REPORT OF A STUDY TRIP TO JAPAN

II. Salmonid Aquaculture and Fisheries

Christopher Toole

University of California Cooperative Extension
Sea Grant Extension Program
Foot of Commercial Street
Eureka, California 95501

Working Paper No. P-T-48

$1.00 (non-residents)

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ACKNOWLEDGMENTS

I wish to thank the following people in the United States who helped arrange this trip: Dr. Bob Wildman (National Sea Grant), Dr. James Sullivan (California Sea Grant), Dr. Conrad Mahnkin (National Marine Fisheries Service), Dr. William Shaw (Humboldt State University), Mr. Bill Osborne (Kodiak Native Association), and Mr. Sus Kato (National Marine Fisheries Service). Drs. Wildman, Mahnkin, and Shaw are present and former members of the UJNR Aquaculture Panel, who were instrumental in obtaining cooperation of their Japanese counterparts in organizing this trip.

In Japan, Dr. K. Fukusho and Dr. T. Honjo (the 1986-87 and 1987-88 chairmen of the UJNR Aquaculture Panel's Visiting Scientist Program Committee) were responsible for arranging the majority of my itinerary. Their kindness and efficiency are greatly appreciated. Dr. K. Nakaya, Dr. M. Kaeriyama, and Dr. T. Seki were contacted independently and they were also extremely helpful and hospitable. Everyone I met in Japan was very generous with their time and information, and I feel very lucky to have developed a number of personal friendships which I hope will persist "long distance" in years to come.

A $1000 travel stipend was awarded by the California Sea Grant Program to allow me to spend a greater amount of time concentrating on molluscan aquaculture in Japan. During this time my salary was provided through University of California Cooperative Extension sabbatical leave funding. Preparation of this report was funded in part by California Sea Grant NA-80AA-D-00120 and State Resources Agency Grant A/EA-1.

Special thanks to Debbie Marshall for transcribing and typing this report.

CONTENTS

INTRODUCTION

I visited Japan for five weeks in March and April, 1987, under the auspices of the Scientist Exchange Program of the US-Japan Cooperative Program in Natural Resources (UJNR). UJNR was formed in 1964 following the Third Cabinet-Level Meeting of the Joint United States - Japan Committee on Trade and Economic Affairs. UJNR consists of several "panels" of experts from each country in areas of mutual interest (ie, national park management, desalinization of seawater, forestry, air pollution, etc.). US and Japanese counterpart panels on Aquaculture were formed in 1969. Semi-annual meetings between the two panels have covered a wide variety of topics. Reports of those meetings are published in the NOAA/NMFS Technical Report series. In addition to the semi-annual meetings, panel members in each country organize study trips for visitors who are recommended to them by members of their counterpart panel, and that is how most of my trip was arranged.

The purposes of this trip were to:

1) Learn about Japanese aquaculture, with an emphasis on salmonid and cold-water molluscan species;
2) Learn about coastal fisheries, organization of fishermen's cooperatives, and methods of marketing seafood products;
3) Learn about fisheries and aquaculture extension activities; and
4) Learn about fisheries education and training programs in Japan.

The trip was extremely well organized by my Japanese hosts and, in the course of visiting facilities in five prefectures (Figure 1) and meeting with nearly 100 biologists and members of the Japanese fishing industry, I was able to satisfy most of the objectives listed above. I gained the most information about cold-water molluscan aquaculture, salmonid aquaculture, and fisheries education and extension. Three reports have been prepared to make this information available to interested parties:

Report of Study Trip To Japan, March - April, 1987

I. Molluscan Aquaculture and Fisheries

II. Salmonid Aquaculture and Fisheries

III. Fisheries Education and Extension Activities

These reports are available from the California Sea Grant College Program, University of California, A-032, La Jolla, CA 92093.

Following the text of each section, a list of relevant publications collected in Japan are listed in Appendix 1. Copies of these are available at cost from the author.

Names and addresses of researchers and people in the fishing industry who I met in Japan are listed in Appendix 2 of the section(s) corresponding to each person's area of expertise. A complete list of all contacts made in Japan is available from the author on request. Similarly, I would be happy to share information collected on subjects not included in the three reports with anyone interested. Other topics about which I gained information while in Japan included aquaculture of sea urchins, flatfish, yellowtail, red sea bream, and various species of marine algae; fisheries for squid, saury, and coastal species caught with gillnets and small trawls; and operations of fish markets and fishermen's cooperatives. I would also be happy to share advice with anyone contemplating a similar trip relative to finances, language, getting around, potential problems which might be encountered by your spouse, and other logistical/cultural concerns.

