcheries that straying of fall chinook and coho adults originating at Toutle Hatchery was occurring. The degree of this straying is still unquantified.

Table 1. Release data - Cowlitz Spring Chinook.

Release Site	Date	Number	Tag Color	Distance from Cowlitz Hatchery
I-5 Bridge	6-4-80	50	Yellow	20.1 miles
Kelso	6-4-80	50	Red	45 miles
Weyerhauser	6-5-80	50	Green	54.3 miles
Kalama	6-5-80	50	White	56.8 miles

Table 2. Cumulative Tag Recoveries.

Week Ending	Release Site I-5	Kelso	Longview	Kalama
July 5	8	4	6	4
July 12	9	11	12	6
July 19	9	12	15	9
July 26	11	16	19	10
Aug. 2	13	16	20	13
Aug. 9	14	18	21	15
Aug. 16	16	20	21	15
Aug. 23	24	21	22	17
Aug. 30	25	24	22	18
	(50%)	(48%)	(44%)	(36%)

Figure 1. Area map with release sites.

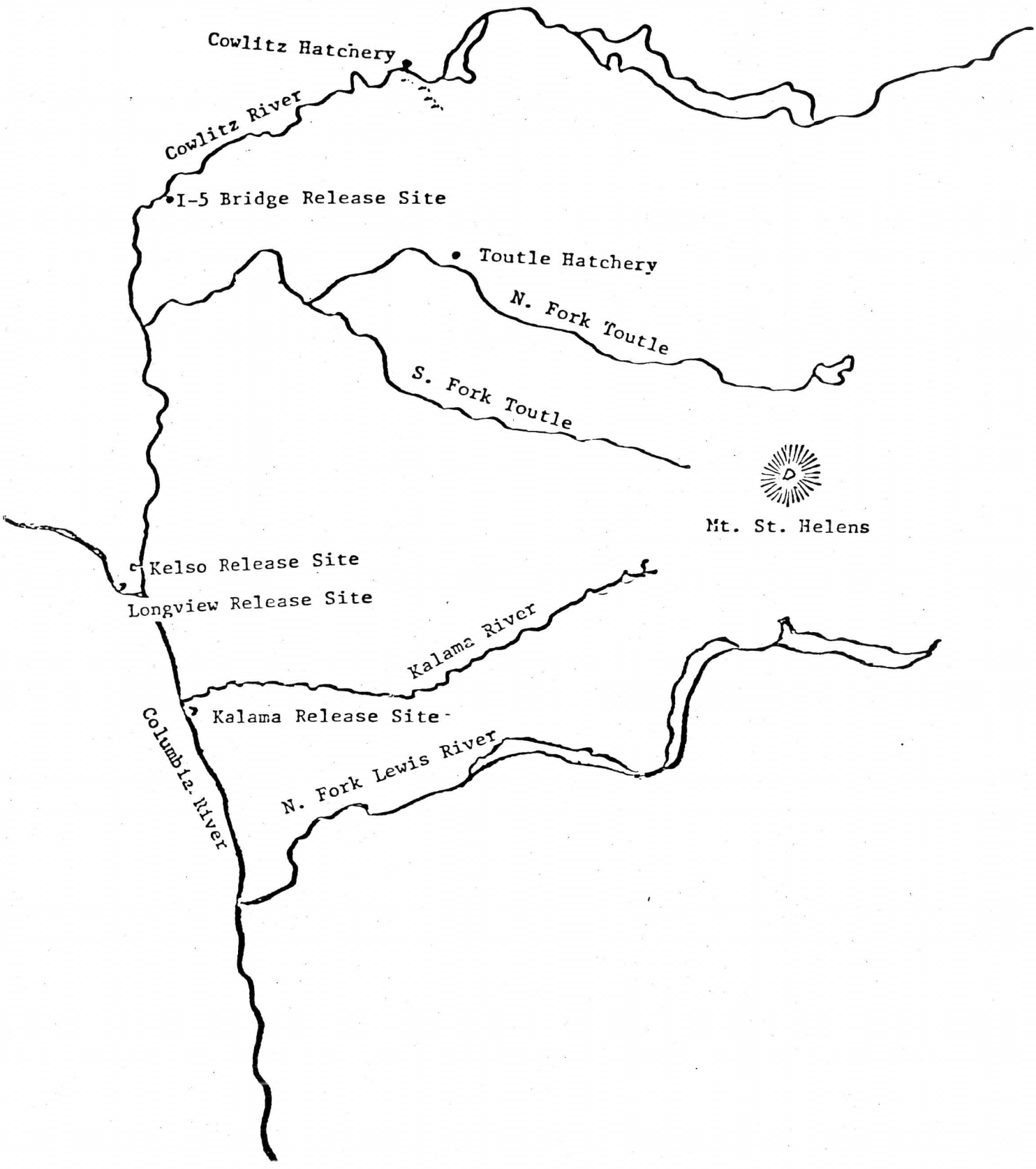
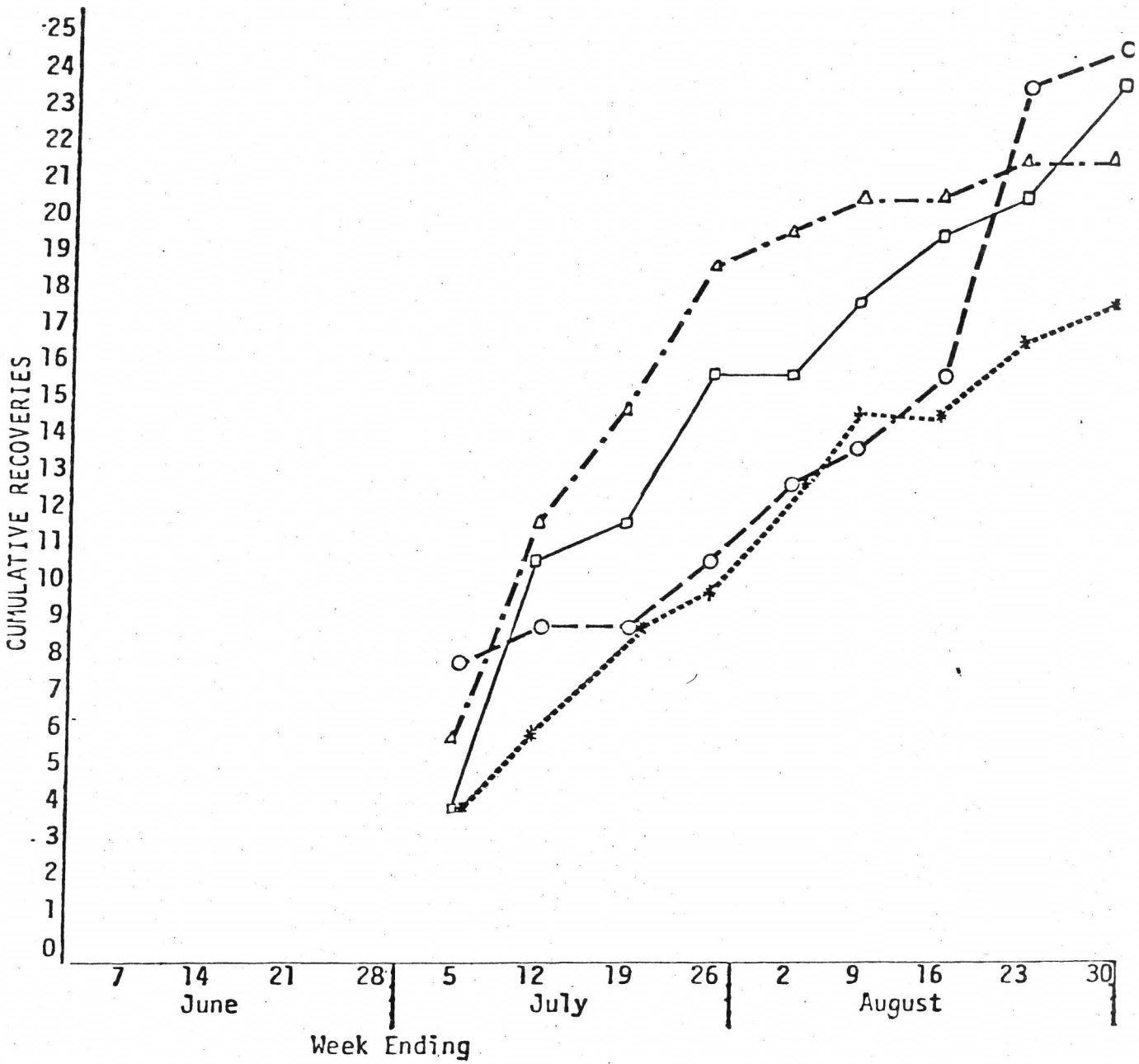


FIGURE 2 - Tag Recoveries

Release Site	Distance from Cowlitz Hatchery
I-5 Bridge	20.1 miles
Kelso Water Plant	45 miles
Longview Boat Ramp	54.3 miles
Kalama Boat Basin	56.8 miles



DEVELOPMENT OF A COHO SALMON (Oncorhynchus kisutch) BROODSTOCK HOLDING SYSTEM FOR A COMMERCIAL OCEAN RANCHING PROGRAM AT OREGON AQUA-FOODS

by

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Introduction

A recent workshop (May 1980) on Salmonid Broodstock Maturation held at the University of Washington documented that maturation entirely confined to salt water is deleterious to adult brood stock survival and resultant egg fertility of some stocks of coho salmon, pink salmon and chum salmon as returning brood stock or for coho salmon as captive brood stock (Nosho 1980).

This paper is an effort to describe results with the saltwater maturation of coho salmon compared to freshwater maturation in a commercial ocean ranching context in Oregon state.

The coho salmon juveniles produced at the Oregon Aqua-Foods facilities are incubated and reared at the freshwater hatchery on the McKenzie River in Springfield, Oregon, and smolts are transported by truck to saltwater facilities at Yaquina and Coos bays on the coast of Oregon. Within these two saltwater sites, smolts are reared for an additional two weeks prior to being released into the ocean. The returning adults which were imprinted as smolts, return to the saltwater sites where they will remain during the maturation period

or be transferred by truck to the freshwater hatchery for maturation and spawning.

