NOVOTNY

INSTITUTE OF FISHERIES MANAGEMENT

(London & S.E. Branch)

CAGE FISH REARING SYMPOSIUM

University of Reading

26th, 27th, March 1980

Organisers

M.J. Bulleid (Chairman)

J. Reeves (Secretary)

A.E. Hodges (Treasurer)

B. Joslin

This is the London & S.E. Branches inaugural attempt to organise a symposium and publish the proceedings. We would thank all the delegates for their support and hope that the enclosed papers and reported discussions provide useful reference material on the subject of rearing fish in cages.

M.J. Bulleid

Branch Chairman

OPENING REMARKS

M.J. Bulleid (Chairman, Institute of Fisheries Management, London & S.E. Branch)

I would like to welcome you all here on behalf of the Institute of Fishery Management, London and South-eastern Branch.

To open the proceedings it is my pleasure to introduce Mr. Brian Stott, the Chairman of the IFM Council. Mr. Brian Stott.

B. Stott (Chairman of the Council of the Institute of Fisheries Management)

Ladies and Gentlemen, it is my pleasant duty to welcome you all to this meeting on 'Cage Rearing' on behalf of the Council and the Institute. I hope you will find the meeting enjoyable and useful.

I have to confess that I am, as it were, a 'second eleven' since normally our President, Mr. Peter Tombleson would have opened the proceedings but unfortunately he cannot be with us today. I know, however, that he would wish me to add his welcome to my own and to express his hope that we shall have a successful meeting.

As many of you will know, our Institute aims to encourage fisheries management in the broadest sense and our activities naturally include organising meetings such as this. In addition we regularly hold our Study Course every September. This year it will be in Brighton, from the 23rd to 25th, and I hope we may see some of you who are here today at this meeting. I can assure you of a warm welcome and an interesting and varied programme. Incidentally, the published Proceedings of our last Study Course are on sale at the reception desk; I think you will find them good value for money.

To get back to this meeting, the original idea for holding a conference on cage culture came, as I remember, from one of our Council members, Mr. R.I. Millichamp. However, ideas are a start but they have to be developed and put into practice and in this connection I have to express the Institute's gratitude to the London Branch, and in particular to Mr. M.J. Bulleid, the Branch Chairman, to whom goes much of the credit for bringing the original idea into practicality.

I must confess that I know very little about practical cage culture. True some of our grass carp are being grown on in cages in a heated effluent but they are being looked after by experts from the CEGB. The technique is certainly developing very rapidly. Obviously cages are extremely useful for cultivating marine species and they are being increasingly used in freshwaters because of their convenience and cheapness; buying a net is much less expensive than constructing ponds and raceways.

How will cage culture develop? I hope we may be afforded a glimpse of the future through this meeting. It seems clear that one of the attribu for a cultivated fish species is that it must command a fairly high price on the market in order to be profitable. With the success of cage culture is there, one wonders, a danger of, say, salmon production becoming so grea that the price will collapse? Or will fish farming succeed the way poultry farming did? What are the prospects of using cage culture for raising non-edible species? Coarse fish culture is certainly something in which ma water authorities are interested. Perhaps eels could be grown in cages - i heated water of course.

Well I may be able to pose these questions but I certainly cannot ans them; this I must leave to you.

I hope the meeting will be successful and again, on behalf of the Institute, I wish you a warm welcome.

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CAGE CULTURE OF SALMONIDS IN THE UNITED STATES

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INTRODUCTION

I must first mention that it is both a pleasure and an honour to address this symposium, and I sincerely appreciate the efforts of the Institute of Fisheries Management and Thames Water in bringing me here.

Most of the salmonid cage culture in the US occurs on the West coast, and the primary fish cultured are the Pacific salmon, genus *Oncorhyncus* . The numbers of salmonids that are cultured in cages is quite small in comparison to the total number of eggs taken for cultural purposes. In my own state of Washington, I would estimate that 2 to 4 million eggs are collected each year for eventual cage culture. In contrast, in 1980, one agency alone (the Washington State Department of Fisheries - WDF) will collect ½ billion salmon eggs. The progeny will be released to the sea after being cultured at some 38 hatcheries scattered around the state. We estimate that by 1985, North Pacific rim peoples (Japan, the USSR, Canada and the US) will be collecting 3 to 5 billion anadromous salmonid eggs per year for cultural purposes. I would guess that over 99% of these will be for release to the sea (I will refrain from using the euphemism 'ocean ranching' in order to avoid adding to a growing list of jargon).

When one has recovered from the shock of these staggering numbers of cultured fish destined for release, the first obvious question is, "Of what earthly value is cage culture to US salmonid production?" The answers to this question are what I intend to explore, and I think that I will approach this from four viewpoints;

1. The development of cage culture in the Pacific Northwest for the commercial production of salmonids.
2. Some aspects of cage culture of salmonids in fresh water.
3. The concepts of cage culture for fisheries restoration.
4. The concepts of cage culture for fisheries enhancement and developing terminal fishing areas.