Adult coho salmon return to South Beach, on Yaquina Bay, from mid-August to late November. The period of maturation lasts from 50 to 100 days during which time the salinity may vary from 28-32 g/l. Time of spawning varies from year to year as the stocks of coho salmon are an admixture of Oregon coastal and Puget Sound origin. In the 1978 brood year, adult coho salmon were transferred by truck in 1,900 liter smolt hauling tanks to Wright Creek, a freshwater stream, in order to complete final maturation and compare to fish which remained at South Beach. In the 1979 brood year, some adult coho salmon were transferred to Wright Creek, but the majority were transferred to a ground water brood holding facility at Turner, Oregon. This facility had a constant temperature of 14°C. In the 1980 brood year, the majority of the brood stock were transferred to the freshwater hatchery at Springfield while a few experimental groups remained in saltwater at the South Beach facility on Yaquina Bay.

Results

Broodstock Survival

Survival of female coho salmon brood stock has always been higher in freshwater holding facilities than in similiar facilities in salt water, i.e., brood years 1976, 1979, and 1980 (Table I).

The highest survivals have been achieved when the source of fresh water has been an ambient surface water stream or river with a declining temperature regime, specifically the 1976 and 1980 brood year (Table I). Survival rates of female coho salmon held in an approximately constant salinity regime of 28-32 g/l in Yaquina Bay, Oregon which have been in good health, will range from 60 to 65 percent except for the 1976 and 1979 brood years (Table I). The survivals of female brood stock during the 1976 and 1979 brood years were compromised by bacterial infections of Vibrio anguillarium in the former and Furunculosis salmonicida in the latter.

Egg Fertility

While the 1980 brood year egg fertility data is preliminary, it clearly suggests that an ambient water source with a declining temperature regime (McKenzie River) is a superior brood stock maturation environment (Table II). Data from the 1978 and 1979 brood year with the ambient freshwater stream held brood stock would presumably be equivalent to the 1980 brood year with ambient hatchery water held brood stock, but a three to four hour transport time is necessary with the former (Table II).

The consistency of poor fertility from salt water held brood stock over three discrete brood years suggest a fundamental reproductive problem is retarding the actual fertilization process for the majority of females mated in this environment, however, fertile females do

Discussion

In order for ocean ranching of coho salmon to be commercially successful, adult salmon must return to salt water so that the product quality is equivalent to an ocean-caught product. It does not appear to be feasible in the near term to obtain satisfactory brood stock performance in either adult survival or egg fertility by maintaining brood stock facilities entirely in salt water (28-32 g/l). Given the range in egg fertility observed in salt water held brood stock over the 1978, 1979, and 1980 brood years, it appears that the potential exists for genetic selection of a salt water held coho salmon brood stock either in an ocean ranching context or a captivity brood stock situation. This is clearly a long term solution.

Osmotic stress in salt water held brood stock would seem to be the reasonable cause of adult prespawning mortality, but the specific cause and effect relationship is not known. It does not appear that osmotic stress, i.e., high levels of blood serum electrolytes is related to low fertility in salt water held coho salmon brood stock or vice versa and therefore other factors, which are presently undefined, such as disease state, stock, method of fertilization, etc., individually or in combination are responsible.

It is quite obvious that transporting adult coho salmon brood stock from salt water to fresh water in order to complete the maturation phase and spawn is the method of choice if the fresh water source is an ambient declining temperature regime.

exist as is evidenced by the range in egg fertilities (Table II). Data described in an earlier paper, point out that the female accounts for 53 to 56 percent of the variability in egg fertility in salt water for the 1978 and 1979 brood year, whereas, the male accounts for 38 to 35 percent respectively (Allee 1980). It would seem to be plausible to hypothesize that osmotic stress was responsible for the lowered egg fertilities in salt water held brood stock but no correlation was found between serum blood sodium, osmolality of males and females or intracellular egg osmolality, and egg fertility.

Table 1

COMPARATIVE SURVIVAL OF FEMALE COHO SALMON BROOD STOCK FROM 1976, 1977, 1978, 1979 AND 1980 BROOD YEAR BY HOLDING ENVIRONMENT

	Percent Survival of Female Coho Salmon by Brood Year				
	1976	1977	1978	1979	*1980
FRESHWATER					
Ambient Stream Water	95	--	--	56	--
Ground Water (14°C)	--	--	--	61	--
Ambient Hatchery Water	--	--	--	--	98
Tempered Hatchery Water (14°C)	--	--	--	--	97
SALTWATER					
Ambient Estuarine Water	14	65	60	13	62

*Preliminary data

Table 2

COMPARATIVE COHO SALMON EGG FERTILITIES
FROM 1978, 1979, and 1980 BROODYEAR
HOLDING ENVIRONMENT

	Percent Egg Fertility at 80 CTU's					
	1978 Brood Year		1979 Brood Year		*1980 Brood Year	
	$\bar{X}$	Range	$\bar{X}$	Range	$\bar{X}$	Range
FRESHWATER						
Ambient Stream Water	77	0–100	84	--	--	--
Ground Water (14°C)			56	0–99	--	--
Ambient Hatchery Water					91	85–100
Tempered Hatchery Water (14°C)					69	18–98
SALTWATER						
Ambient Estuarine Water	56	0–100	50	0–97	58	0–96

*Preliminary Data

Table 3

EFFICACY OF TERRAMYCIN IN COHO SALMON BROOD STOCK HELD IN FRESH WATER FROM 1979 AND 1980 YEARS

	Percent Survival of Coho Salmon Brood Stock By Brood Year	
	1979	*1980
AMBIENT GROUND WATER (14°C)		
Saline Injection	67	
Terramycin Injected	97	
AMBIENT HATCHERY WATER		
Saline Injected		99
Terramycin Injected		99
TEMPERED HATCHERY WATER (14°C)		
Saline Injected		88
Terramycin Injected		95

*Preliminary data

Table 4

PRELIMINARY COMPARATIVE MATURATION TIME
AND EGG FERTILITY FOR COHO SALMON BROOD STOCK
BETWEEN INDUCED OVULATION GROUPS AND CONTROL GROUPS
BY BROOD HOLDING ENVIRONMENT

	Average Days To Spawning	Percent Fertility
FRESHWATER		
Ambient Hatchery Water		
Hormone Injected	17.7	95
Saline Injected	27.0	93
Tempered Hatchery Water (14°C)		
Hormone Injected	14.5	69
Saline Injected	32.6	93
SALTWATER		
Ambient Estuarine Water		
Hormone Injected	13.1	58
Saline Injected	26.1	68

Table 5

COHO SALMON BROOD STOCK MALE VS. FEMALE
INFLUENCE ON EGG FERTILITY

	Brood Year 1978		Brood Year 1979	
	Female	Male	Female	Male
SALTWATER				
South Beach	53%	38%	56%	35%
FRESHWATER				
Wright Creek	94%	0%		
Turner (14°C)			84%	8%

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Nosho , T.,1980. Editor of Salmonid Broodstock Maturation Workshop. University of Washington (in press).

PROGRESS TOWARD DEVELOPING A SURVIVAL ENHANCEING DIET FOR PACIFIC SALMON

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Survival of Pacific salmon smolts released from Oregon hatcheries has declined in recent years, judging from numbers released and caught, coho salmon in particular. Although there may be several factors causing this decline, I believe post-release survival can be increased by feeding higher quality protein. This contention is supported by information supplied by Dr. L. R. Donaldson of the University of Washington. At UW, fall chinook salmon fed a diet consisting essentially of vacuum-dried and evaporated fish, very high quality protein and fat, apparently survive at several times the rates of those fed OMP at nearby hatcheries. One year UW fed OMP. Fish size was down to 75% of usual and returns were only 25% of expected.

High quality protein may increase survival by promoting faster growth, and thus larger fish at release. That may be particularly beneficial in the case of fall chinook salmon. In addition, even when fish size is held equivalent, perhaps the nutrition that would promote faster growth might also increase survival of the same size fish. This might be particularly important with coho salmon, which most diets grow to acceptable size in Oregon. I have no idea what it might be about protein quality that could promote larger fish, assuming all the essential amino acids are available to the fish in the right proportions.

The approach we are taking to improve protein quality is to replace nonfish protein with fish protein and to replace regular fish meal protein with low temperature processed fish protein. Low temperature processed fish protein may take the form of vacuum-dried fish meal and pressed or evaporated fish,

and has the added advantage of having the lipid fraction less oxidized than that found in conventional fish meal.

In our first laboratory feeding trial, we compared our standard OMP-2 containing regular herring meal; OMP-4 diets containing regular herring meal, vacuum-dried salmon meal, and steam-tube dried fish meal; and the University of Washington moist diet containing mostly vacuum-dried and evaporated salmon. The regular herring meal originated in British Columbia and contained a maximum of 5% salt. The OMP-4 is similar to OMP-2, except it has an equivalent protein level (52%) supplied entirely from fish sources (plus a small amount of nonfish protein), and also a higher fat level (22% versus 18%). The diets were fed ad libitum for 12 weeks to duplicate lots of fall chinook salmon averaging 1.65 grams at the start and reared at 12 C.

Table 1 summarizes results of this first trial. OMP-4 with regular herring meal produced significantly ($P<0.05$) more weight gain than OMP-2, but food conversion was no better. When vacuum-dried salmon meal replaced regular herring meal on an isonitrogenous and isocaloric basis, improvement in growth and feed conversion was truly phenomenal, being equalled only by the University of Washington diet. Steam-tube dried capelin meal did not produce significantly ($P<0.05$) more growth than regular herring meal, but it did give a better feed conversion.

Our second laboratory feeding trial was conducted with triplicate lots of spring chinook fingerlings averaging 17.2 grams each at the start. It lasted for 20 weeks. Feeding and water temperature conditions were the same as in the first trial, ad libitum and 12 C.

Results (Table 2) show OMP-4 again superior to OMP-2, but we failed to repeat the phenomenal performance of vacuum-dried salmon meal. Batch No. 1 was the same as used in the first feeding trial. Both were more than a year old when the second trial ended, although supposedly protected with antioxidant. The University of Washington provided the salmon meals, and communicated their experience that vacuum-dried fish meal often performs best with relatively small fish. The test fish in this second trial were much larger than the first.

We recently completed our third feeding trial, after 23 weeks. In this study we compared OMP-2 versus OMP-4 with regular herring meal, vacuum-dried hake meal in OMP-4, a new presscake diet composed mostly of the pressed fish before drying into meal, and salmon meal from unspawned fish with and without heads and gonads. The salmon meal was freeze-dried, not because we thought it was economical, but because we wanted to get a fix on whether hormones had any influence on the excellent growth we experienced previously. The presscake diet contained 71% presscake, 11% herring meal, 6% fish oil, plus vitamins and binders. We used duplicate lots of spring chinook salmon, averaging 4.8 gm at the start, and reared at 12 to 13 C. We attempted to feed an equal dry weight of food per fish.

Results of this third trial are given in Table 3. OMP-4 produced more fish weight gain but not longer fish than those fed OMP-2. When vacuum-dried hake meal replaced regular herring meal, neither fish length nor weight increased significantly. Freeze-dried salmon meal with heads and gonads intact produced significantly longer fish than all others. When the heads and gonads were removed, weight gain was the same, being equalled only

by presscake, but the fish were significantly shorter. Determination of fish carcass proximate analysis has not been completed.

Since the purpose of this work is to develop a diet that will enhance survival of Pacific salmon, we are also conducting hatchery scale feeding trials of OMP-4 and presscake that include coded wire tagging. Our plan is to coded wire tag 3 brood years of fall chinook and coho salmon. We expect our first tag recoveries in 1982.

Table 1. Summary of Results, First Laboratory Feeding Trial 1/

Diet Fed	Fish Size (gm)	Weight Gain (%)	Feed Conversion As Fed 3/	Feed Conversion Dry Weight 4/
OMP-2 Regular Herring Meal	12.9	668c	1.46	1.020c
OMP-4 Regular Herring Meal	13.3	720b	1.40	1.060c
OMP-4 Vacuum-dried Salmon Meal	18.3	1,026a	0.90	0.675a
OMP-4 Steam-tube Dried Fish Meal 2/	13.8	757b	1.26	9.980b
University of Washington	18.5	1,012a	1.11	0.645a

1/ *Means in a column with the same letter do not vary significantly (P>0.05).*

2/ *Mostly capelin.*

3/ *Wet weight of food/wet weight of fish gain.*

4/ *Dry weight of food/wet weight of fish gain.*

Table 2. Summary of Results, Second Laboratory Feeding Trial 1/

Diet Fed	Fish Size (gm)	Weight Gain (%)	Feed Conversion As Fed 2/	Feed Conversion Dry Weight 3/
OMP-2 Regular Herring Meal	59.6	244b	1.55	1.10b
OMP-4 Regular Herring Meal	66.2	286a	1.28	0.94a
OMP-4 Vacuum-dried Salmon Meal #1	69.1	300a	1.27	0.91a
OMP-4 Vacuum-dried Salmon Meal #2	70.9	311a	1.22	0.88a

1/ *Means in a column with the same letter do not vary significantly (P>0.05).*

2/ *Wet weight of food/wet weight of fish gain.*

3/ *Dry weight of food/wet weight of fish gain.*

Table 3. Summary of Results, Third Laboratory Feeding Trial 1/

Diet Fed	Fish Size (gm)	Fish Size (mm)	Weight Gain %	Feed Conversion Dry Weight 2/
OMP-2 Regular Herring Meal	52.2	159.3e	976d	0.85c
OMP-4 Regular Herring Meal	55.2	160.5de	1,068c	0.81bc
OMP-4 Vacuum-dried Hake Meal	58.3	162.5cd	1,120bc	0.77b
OMP-4 Salmon Meal #1	64.8	170.7a	1,240a	0.69a
OMP-4 Salmon Meal #2	64.9	167.4b	1,240a	0.68a
Herring Presscake	61.3	166.0b	1,177ab	0.79b

1/ *Means in a column with the same letter do not vary significantly (P>0.05).*

2/ *Dry weight of food/wet weight of fish gain.*

GROWTH RATES OF JUVENILE CHUM IN COLD WATER FED ON FIVE DIFFERENT RATION TYPES

by

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INTRODUCTION

On the west coast of North America many chum hatcheries are being developed. Most of these projects will have to be adapted to their geographic location. At remote locations well water, refrigeration, electricity and extensive freshwater rearing facilities may not be available for chum enhancement. Rearing for imprinting in salt water as is presently carried out by the Southern Southeast Regional Aquaculture Association in Alaska necessitate ponding chum at extremely low temperatures (2.5^{o}C) and switching from a refrigerated diet to a dry diet.

The main objective for the experimental study, funded by the Department of Fisheries and Oceans, Special Projects Division was to duplicate and test a special diet made for coldwater feeding on summer chum fry in Alaska.

Frozen euphausiids were added to the Oregon Moist Pellets with the wet fish components being removed at Moore Clarke & Co., and several other diets were tested to determine which would easily adapt to the various rearing conditions mentioned.

*Part of this work was carried out under contract with the Department of Fisheries, Special Projects Division, 1090 West Pender Street, Vancouver, B. C.

METHODS

The experimental study on Oncorhynchus keta was done at the Conuma Hatchery on Vancouver Island, B. C. Only ambient temperature hatchery water 3.1°C to 7°C was used for this feeding experiment from March 7 to May 18, 1980.

Two thousand unfed chum fry with a mean of 0.41 grams (1,118/lb) were randomly assigned in duplicate to 20 experimental tanks. Hand feeding was conducted six times daily from 8:00 a.m. to 6:00 p.m. Fifty-four chum fry were randomly sampled from each tank on a weekly basis and individually weighed and measured after 12 hours starvation.

In Experiment I five commercially available diets were compared and the amounts of all the food fed was corrected on a dry weight basis to the moisture content of the O.M.P. control diet.

Diet	Approx. Price/lb	$\bar{x}$ Dry Wt. %
O.M.P.	0.32	72.4
O.M.P. with plankton substitute	0.75	72.4
Silver Cup	0.25	97.7
Freeze dried Plankton	6.00	96.5
Bio-Diet	0.55	79.2

In Experiment II O.M.P., O.M.P. with plankton and Freeze dried Plankton were changed to Silver Cup after 35 days (0.7 gm) to represent a hypothetical move to a remote location.

Samples of all diets and fish were sent to be analyzed at the Pacific Environmental Institute at the start and finish of the experiment.

In the Production Test on 1.3 million summer chum O.M.P. with the plankton substitute and regular O.M.P. were fed to two lots of juvenile fish for 35 days at the Whitman lake hatchery in Ketchikan, Alaska.

Temperatures at the hatchery ranged from 2.4 C to 2.9 C. All fry were fed regular O.M.P. for the remaining 31 days until transferred to the saltwater netpen site at Nakat Inlet. After saltwater adaptation the juvenile chum were fed a 50% mixture of O.M.P. and Silver Cup for 42 days until released.

RESULTS

Experiment I

In this experiment the growth rate of the five diets tested were compared (Table 1).

The final wet weights showed, by using a t-test at $p = 0.05$ level, the regular O.M.P. diet was significantly less productive than Bio-diet or freeze-dried plankton. However, the regular O.M.P. was significantly better than the Silver Cup diet. No significant difference was seen between the O.M.P. diet and the O.M.P. diet supplemented with the frozen plankton (see Fig. 1).

Mortalities occurred with every diet mainly due to pinheading. Highest mortality and death of large healthy fry occurred in the chum lots fed on freeze-dried plankton due to gut blockage.

Experiment II

In this experiment three different feeding regimes were compared. The two O.M.P. diets and freeze-dried plankton were changed over to Silver Cup after 35 days of feeding at the mean weight of 0.7 gm (Table 1).

Final weight analysis showed that the O.M.P. and plankton supplemented O.M.P. followed by Silver Cup were not significantly different from one another.

All daily specific growth rates dropped significantly after the diet changeover, (Fig. 2).

Mortality rates were about the same as that of the control diet.

Production Test

Chum fry fed for 66 days in fresh water with water temperatures from 2.4°C to 2.9°C (Table II). After 35 days of feeding the O.M.P. with plankton substitute no advantage was noted over the regular O.M.P. control diet and all fry were fed O.M.P. for their remaining days in freshwater raceways.

After being moved to netpens in 25‰ salinity the fry were fed a mixture of O.M.P. and Silver Cup for 42 days with saltwater temperatures ranging from 5.5°C to 8.0°C.

Growth rates did not drop after the transfer to salt water or the changeover to the mixed diet (Fig. 3).

CONCLUSION

Growth of juvenile chum under cold water conditions did not improve by supplementing O.M.P. with plankton. The new fish food, Bio-Diet" proved superior to all other diets tested. The fish fed on Bio-Diet were 30 percent heavier than the O.M.P. control. We concluded after these and other tests on juvenile salmon to recommend the Bio-Diet for rearing in remote locations. Ground freeze-dried euphausiids may prove a good starter diet for Japanese style keeper ponds and spawning channels for its buoyancy will eliminate fouling of the substrate.

Switching the diet for feeding juveniles from O.M.P. and freeze-dried plankton directly to Silver Cup proved poor practice as is well known to fish culturists. However, in saltwater netpens when a mixture of 1/2 O.M.P. and 1/2 Silver Cup was used good growth rates were achieved in all fish.