1. THE DEVELOPMENT OF CAGE CULTURE IN THE PACIFIC NORTHWEST FOR THE COMMERCIAL PRODUCTION OF SALMONIDS

It was in 1969 and 1970 that we performed our first experiments with cage culture of Pacific salmon in Puget Sound (Washington). The location of the National Marine Fisheries Service (NMFS) Manchester station was in prime habitat for salmon, and indeed, salmon are caught there by sports anglers the year around. The two species found in the greatest abundance the year around are the coho (*O. kisutch*) and chinook (*O. tshawytscha*) salmon. These two species appear to prefer oceanic waters of temperatures in the range of 4 to 14°C. Temperatures at the NMFS Manchester station range from 5 to 16^{o}C, with occasional temperatures of 18^{o}C under certain extreme conditions. Salinities range from 26.5 to 31 $^{o}/_{oo}$, which are lower than the open North Pacific.

During this early period, we explored many possible cage designs and sizes, and enclosure materials. All of the cage systems were secured to a large stationary dock via a floating platform (laboratory), which moved up and down with the tide. Tidal fluctuations are about 4 metres per day at the NMFS location, and the flushing currents and upwellings are quite good. There is no stratification of water except under the most extreme conditions of air temperature or run-off from a stream at the head of the bay. Experimental cage enclosures were made of stiff polypropylene mesh, knotted nylon (raw and treated with anti-foulants), and knotless nylon. The results indicated that knotless nylon caused the least damage to the fish, even thou it required frequent cleaning. Cages of various sizes and configurations were used, but the most efficient and successful cages were: (1) rectangular (2) supported by wide perimeter flotation for both support and ease of access (3) of a size that could be handled by 2 or 3 people without mechanical advantages; and (4) generally less than 4 metres deep. Cages less than 100 cubic metres would be the most suitable.

We studied the growth and survival of all of the Pacific salmon species cultured in seawater cages. The growth rates of the chum (*O. keta*) and the pink salmon (*O. garbuscha*) were excellent, and they have the unique advantage of adapting to full seawater within a few short weeks after absorption of the yolk sac (Figure 1). However, the long term survival during cage culture in seawater has not been good (Figure 2). The salt water survival of the sockeye salmon (*O. nerka*) is generally much better than that of the pink or chum, and the growth rate in seawater is almost comparable. However, this species requires a minimum of one year in freshwater before it smolts, and the normal cycle requires 2 years in freshwater.

The results of the initial studies indicated that the coho and fall chinook salmon offered the best compromise (Figure 3). The conclusions of the experiments conducted some 10 years ago were that sea cage farms could be economically viable if a product could be put to market within 18 months of egg fertilisation. Coho and chinook salmon growth could be accelerated in freshwater during the early phases by controlling water temperature. This technique would produce a large percentage of first summer (0-age) smolts, which was most important for the coho salmon. Transferring 0-age coho smolts to the 28 to 30$^{o}/$oo seawater in Puget Sound from June through early July at a graded size of 15 g or more could produce graded 250 to 400 g fish (pan-sized) within 6 months, and harvesting could be completed by spring (18 months from fertilisation). This had the distinct advantage of presenting a fresh product during the off season. However, the product was entirely new, since the consumer had never had access to a pan-sized salmon before this. At the time, it was determined that it would not be economically feasible to continue the grow-out period to produce larger fish, as (1) they would be marketed at the same time as wild fish; (2) more sea cages would be required to contain both harvestable fish and incoming smolts, thus increasing capital costs; (3) less efficient food conversion of larger fish would raise the production costs above the going price of wild fish.