Table 1. -- Summarized Experimental Data - Conuma Hatchery — Fall chum $\bar{x}$ temp. - 4°C

Experiment	Diets - 65 days	Start Wt. $\bar{x}$ gm.	Final Wt. $\bar{x}$ gm.	S. Dev.	$\bar{x}$ Specific Growth Rate %/day	Mortality
I	O.M.P.	0.41	1.05	0.30	1.45	2.8
II	O.M.P./Silver Cup	0.41	0.94	0.29	1.27	2.3
I	O.M.P., Plankton	0.41	1.09	0.29	1.50	1.8
II	O.M.P. + Plankton/Silver Cup	0.41	0.88	0.33	1.18	2.2
I	Freeze-dried Plankton	0.41	1.23	0.20	1.69	5.1
II	Freeze-dried Plankton/Silver Cup	0.41	0.73	0.24	0.88	6.2
I	Silver Cup	0.41	0.88	0.33	1.18	3.8
I	Bio-Diet	0.41	1.37	0.25	1.86	1.5

Table II. -- Production Data - Whitman Lake Hatchery - Summer Chum

Experiment	Diets	Start Wt. $\bar{x}$ gm.	Final Wt. $\bar{x}$ gm.	S. Dev.	$\bar{x}$ Specific Growth Rate %/day	Mortality
-	*O.M.P., Plankton - 35 days	0.423	0.614	-	1.06	0.4
-	*O.M.P. - 33 days	0.423	0.634	-	1.2	0.4
-	*O.M.P. - 31 days	0.624	0.814	-	0.851	0.4
-	**Salt water - 42 days O.M.P. 50%, Silver Cup 50%	0.813	2.71	-	2.87	0.5

*Freshwater $\bar{x}$ temperature - 2.6 C.
**Saltwater $\bar{x}$ temperature - 6.3°C

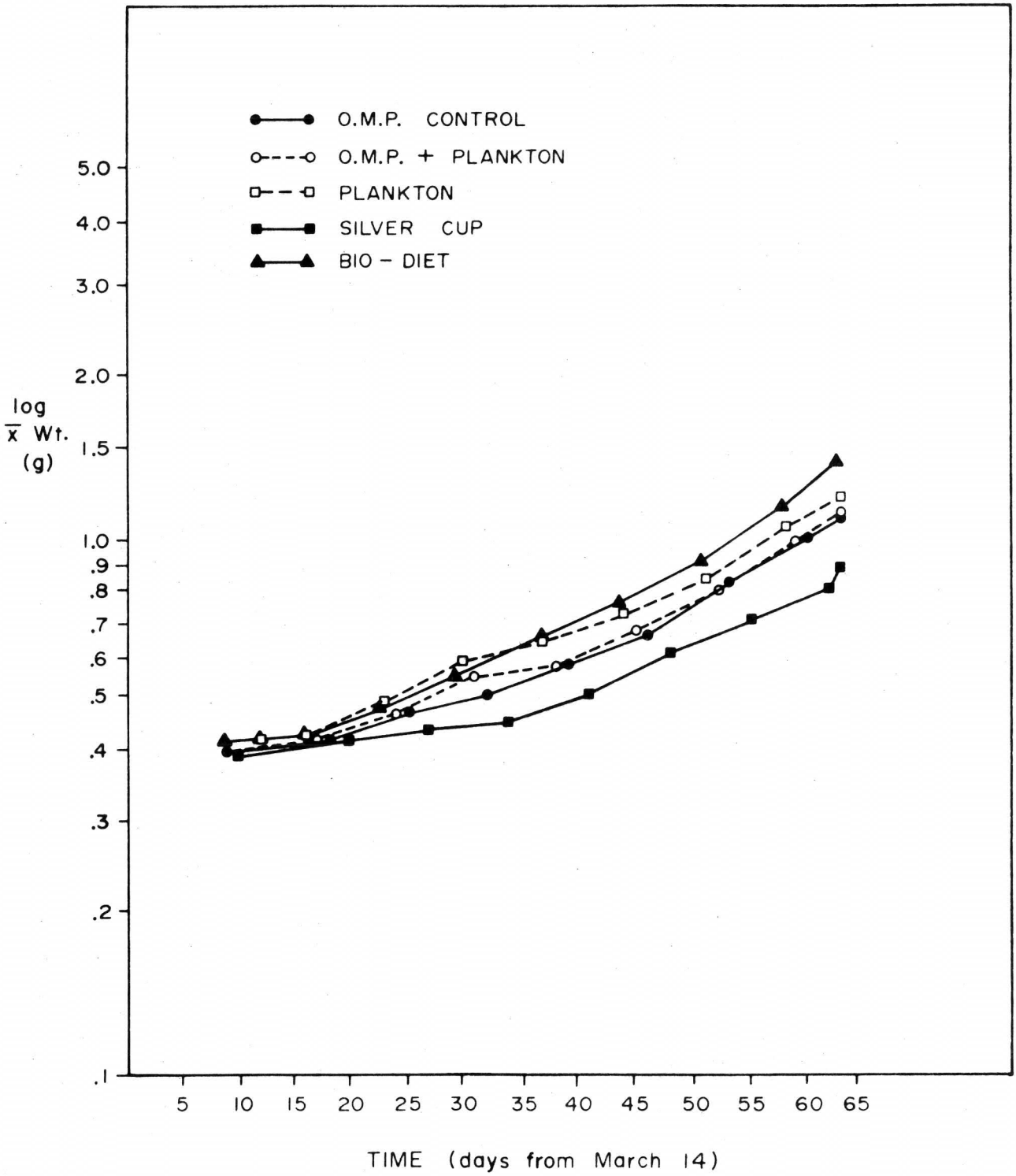

Fig. 1. Exp. I. Growth rates for various diets (mean temp. 4°C).

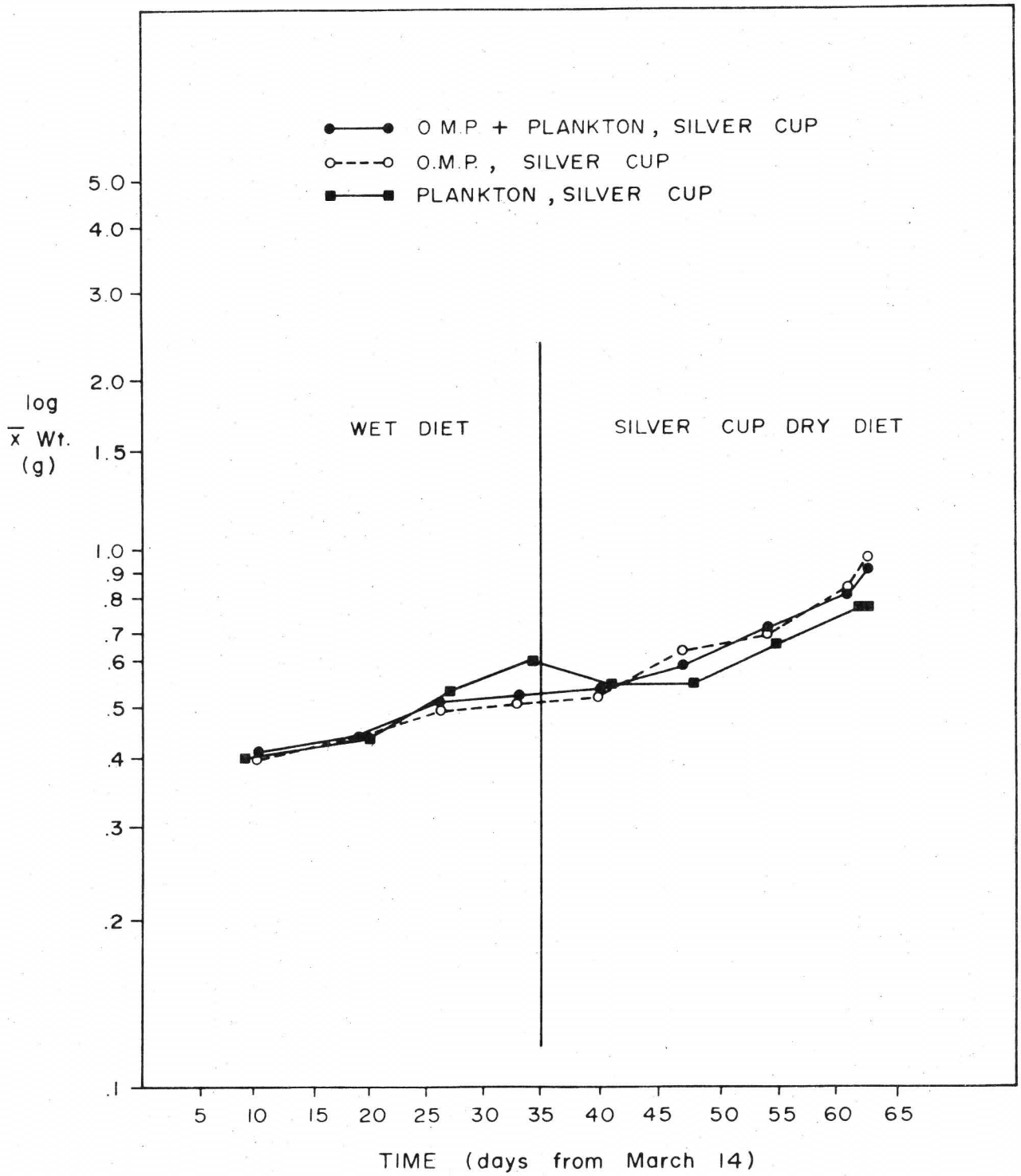

Fig. 2. Exp. II. Growth rates on starting diets followed by Silver Cup dry diet on 36th day.

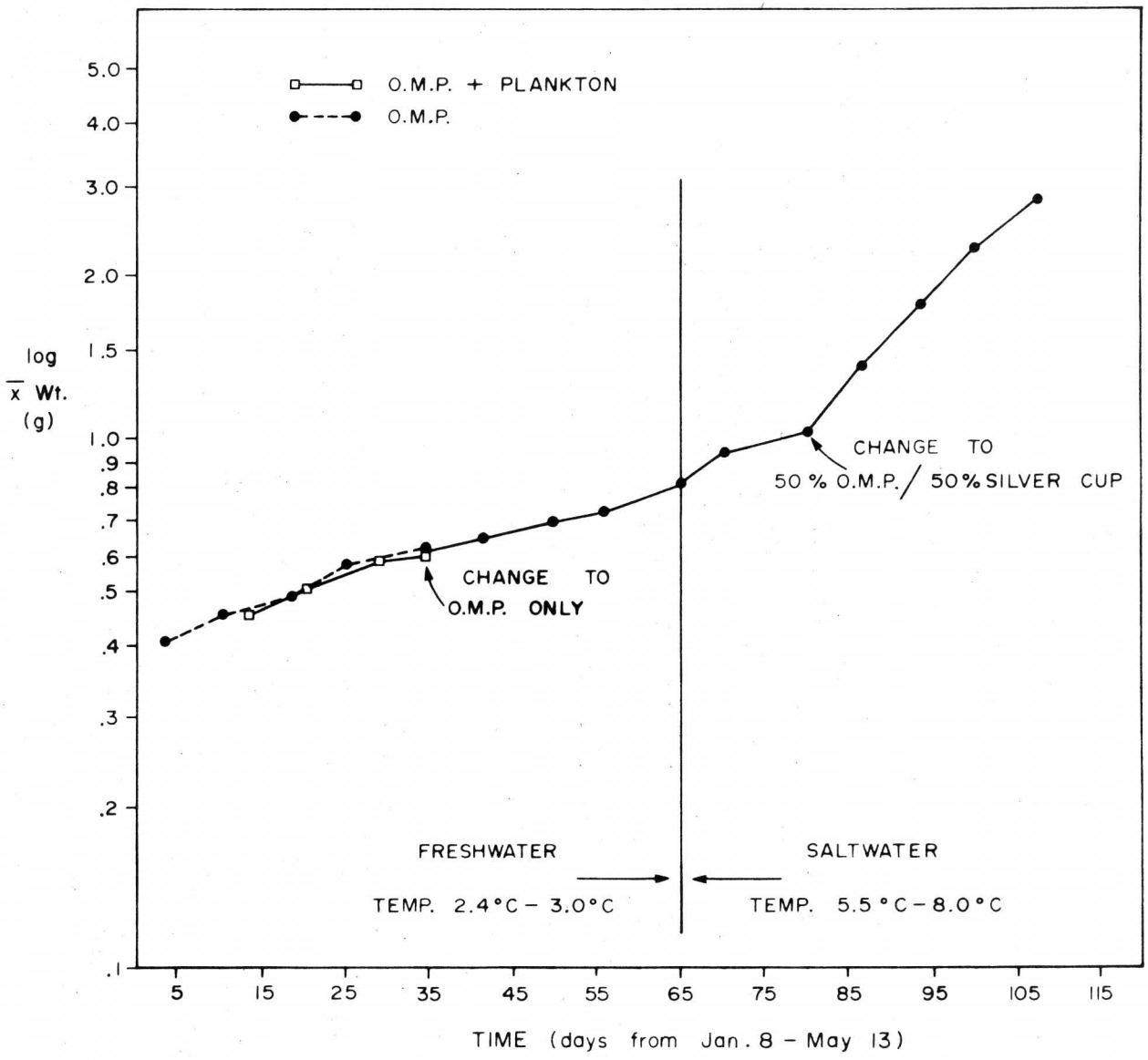

Fig. 3. Growth rates of Summer chum production lot.

CHINOOK SALMON DIETS BASED IN PRESCRIBED PERFORMANCE AND BODY COMPOSITION

by

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There is very little information on the chemical and physiological condition of cultured salmon fingerlings, and how smolt quality influences adult survival. Burrows (1969) attributes the differences in the characteristics of hatchery reared fish to genetic, pathological, environmental and nutritional factors.

Fundamental information on the nutritional quality of food protein sources is required to facilitate the formulation of successful diets for the Salmon Enhancement Program. The utilization of dietary protein is affected by the quality and digestibility of the ingredients, the proportion of protein in the diet, the proportions of the other nutrients in the diet, appetite, the genetic potential and rearing conditions for the fish.

Two experiments were carried out at the West Vancouver Laboratory to investigate the influence of very high quality dietary protein, lipid and carbohydrate levels on the performance and body composition of chinook at release time. This information could then be applied as a basis for quantitatively evaluating commercial fish feed ingredients under standard conditions.

Three levels of dietary fat (6, 13 and 20%) were fed with each of five levels of dietary protein (15, 25, 35, 45 and 55%) (Table 1). The protein was supplied by freeze dried pollock muscle and euphausids. Freeze drying best preserves the nutritional integrity of the natural ingredient

for fish diet purposes. Euphausids were included because we think that they may provide a flavor enhancer to salmon food Dextrin which is partially hydrolyzed starch, and, dextrose which is glucose monohydrate are highly digestible carbohydrates. Cellulose is a non-nutritive diet filler. The diets were formulated to contain identical amounts of vitamins and minerals. Each diet was fed to duplicate groups of 150 fish per 110 litre tank held at 11.5°C. Fish were fed by hand three times daily to satiation.

The pollock based diets supported good weight gains under laboratory conditions (Fig. 1). The results indicate that dietary protein levels may be substantially reduced by selecting a good protein source. For example, a casein (milk protein) diet, H440, supported poor weight gain compared to OMP and a pollock based diet of similar dietary protein level. Casein is deficient in the amounts of certain amino acid constituents of protein that are necessary for fish. Freeze dried pollock muscle contains a better proportion of these essential components of protein (amino acids) therefore less protein is required to support growth. The weight gain may have been greater had the experiment been initiated earlier in the year to take advantage of a longer daylight period.

The following year we tested levels of dietary protein at 15, 25 and 35%. There was a marked response to protein level in the diet (Fig. 2). In addition, we compared moist OMP (29% H_2O) to freeze dried OMP (2% H_2O), both lots taken from the same batch, to determine if dietary moisture content would influence performance. Clearly, it did not. Fish feeding on moist diets only appeared to be feeding more actively, actually, food intake on a dry basis remained the same. The superior weight gains of fish in the 1980 trial receiving the same diets that were employed in 1979 are due to a higher

feed intake as a consequence of longer daylength.

We noted that the level of dietary fat has a pronounced effect on the body fat content of fish (Fig. 3). This effect was greatest at the 45% level of dietary protein. The significance of the fat content of juvenile chinook on ocean survival and return to the hatchery has not been elucidated. Unfortunately we did not make any comparisons with wild chinook smolts. Also, we could not find any reference in the literature on the composition of wild chinook smolts. A recent study by Ludwig (1980) on coho and steelhead showed a much higher body fat content in cultured fish compared to wild ones. What influence fish obesity has on ocean survival is purely speculative. For instance, do fat fish carry with them substantial energy reserves which will assist them to survive in estuarine or ocean conditions while predatory instincts develop fully? Or does excess body fat impede swimming especially when being chased by a predator or when catching food?

In an attempt to estimate the effect of dietary constituents on fish composition; as it affect swimming performance, we conducted critical swimming speed tests at the end of the 1979 growth trial. The apparatus is similar to that described by Brett (1964). Groups of fish were placed in the swimming chamber and forced to swim against a turbulent current. After an initial adjustment period at a low velocity, the test consisted of raising the velocity in stepwise increments of 10 cm/sec every 60 minutes until the fish, one by one, eventually fatigued and fell back on an electrically charged screen. In order to correct for differences in fish size, the results have been expressed in body lengths per sec (L/sec) (Fig. 4). It should be mentioned that critical swimming speed for 50% fatigue is a close measure of the maximum sustained speed at which 50% of a group of

fish will fatigue. Fish that did not adjust to the swim tunnel during the initial velocities were not included in the test. These were fish that behaved erratically and would not maintain a steady position in the stream. The results based on the performance of small samples of fish failed to demonstrate any dietary effect on critical swimming speed. The high variability in performance within treatment groups suggests that there exists a considerable variation in physical fitness within a population of chinook salmon. A larger sample would need to be subjected to a swim stamina test to detect any dietary effects. Again, we regret not having any data to report on the performance of wild chinook smolts under identical test conditions.

The liver is an important organ involved in metabolism, synthesis and detoxification and may be a determinate of smolt quality. It was observed that the level of carbohydrate in the diet had a marked effect on liver weight expressed as a percentage of body weight (Fig. 5). The large livers are due to the storage of glycogen which can be readily converted to glucose and provide energy for the fish. The importance of the liver as an energy store for the ocean bound fish needs to be examined more thoroughly. Certainly, increasing the carbohydrate and reducing the protein content of fish diets would lower feed costs.

In conclusion, dietary manipulation could prove to be a useful tool for the production of chinook smolts for better ocean survival and return to the fishery. The influence of nutrition on ocean survival of chinook needs to be investigated since the average return rate of this species is markedly lower than that of coho. It may be possible through nutritional means, by maximizing protein quality and manipulating the rearing conditions, to grow chinook to a larger size in a shorter time. Larger fish in excess of 5 g

are thought to have a better chance of survival (Fowler et al. 1980) and have shown better osmoregulatory capacity (Clarke and Blackburn 1977).

ACKNOWLEDGMENTS

The authors are indebted for the assistance of Nancy Richardson, Sharon Chestnut, Dianne Plotnikoff, Bakhshish Dosanjh, Ulf Fagerlund, Ian Baker, Andy Lamb, Phil Edgell and Lesley Jamison and the Staff of the West Vancouver Laboratory. We thank Dr. D. Alderdice for the use of the swim tunnel apparatus. The authors thank Helen Dye for preparation of the figures and Morva Young for typing the manuscript.

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Fowler, L.G., R.E. Burrows, B.D. Combs and J.L. Banks. 1980. The effect of size and time of release of fall chinook salmon fingerlings on adult survival. Abernathy Salmon Cultural Development Center, Technology Transfer Series, No. 80-3. 13 pp.

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TABLE 1.