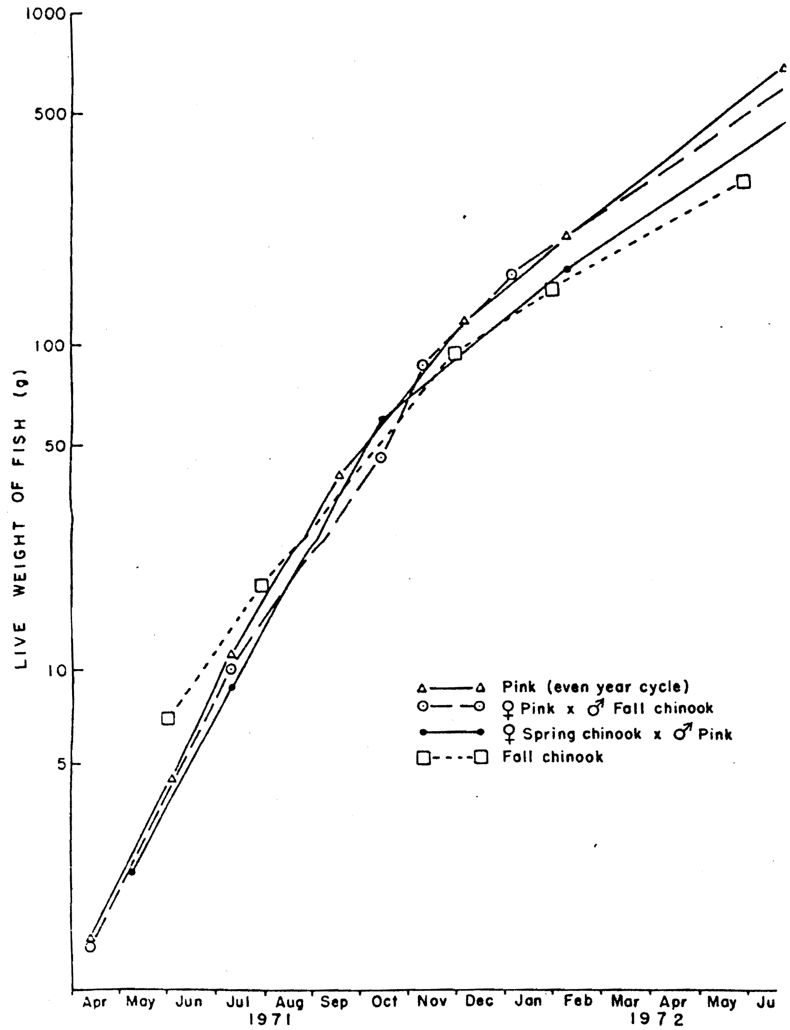

Fig. 1. Some comparative growth curves of pink and chinook salmon and their hybrids in sea cages during the earliest studies by NMFS.

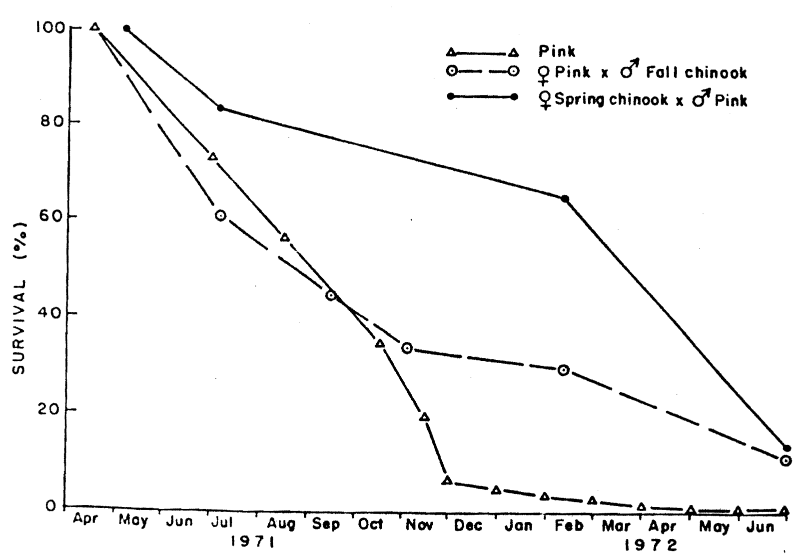

Fig. 2. Comparative survival curves of pink salmon and pink-chinook hybrids during long-term seawater cage culture trials. Note that the chinook salmon (females) hybrid has a higher over-wintering survival. Most of the mortalities are due to infectious bacterial diseases.

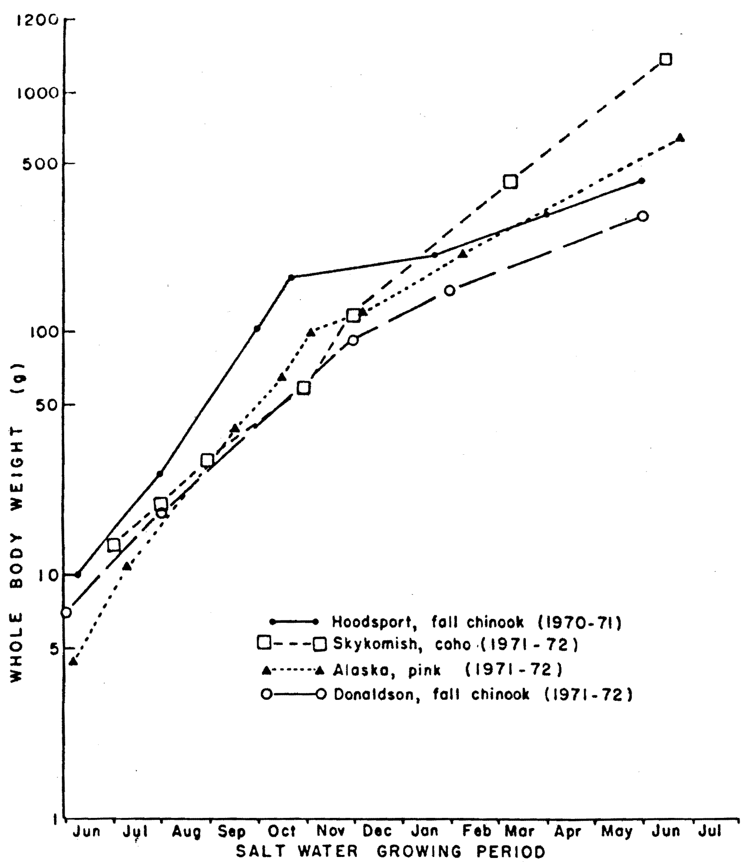

Fig. 3. Comparative growth curves of pink, chinook and first-year coho salmon cultured in seawater cages.