NUTRIENT	% COMPOSITION OF DIETS														
PROTEIN	15	15	15	25	25	25	35	35	35	45	45	45	55	55	55
F.D. POLLOCK MUSCLE 90%															
F.D. EUPHASID PACIFIC 10%															
LIPID	6	13	20	6	13	20	6	13	20	6	13	20	6	13	20
HERRING OIL															
CARBOHYDRATE	45	50.1	55.3	33.8	38.9	44	22.5	27.6	32.8	11.3	16.4	21.5	0	5.1	10.3
DEXTRIN 50%															
DEXTROSE 50%															
CELLULOSE	34	21.9	19.7	35.2	23.1	11	36.5	34.4	12.2	37.7	25.6	13.5	39	26.9	14.7
INCLUDING VITAMIN															
+ MINERAL SUPPLEMENT															
+ BINDER															
PROTEIN MG/KCAL	49.3	38.3	31.3	82.1	63.8	52.2	114.9	89.4	73.1	147.8	114.9	9.4	180.6	140.5	114.9

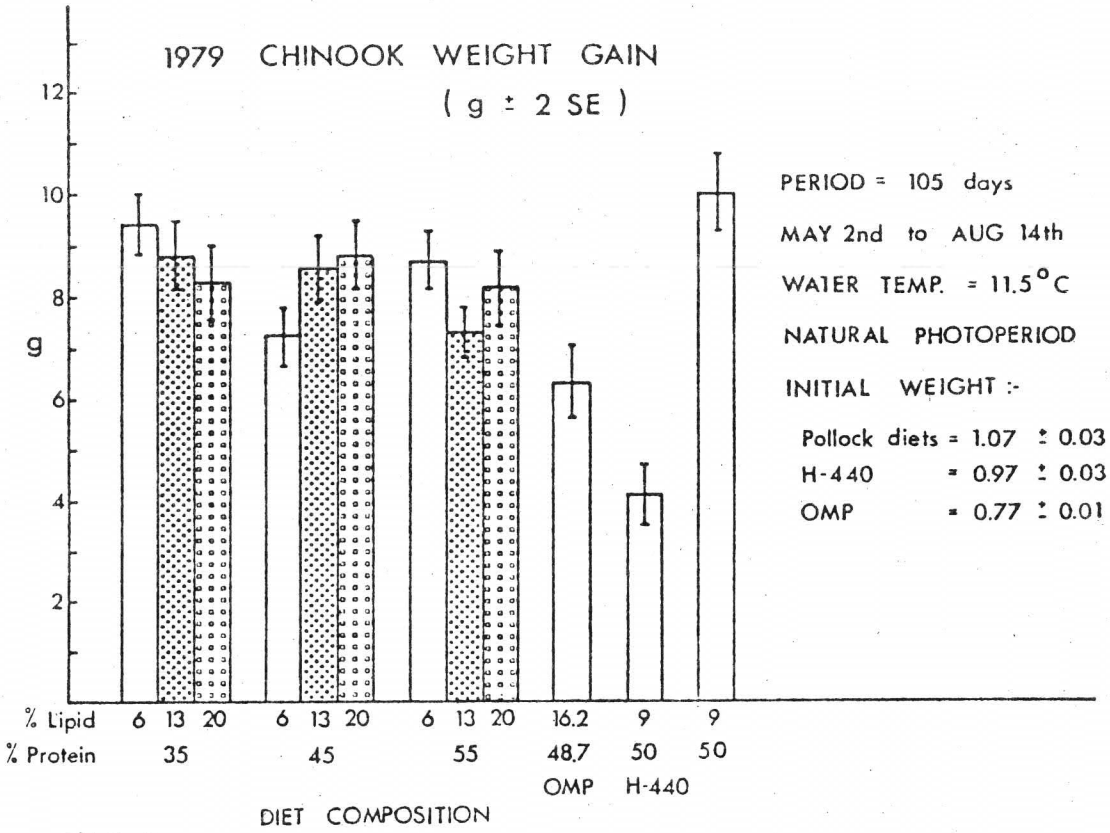

1979 CHINOOK WEIGHT GAIN
(g ± 2 SE)
g
12
10
8
6
4
2
PERIOD = 105 days
MAY 2nd to AUG 14th
WATER TEMP. = 11.5°C
NATURAL PHOTOPERIOD
INITIAL WEIGHT :-
Pollock diets = 1.07 ± 0.03
H-440 = 0.97 ± 0.03
OMP = 0.77 ± 0.01
% Lipid 6 13 20 6 13 20 6 13 20 16.2 9 9
% Protein 35 45 55 48.7 50 50
OMP H-440
DIET COMPOSITION

FIG. 1.

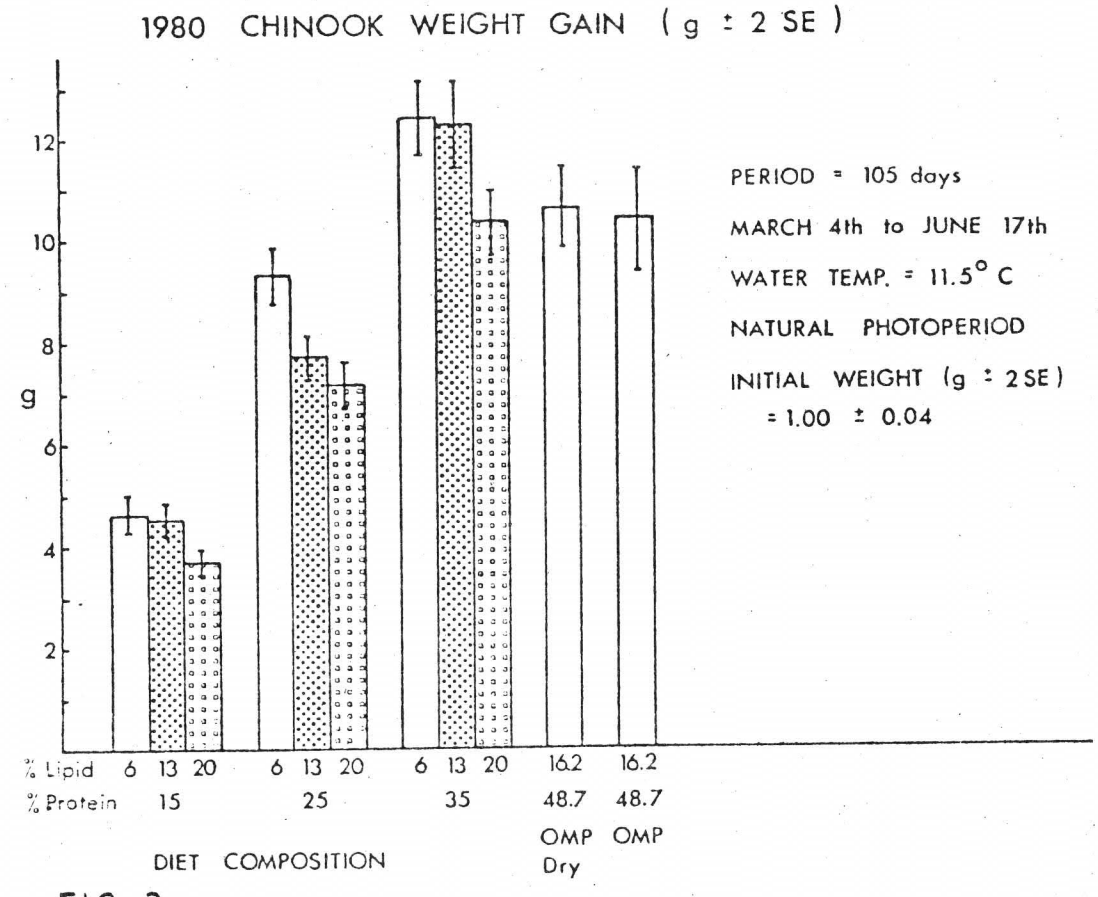

1980 CHINOOK WEIGHT GAIN (g ± 2 SE)
g
12
10
8
6
4
2
PERIOD = 105 days
MARCH 4th to JUNE 17th
WATER TEMP. = 11.5° C
NATURAL PHOTOPERIOD
INITIAL WEIGHT (g ± 2SE)
= 1.00 ± 0.04
% Lipid 6 13 20 6 13 20 6 13 20 16.2 16.2
% Protein 15 25 35 48.7 48.7
OMP OMP
Dry
DIET COMPOSITION

FIG. 2.