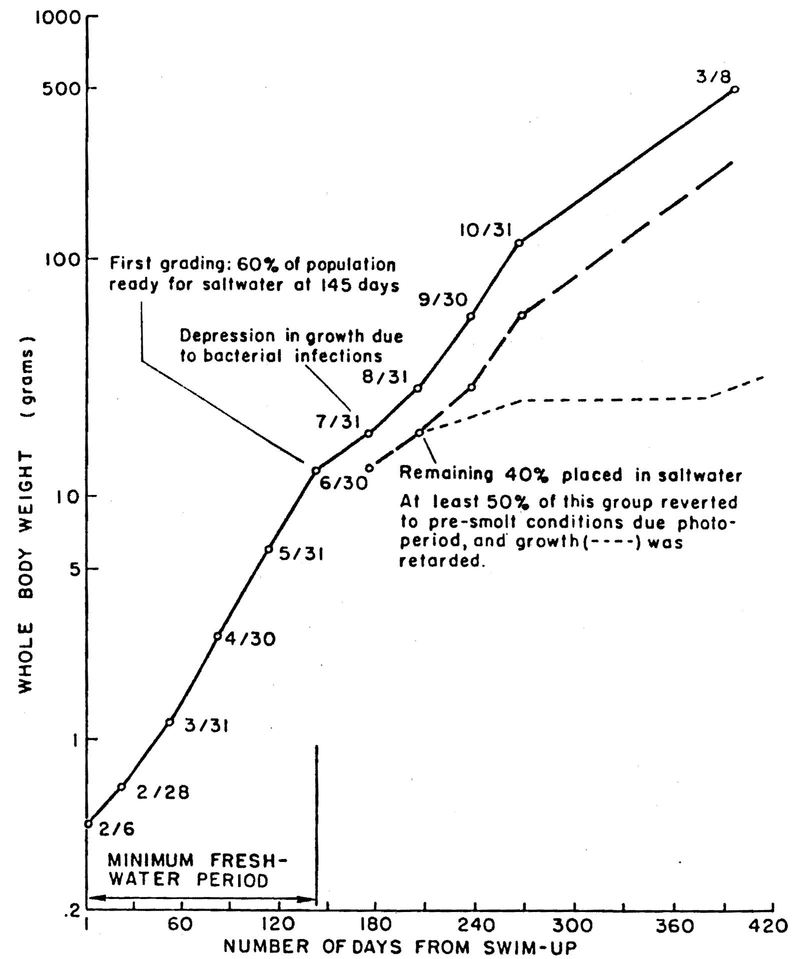

Fig. 4. The growth and staging phases of zero-age coho salmon in a large-scale pilot farm operation.

A pilot farm was established about 10 years ago to demonstrate the feasibility of growing pan-sized salmon in sea cages. The entire operation was conducted over a 22 month period, including all of the freshwater culture beginning with the collection of the eggs and fertilisation (Figure 4). During that time, over 61 metric tonnes of salmon were harvested and marketed from a cage culture system that covered a surface area of 0.1 hectares. In addition, approximately 10 metric tonnes of graded over-sized fish were kept for broodstocks, and a similar amount was inadvertently released. Thus, the total production was actually over 80 metric tonnes, and the product was considered to be a success (Figure 5). The growth patterns for the chinook salmon were quite similar to those shown in Figure 6.

The success of the pilot farm was due to the fact that we were able to achieve good flesh coloration by the addition of canthaxanthines to the diet, and we were able to control infectious bacterial diseases with the appropriate therapeutic agents.

Since that time, a number of commercial operations have developed for sea cage culture of salmonids on the West coast of the US and Canada. At least three of these are still viable: (1) Apex Bioresources Ltd. (a subsidiary of Union Carbide of Canada) in British Columbia; (2) Aquasea Farms of Shoal Bay, Lopez Island (Washington), and (3) Domsea farms of Clam Bay (Bremerton), Washington.

Domsea Farms now has 250 sea cages, approximately 6.2 m by 12.4 m, and 3 to 4.5 m deep, all in two complexes. The 1979 - 1980 crop is estimated to be over 450 metric tonnes, mostly coho. Feed is purchased on contract to their own formula specifications. Domsea is developing their own coho brood programme and has a main goal of being self-sufficient in eggs. They employ approximately 100 people in all operations, which include processing, freshwater hatcheries, sea-ranching in Oregon and Chile, research and development and administration.

Aquasea Farms grows coho salmon for market at pan-size and larger (1 kg), and is also conducting experiments with Atlantic salmon (*S. salar*). The 1979 - 1980 production is expected to be about 225 metric tonnes. They are making their own feed for now, partially from local resources. They operate 48 sea cages in Shoal Bay, 4.5 m by 12.4 m and 4.5 m by 9.2 m, and all 4.5 m deep. They purchase all of their smolts from private freshwater hatcheries. Aquasea's mortalities range from 22 to 60% per year, mostly from smolt reversion in 0-age fish. Uneven growth and inventory shrinkage (10 to 30% per year) are the biggest problems.

Research and development by publicly financed agencies has led to the commercial production of fish vaccines and mass immunisation against vibriosis, and this is now used routinely by salmon growers. Also, although canthaxanthines are still widely used to pigment the flesh, extensive R & D has demonstrated a number of products (or by-products) that work as well or better. These include the addition to the diets of whole products from under-utilised resources, such as certain species of pelagic crabs and euphausids, and simple extracts of carotenoids from the waste products of commercial shrimp and crab processing operations.

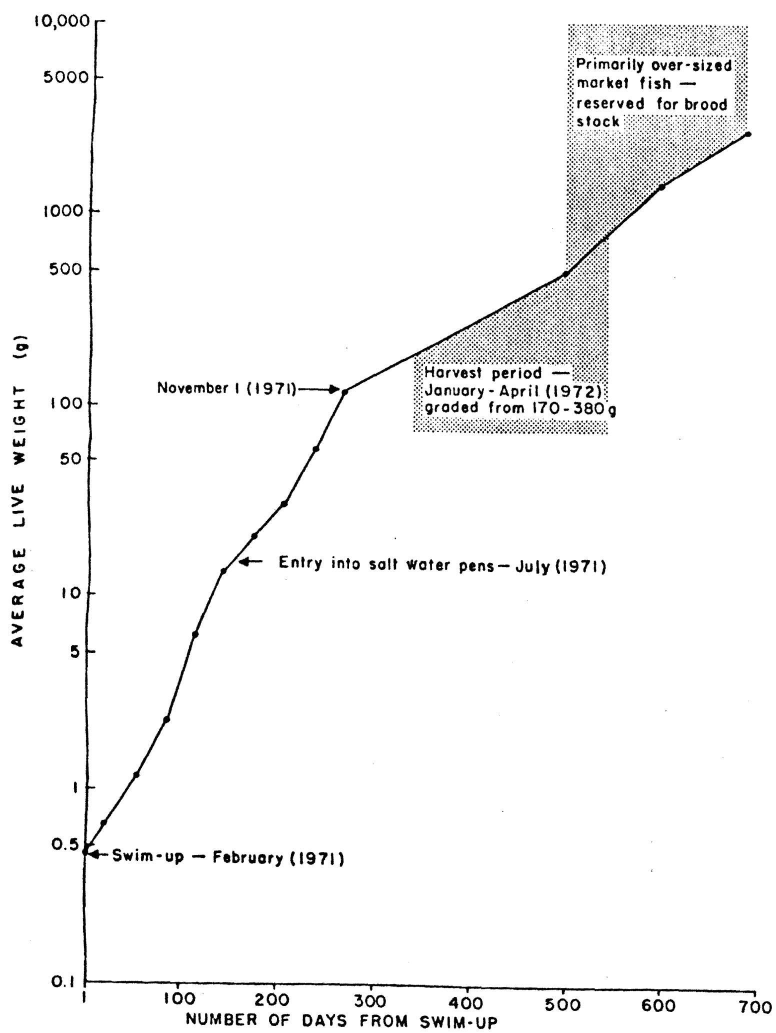

Fig. 5. Complete schedule of a successful coho salmon pilot farm operation for marine cage culture.

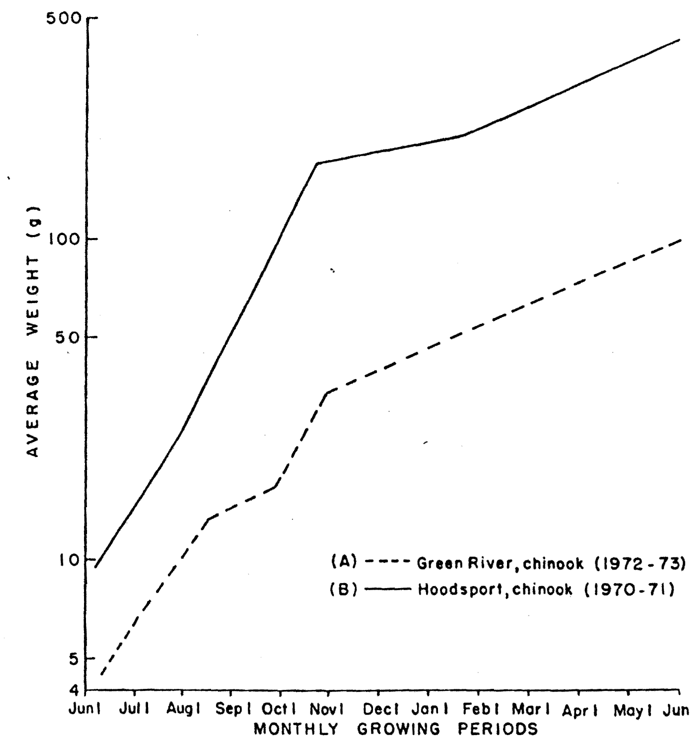

Fig. 6. Typical growth patterns for fall chinook salmon in sea cages. The main point of this graph is that if you can introduce larger, healthier fish into the sea cages early in June, you can reach a larger size at an earlier time.