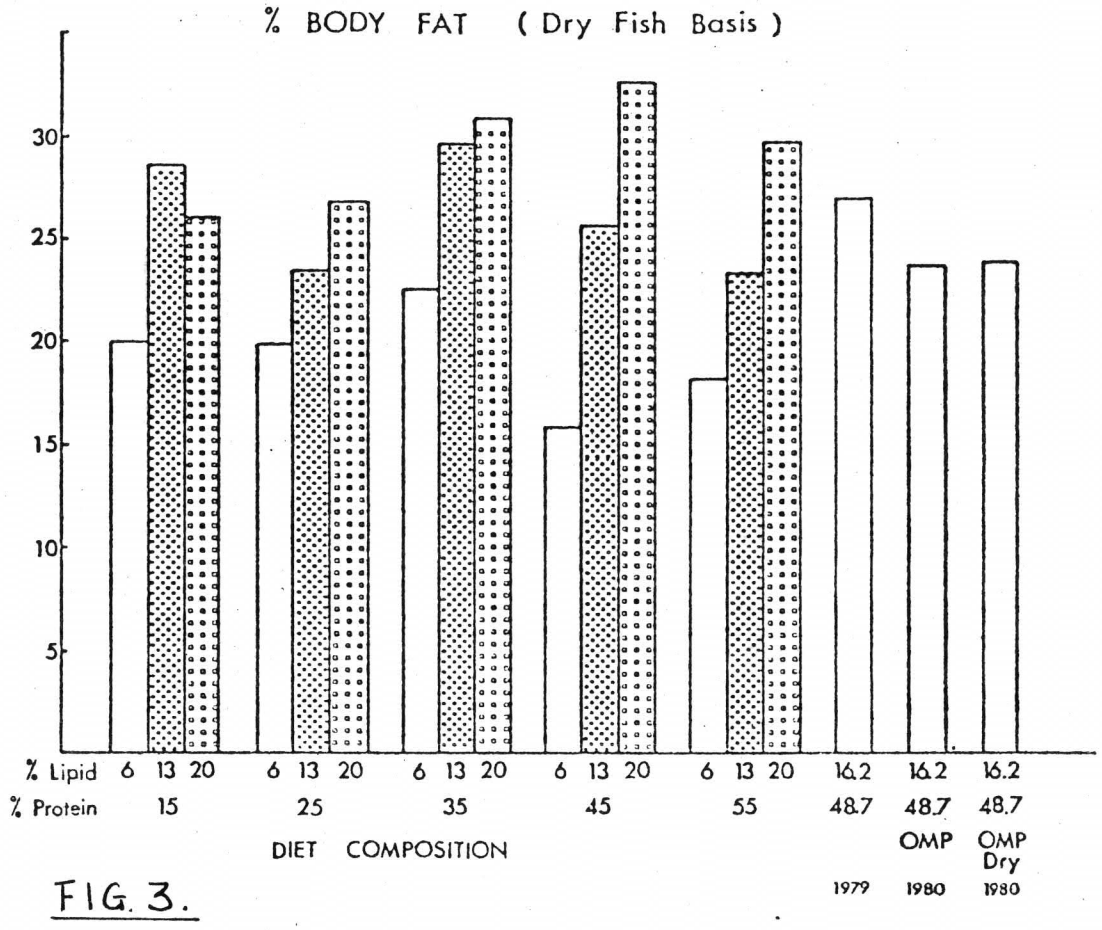
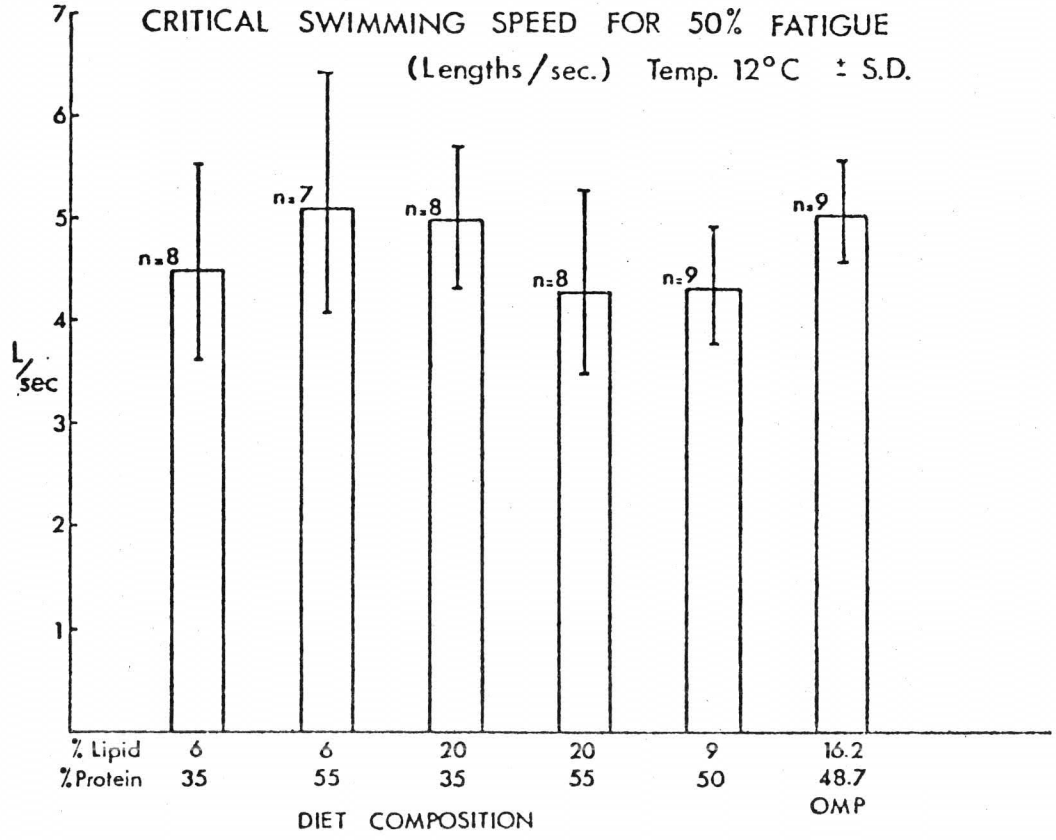

% BODY FAT (Dry Fish Basis)
30
25
20
15
10
5
% Lipid 6 13 20 6 13 20 6 13 20 6 13 20 6 13 20 16.2 16.2 16.2
% Protein 15 25 35 45 55 48.7 48.7 48.7
OMP
OMP Dry
DIET COMPOSITION
1979 1980 1980

FIG. 3.


CRITICAL SWIMMING SPEED FOR 50% FATIGUE
(Lengths/sec.) Temp. 12°C ± S.D.
7
6
5
4
3
2
1
L/sec
n=8
n=7
n=8
n=8
n=9
n=9
% Lipid 6 6 20 20 9 16.2
%Protein 35 55 35 55 50 48.7 OMP
DIET COMPOSITION

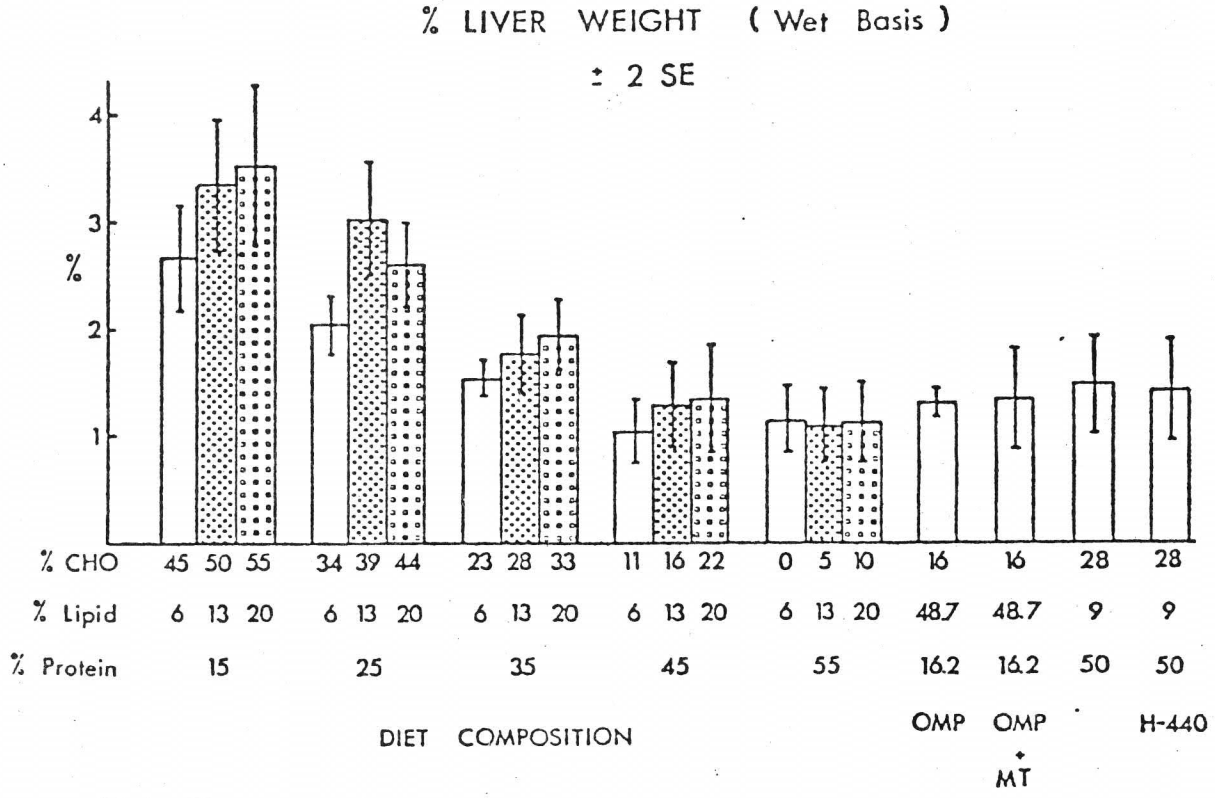

% LIVER WEIGHT (Wet Basis)
± 2 SE
%
4
3
2
1
% CHO 45 50 55 34 39 44 23 28 33 11 16 22 0 5 10 16 16 28 28
% Lipid 6 13 20 6 13 20 6 13 20 6 13 20 6 13 20 48.7 48.7 9 9
% Protein 15 25 35 45 55 16.2 16.2 50 50
OMP OMP + MT H-440
DIET COMPOSITION

FIG. 5.

EXPERIMENTAL PRODUCTION OF ALL FEMALE AND STERILE GROUPS OF COHO SALMON (Oncorhynchus kisutch)

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INTRODUCTION

In an earlier study at this laboratory (Goetz et al. 1979), found that groups of 3 month old coho salmon which had been treated with appropriate dosages of either 17β estradiol of 17α - methyltestosterone as eyed eggs, alevins and fry exhibited 100% female or sterile gonads. Subsequent to this discovery, a second experiment was initiated to determine whether 100% female or sterile adult coho salmon could be produced.

MATERIALS AND METHODS

In May 1977, 1,250 eyed eggs were obtained from coho spawned as part of a controlled photoperiod experiment (MacQuarrie et al. 1978). These eggs were divided into 5 groups and held in containers constructed of plexiglas and nylon mesh which permitted free water flow. These containers were in turn held, four to a tray in Heath incubators. The Heath incubators were supplied with aerated well water at a constant 10°C. Two groups of fish were treated with estradiol by immersion in an aqueous solution of the steroid at concentrations of either 400 or 100 µg/L for two 2 hour periods in both the eyed egg and alevin stages. The two treatment periods in each stage were separated by one week. A third and fourth group received identical treatment but were administered 17α - methyltestosterone. The fifth group served as a control. Administration of the steroids continued for 90 days after first feeding by spraying an ethanol solution of the steroids on

Abernathy diet (Murray Elevators, Utah) at concentrations of 5 and 10 mg/Kg diet for the estradiol and methyltestosterone respectively. Following treatment the five groups of fish were fed Oregon Moist Pellet diet (Moore Clarke Co., Wash.) and reared to maturity in 3 diameter fiberglas tanks in accordance with normal fish culture procedures.

RESULTS

The results of treatment with estradiol or methyltestosterone on the proportions of male, female and sterile adult fish are presented in Table 1. The control group and both estradiol treated groups matured and spawned in the fall of 1979. The 400 µg/L, 100 µg/L estradiol and control groups contained 100, 96 and 54% females, respectively. The 400 µg/L, 100 µg/L methyltestosterone groups contained 4 and 40% mature males and 94 and 70% presumably sterile fish compared to 46% mature male and 0% sterile fish in the control.

The eggs from 20 fish in each of the estradiol treated groups and 19 control fish were fertilized with normal milt and reared to 9 months of age to determine egg survival and the proportion of males and females in the off-spring Table 2. Survival to the eyed stage and to hatch ranged from 86-95% and 83-87% for the three groups. No significant differences occurred between groups. The off-spring from the 20 fish in the 400 µg/L and 100 µg/L estradiol groups exhibited male:female ratios of either 1:1 or 3:1 in a ratio of 12:8 or 11:9, respectively. All 19 control groups exhibited a 1:1 male to female ratio.

The mean standard lengths of adult fish from all 5 groups are presented in Table 3. In December 1979, the range in size for the five groups was 40.7 - 43.1 cm. No significant difference in size was observed. The mean lengths of the 400 µg/L and 100 µg/L methyltestosterone groups in November 1980 were 48.5 ± 6.5 and 47.3 ± 10.2 cm, respectively.

DISCUSSION

The work presented here represents the first successful production of essentially all female or sterile groups of Pacific salmon The potential applications of this technique to the management of the salmon resource are indicated in Fig. 1.

The results of this study demonstrate that sterile coho salmon remain alive and continue to grow past the normal time of spawning. In situations where sterile fish are to be released it is probable that these fish would not undergo the normal anadromous migration but remain in the fishery. This would result in an increase in the number of individuals and average weight per individual available to the fishery. Direct benefits would be provided to the commercial fishery through an increase in the landed catch. Also, a prolonged ocean residence would allow for potential production of trophy sized fish which would provide additional benefits to the recreational fishery. This technique would be most effective when used on stocks which remain in coastal waters or are enclosed in fresh water systems. The sterilization of fish held in aquaculture facilities would provide benefits including the elimination of gonadal development which is associated with a decrease in adult growth rate and deterioration in flesh quality and the capability of providing adult sized fish on a year round basis.

The production of all female stocks for release would benefit the fishery directly by increasing the percentage of salmon containing roe and thus improving the landed value of the catch. The problem of jacks returning to hatchery facilities and precocious male development in aquaculture facilities would be eliminated. In addition, the technique provide for an increase in hatchery egg take. The results of this experiment

indicate that all female stocks may be produced by direct hormonal intervention. However, as indicated by this experiment, the ova produced from feminized males when fertilized with normal milt produce off-spring with a male:female ratio of between 2:1 and 3:1. This still results in a net gain in fish, and more importantly females, due to the fact that these feminized males would not normally have produced any off-spring. The results of the above crosses between the ova of feminized males and normal milt, indicate that in coho the female is the homogametic sex. This allows for the possibility of producing all female groups by an indirect method. The technique involved would be similar to that described in this paper with the exception that a much lower dose of androgen would be administered with the objective of masculinizing genetically female fish. The homogametic "female" milt produced by these fish when used to fertilize normal ova would result in 100% female off-spring. The necessity of isolating only the milt from masculinized females would require either the cryopreservation of the milt from masculinized females and true males and subsequent screening using small numbers of test ova or the direct production of all female ova by gynogenetic techniques which could then be treated with androgen.

Studies related to each of these possibilities are currently underway at the West Vancouver Laboratory of the Resource Services Branch.

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TABLE 1

EFFECT OF TREATMENT WITH ESTRADIOL OR METHYLTESTOSTERONE ON THE PROPORTION OF MALE, FEMALE AND STERILE ADULT COHO SALMON.

TREATMENT STEROID	IMMERSION CONCENTRATION µG/L	DIETARY CONCENTRATION MG/KG	NO. OF FISH	% FEMALE MATURE/IMMATURE	% MALE MATURE	% STERILE
ESTRADIOL	400	5	34	94/6	-	-
ESTRADIOL	100	5	52	92/4	-	4
CONTROL	-	-	41	51/3	46	-
METHYLTESTOSTERONE	400	10	48	2/-	4	94
METHYLTESTOSTERONE	100	10	10	-	30	70

TABLE 2

SURVIVAL OF EGGS AND PROPORTION OF MALE AND FEMALE OFF-SPRING FROM ADULT COHO TREATED WITH ESTRADIOL AS EYED EGGS, ALEVINS AND FRY.

TREATMENT STERIOD	IMMERSION CONCENTRATION µG/L	DIETARY CONCENTRATION MG/KG	EGG SURVIVAL % EYED	HATCH	N	SEX RATIO ♂/♀ OF OFF-SPRING 1:1	3:1
ESTRADIOL	400	5	86 ± 17	84 ± 17	20	12	8
ESTRADIOL	100	5	95 ± 8	87 ± 14	20	11	9
CONTROL	-	-	86 ± 21	83 ± 20	19	19	-

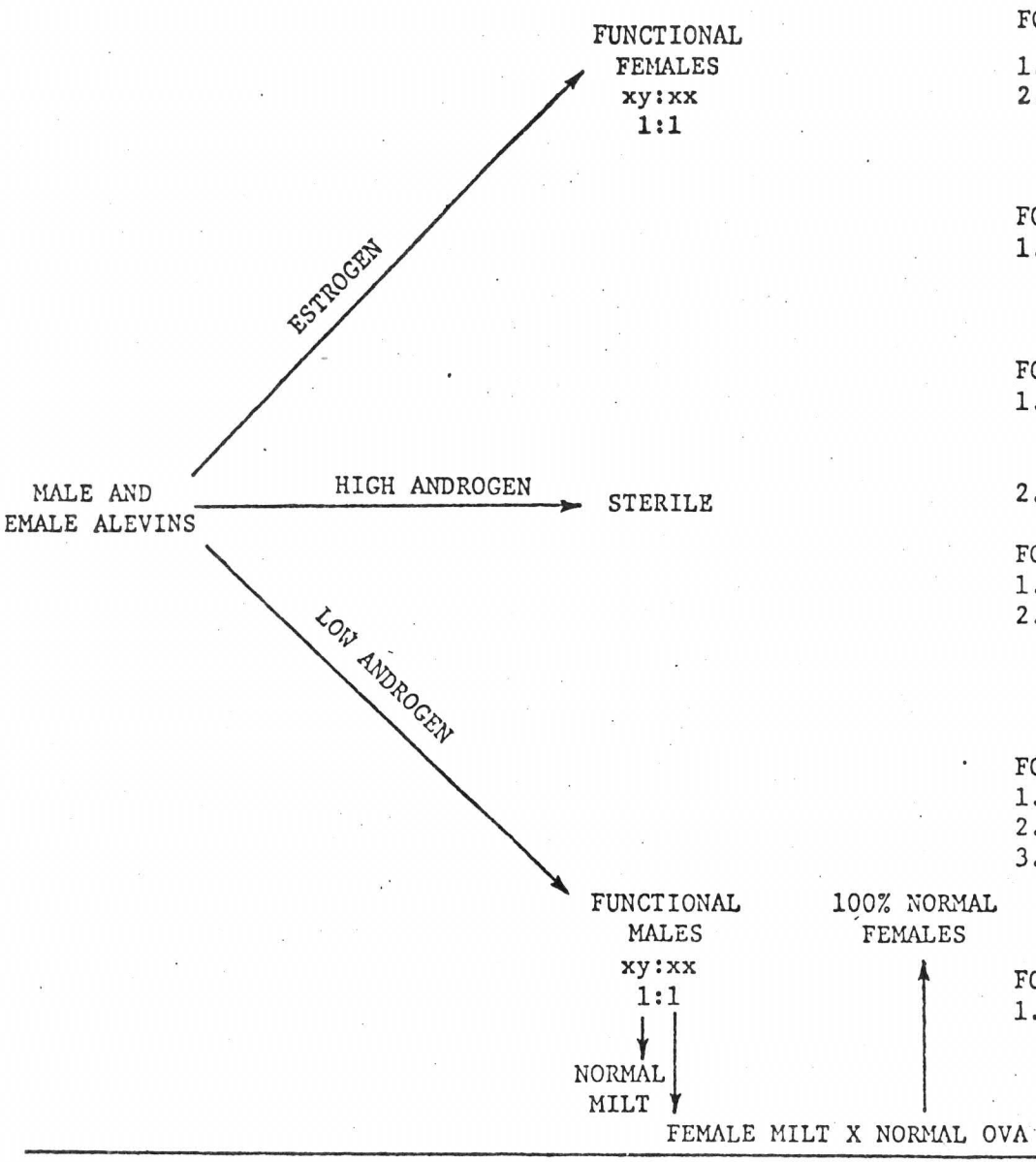
TABLE 3

MEAN LENGTH OF ADULT COHO TREATED WITH EITHER ESTRADIOL OR METHYLTESTOSTERONE AS EYED EGGS, ALEVINS AND FRY.

TREATMENT STEROID	IMMERSION CONCENTRATION µG/L	DIETARY CONCENTRATION MG/KG	MEAN LENGTH ± SD CM DEC. 1979	NOV. 1980
ESTRADIOL	400	5	42.1 ± 3.2	-
ESTRADIOL	100	5	41.9 ± 2.7	-
CONTROL	-	-	40.7 ± 2.5	-
METHYLTESTOSTERONE	400	10	43.1 ± 2.9	48.5 ± 6.5
METHYLTESTOSTERONE	100	10	42.4 ± 7.1	47.3 ±10.2

FIGURE 1

POTENTIAL APPLICATION OF THE PRODUCTION OF ALL FEMALE OR STERILE STOCKS OF COHO SALMON.



	COMMENTS
FOR RELEASE 1. TO INCREASE LANDED VALUE (ROE) 2. TO REDUCE JACKS FOR AQUACULTURE 1. ELIMINATES PRECOCIOUS MALES	FEMALES WITH (xy) GENOTYPE WHEN CROSSED WITH NORMAL MALES WILL PRODUCE OFF-SPRING IN A RATIO ♂:♀ OF 2:1 OR 3:1. †
FOR RELEASE 1. MAY REMAIN IN FISHERY RATHER THAN UNDERGO ANADROMOUS MIGRATION 2. MAY GROW TO TROPHY SIZE FOR AQUACULTURE 1. NO GONADAL DEVELOPMENT 2. CAN SUPPLY ADULT SIZED FISH ON YEAR ROUND BASIS	MOST EFFECTIVE WHEN USED ON STOCKS WHICH REMAIN IN COASTAL WATERS.
FOR RELEASE 1. TO INCREASE HATCHERY EGG TAKE 2. TO INCREASE LANDED VALUE (ROE) 3. TO REDUCE JACKS FOR AQUACULTURE 1. ELIMINATES PRECOCIOUS MALES	MOST EFFECTIVE WHEN COMBINED WITH GYNOGENETIC PRODUCTION OF ALL FEMALE (xx) PRE-TREATMENT STOCK OR SPERM CRYOPRESERVATION AND TESTING.