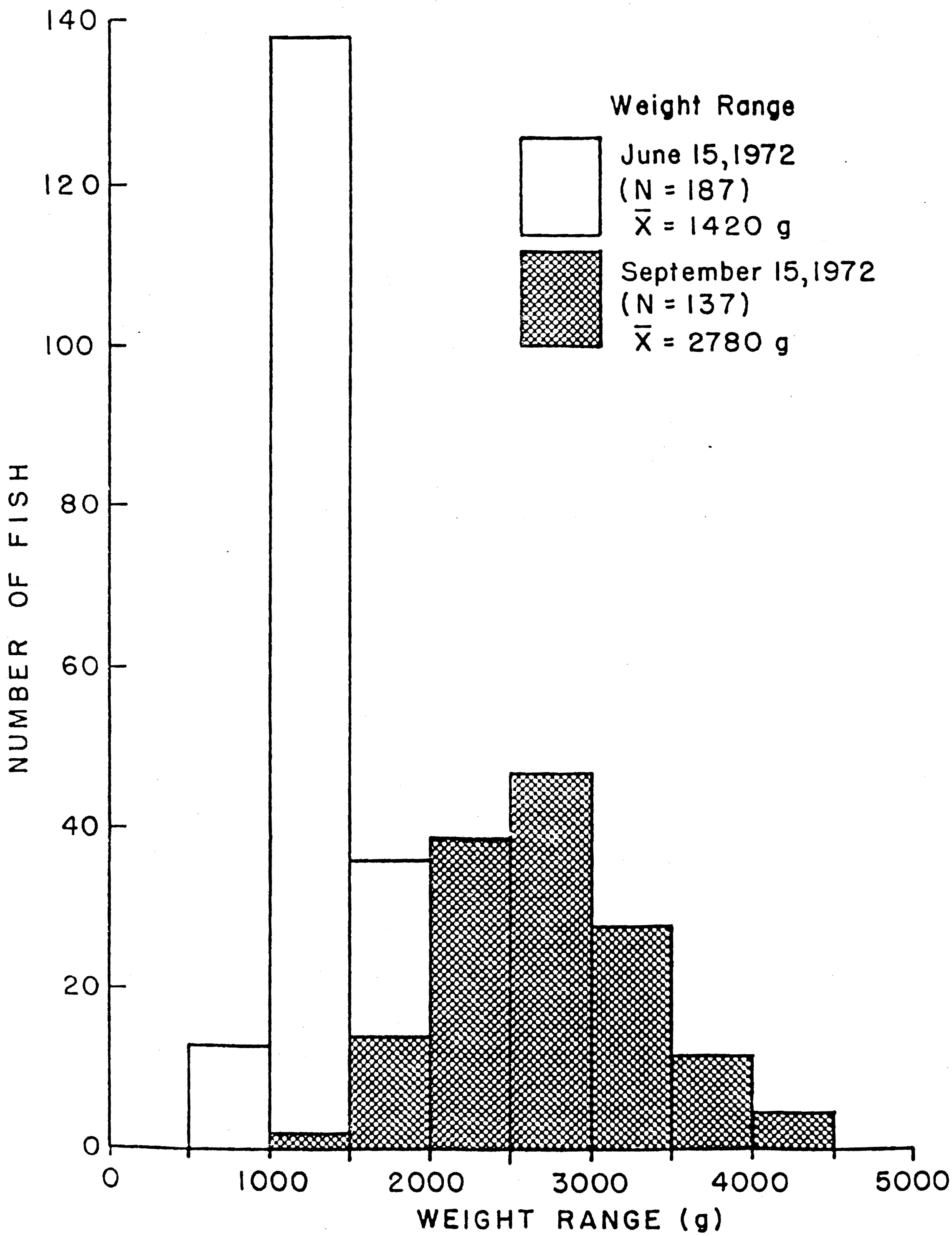

Fig. 7. The size of age 1+ coho from the pilot farm held over for two-year breeding cycle fish. The average size almost doubled in 90 days.

Fig. 5. Complete schedule of a successful coho salmon pilot farm operation for marine cage culture.

Expansion of the industry may not occur for some time for a number of reasons: (1) although much progress has been made in the prevention and control of some of the more common infectious diseases, new disease problem are cropping up. Most recently, we have seen the appearance of a sporozoan parasite that appears to be the cause of a proliferative type of kidney disease (PKD). In addition, many areas in Puget Sound and British Columbia are not suitable because of the seasonal appearance of great quantities of a spiculated diatom (*Chaetoceros* sp.). When the organism reaches certain densities, the tough, sharp, silaceous spicules clog the gills. If the fis does not suffocate, it dies from loss of blood, as the gill tissue is sever damaged. The blooms frequently occur in October, just prior to first marketing. The largest fish die first, and mortalities in excess of 90% ha been known to occur within 48 hours. Avoidance is the only remedy. Sea ca culture of salmon is not permitted in Oregon, and California is limited in suitable environments. It is also my opinion that future expansion will be limited or non-existent until there are: (1) major improvements in the diet (2) extensive efforts in brood stock development; and (3) qualitative and quantitative methods of determining the maximum loading capacities of each site, or the safe loading capacities. The latter factor will probably prove to be the most important, and yet will continue to be the most ignored for at least another 5 years. There seems to be a prevailing attitude in marine aquaculture that since the seas cover 4/5 of the earth's surface, they can absorb any kind of punishment. In the more populated areas of the United States, there is also the burden of conflicting multiple uses of the surface waters, and aquaculture generally gets last priority, even when the environment is best suited for aquaculture.

About 8 years ago, I predicted that the industry would eventually form 3 productive components: (1) freshwater farms for producing and selling smolts; (2) sea farms for growing salmon from smolt to market in sea cages; and (3) brood stock farmers who would grow fish from smolt to breeding in sea cages. Thus far, only the separate broodstock farms have not developed, but this will have to come.

2. SOME ASPECTS OF CAGE CULTURE OF SALMONIDS IN FRESHWATERS

I will only touch on this subject briefly here. The economics of trou culture in cages have been examined many times, and tested, and they just do not look promising. There is still some brackish water cage culture of trout in the eastern maritime provinces of Canada. In Arichat Bay, Nova Scotia, rainbow trout could be grown from 50 g to 500 g in 90 days on a very cheap fodder diet. However, this is probably an exceptional situation.

In the Pacific Northwest, the major interest seems to be in using the cages for extended growing or relieving pressure on crowded hatcheries witho dropping production. For example, the Washington State Department of Game (WDG) has had a very successful programme of growing native cutthroat trout (*S. clarki*) in cages in Lake Cushman from the late fry state to almost legal size. The trout are released into the lake where they eventually contribute very heavily to the sport fishery in the lake. The same type of fishery enhancement programme is taking place in Pyramid Lake, Nevada with the Paiut Indian project for the native cutthroat trout in that lake. The Quinnault Indians have also used cages in large numbers to culture sockeye salmon and steelhead trout (*S. gairdneri*) to smolt size in Quinnault Lake. The fish are released in the lake and emigrate with the normal populations through the outlet, down the Quinnault River and to the Pacific Ocean.

3. FISHERIES RESTORATION

This is a unique use of cage culture technology that has not been exploited to any extent, and I think that it is worth discussing here because of its potential. I can think of three cases that may illustrate some of these uses.

A. <u>The famous Lahontan cutthroat trout (*S. clarki henshawi*) of Pyramid Lake, Nevada</u>

Almost 10,000 years ago, when the glaciers started receding in North America, a series of large lakes formed in Northeastern Nevada. As the climate changed to near desert, these lakes evaporated, leaving Pyramid Lake (plus a few smaller lakes) and its acclimated fauna, including the Lahontan cutthroat trout. Pyramid Lake is fed by the Truckee River from the high Sierra Mountains. It has no outlet, because the evaporation rate equals or exceeds the total input. The surface area is about 40,500 hectares, and the evaporation rate is close to 500 million cubic metres per annum. Thus, all of the dissolved and undissolved mineral matter in the river enters the lake and never leaves. Pyramid Lake is now highly alkaline, with a salinity of about 5.5 $^{o}/oo$, and a pH of about 9. It also has one of the highest standing crops of zooplankton of any lake in North America. Some day, of course, it will become too alkaline to support any life at all.

The Lahontan cutthroat trout adapted to this environment and thrived. There are accurate records of sport caught trophies weighing over 19 kg. Although the entire lake is on the Paiute Indian Reservation, adults ascended the Truckee River (off the reservation) for many miles to spawn. Unfortunately, loss of habitat and over-fishing in the lake reduced spawning populations and recruitment. A combination of shore-based hatchery facilities and a floating cage culture operation in the lake were established by the Paiute Tribal Council. The primary objective was to restore populations of this famous trout in the lake by releasing cultured fish from the floating cages. This would increase the availability of fish for the demanding sport fishery and eventually brood stocks which would be collected near the mouth of the river as they ascended it. The cages had to be built to withstand steady desert winds of 50 mph with an unbroken fetch of almost 50 miles. Infectious diseases do not seem to be as big a problem in this environment as in sea water, presumably because of the high alkalinity and isolated ecology. The project has been successful and is continuing.

A similar project has been going on in Clam Bay, Washington, where the WDG is culturing broodstocks of sea run cutthroat trout (*S. clarki clarki*) in sea cages to provide upward of a million eggs per year to help restore over-fished populations in certain Puget Sound streams. The progeny are to be planted as fry, and are expected to reside in these streams for one year before they emigrate as smolts. The survivors should return as adults to the streams in which they were planted. thus restoring the stocks.

There has also been a prospect of using this application to restore certain stocks of Atlantic salmon on the Eastern seaboard of the United States. We have already demonstrated that Atlantic salmon could be grown through the breeding cycle in sea water cages in Puget Sound, and provide unlimited supplies of fertile eggs for almost any type of restoration project.

4. FISHERIES ENHANCEMENT

We think that the first practical use of sea cage culture for fisher enhancement began with the pilot farm in Clam Bay. Two releases of coho salmon occurred inadvertently: the first during the harvesting (as pan-siz fish), and the second during the second summer as large fish from a major stock of graded fast-growing fish being reserved for future brood supplies The early releases seemed to move about Puget Sound within an approximate 30 mile radius, and began appearing in the active Puget Sound sport fisher in early spring in large numbers. They were recognised by fisheries agent because of the slightly rounded tips of the caudal fins (from close confin ment in the cages). The larger fish released in the second summer appeare to stay within a much closer radius, and because of their size and abundan they immediately attracted a large contingent of eager sport fishermen in the local area where they were caught in great numbers. Appproximately 10 metric tonnes of fish were involved in these releases, but there was no wa of accurately asessing the impact. As a result of this activity, a number of delayed release studies and programmes were initiated up and down the Pacific coast, most with the idea of enhancing some regional or local spor fishery.

Sea-run cutthroat trout are cultured in sea cages by the WDG for an entire summer. They are trucked to selected salt water release sites to contribute to the salt water sport fishery. As a result of this, the tota recoveries in the sport fishery in salt water jumped from 0.1% (from norma hatchery plants of downstream migrating smolts) to 9.0%. Needless to say, this programme is considered to be quite successful.

The salmon sport fishery enhancement programmes are more complex. In Puget Sound, trucking of tagged coho salmon cultured in sea cages for relea in southern Puget Sound was more successful than with fish that were releas simultaneously directly from the cages in Clam Bay. Up to 14.3% were recovered in the sport fishery in 17 months, and most of these were in southern Puget Sound. Success varies from year to year also. For example, August releases of cage cultured coho in Elliott Bay (Puget Sound) in 1973 produced a sport fishery recovery of 12.4%, but the recoveries from a 1974 release jumped to 28.3%.

A major objective of these delayed releases is to establish a greater population of resident (local) fish, and thus increase the availability of the local sport fishery. This seems to work quite well for both coho and chinook salmon in Puget Sound, especially the southern portion. However, delayed releases of coho and chinook salmon from sea cages in San Francisco Bay (California) showed that 52% of all coho recovered were caught in the San Francisco Bay sport fishery in comparison to only 5.7% of the chinook. In some cases of delayed releases of salmon in Puget Sound, the recoveries in the sport fishery were almost non-existent.

In spite of the many vagaries and inconsistencies that have appeared, a number of enhancement programmes are in full production. The WDF culture fall chinook salmon in their sea cages at Fox Island in southern Puget Soun About ¼ million are transferred to the sea cages in early June at 7.5 to 10 and released when they reach 45 to 55 g. At Squaxin Island (southern Puget Sound), the Squaxin Indians culture from ¼ to ½ million coho in sea cages for the State for delayed release, and these fish produce annual contributi of 10 to 20% to all fisheries.

One of the most interesting aspects of the delayed releases from sea cages is that the salmon return as maturing adults to the sea cage site, and not to their natal hatchery, unless the hatchery is in close proximity. This gives the fishery manager the potential to develop exclusive fisheries in specific locations of terminus points. That is, the fish would imprint to the sea release site and return to it. All of the commercial fishing for this release would be conducted in this terminal area. As an example, one small hatchery in southern Puget Sound easily releases 2.5 million coho salmon smolts each year. In spite of intense commercial fisheries region-wide, over 125,000 adults can sometimes escape and return to the hatchery racks. This is far more than is needed to maintain the run, and creates a multitude of problems. However, if the hatchery were to release only the number of smolts needed to maintain the run, the remainder could be outplanted to sea cage culture sites for imprinting and release, and these sites would then become terminal fishing areas. All of the adults returning to the sea release site would be harvested by the commercial fisheries, and no fishing would be allowed in the proximity of the hatchery. This would not only protect the returning run of spawners, but would prevent selective fishing by drift gill nets, thus preserving the diversity of the genetic pool within the stock. We have seen this work successfully with both sea cages and dyked, tidal lagoons, where delayed release coho returned to the sea release sites and were 100% harvested. None of the sea-released fish returned to the hatchery (20 miles away), and yet the total contributions to all fisheries were a healthy 14%. In southeastern Alaska, the big successes have been with 4 to 6 week rearing of pinks and chums. At the NMFS Little Port Walter station for example, releases of the 1974 brood of pink salmon after zero days of culture had a total recovery of 2.7%, and a similar lot reared 60 days in sea cages and released had a total recovery of 4.6%. Short term rearing of chums at many sites distant to a central hatchery is being proposed for some parts of southeastern Alaska not only as a means of impacting fisheries in selected locations through salt water imprinting, but as a conservation device ..... it would eliminate the need for building a great many hatcheries.

Even though we have been working with sea cage culture of salmonids for over 10 years in North America, I still believe that we are operating in the dark about 50% of the time, and that it will be at least another ten years before we can realise the full benefits of this technology.

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DISCUSSION

<u>C. Purdom</u> (Ministry of Agriculture, Fisheries & Food)

You mentioned hybrids between pink and chum salmon. Is there any commercial production?

<u>A. Novotny</u> (US Department of Commerce)

No, not at the present time, because the commercial farms are just not set up to do this sort of thing. They are still in the experimental stages. There were some experimental releases of a cross between a chum and a pink, by the Washington State Department of Fisheries about ten years ago, but the actual returns on these were very poor. At the time that this was done, I questioned why they were doing it because both the chum and the pink are very disease prone. Normally, in hybridisation you want to cross something that will give you more disease resistance - not something that is disease prone with something else that is disease prone. It did not surprise me that they did not get any returns.

<u>T.J. Wills</u> (Wessex Water Authority)

I noticed from the design of your commercial farm that the nets were very close together. If you got a disease, did it pass from one to the other like an epidemic? How did you stop disease spreading?

<u>A. Novotny</u>

I do not know if they suffered any disease epidemics. In my estimation I think they should have broken the cages up more. They have reached their limit in this particular farm and they are seeing some changes in the water quality in the immediate area. I do not know if they will eventually break them up or not, but I think they have seen the type of thing that you are talking about; especially with the dropping of oxygen levels at certain tidal flushings. In this area the currents are quite good; they are generally running at about 2 knots.