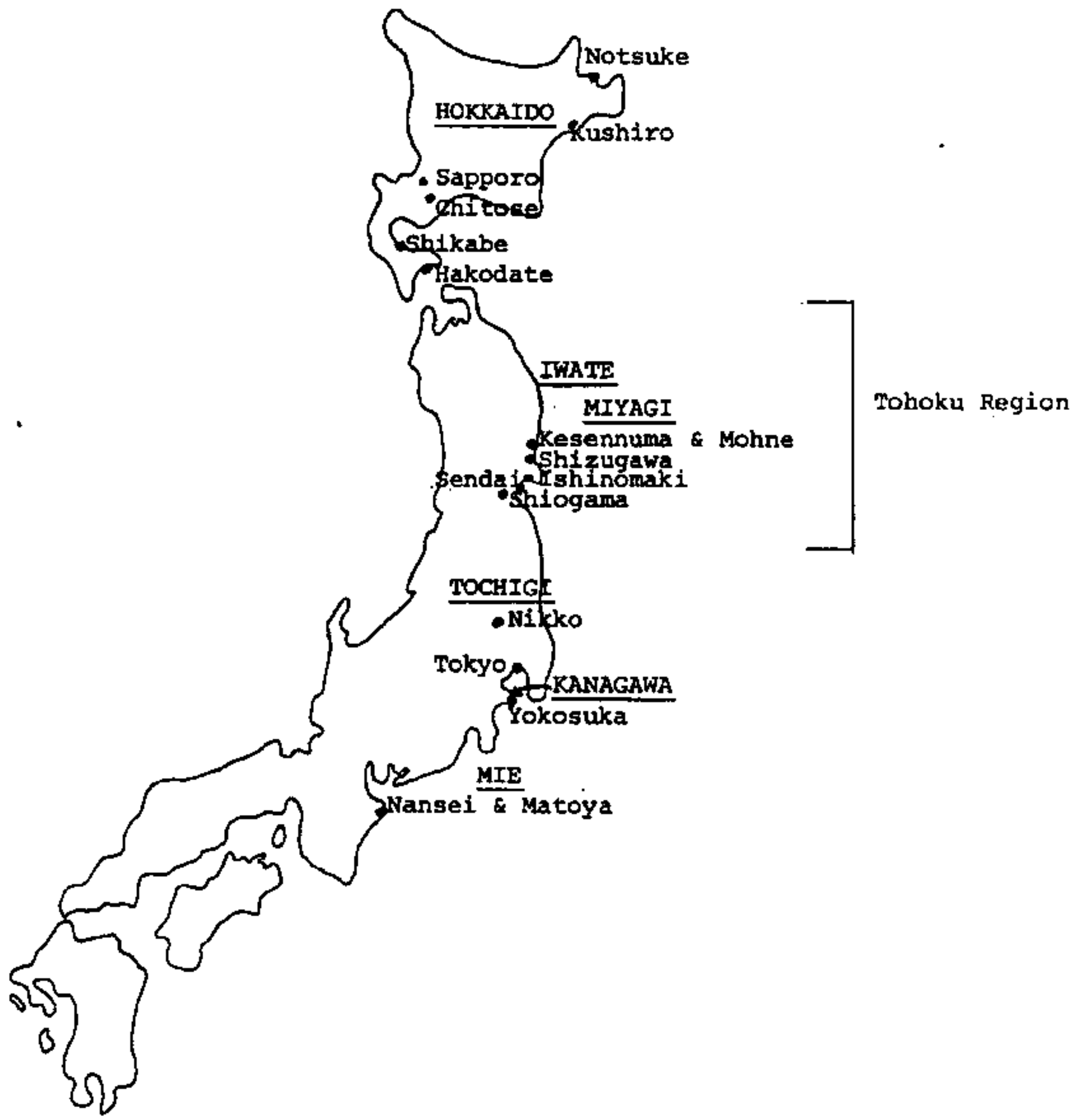


Figure 1. Map of Japan showing principal areas visited and described in text. Names of prefectures are underlined.

Chum Salmon

(*Oncorhynchus keta*)

Chum salmon is the major salmonid species cultured in Japan. Since 1980, over 1 billion fry per year have been released from hatcheries on Hokkaido (Table 1). Return rates since 1968 have averaged 2-3%. In 1983 the Japanese caught 166,000 tons of salmon of all species, of which approximately 75% came from coastal fisheries for chum salmon.

Salmon ranching in Japan is controlled by the federal government through the Japan Fisheries Agency (JFA) (Figure 2). The Hokkaido Salmon Hatchery is the primary arm of the JFA involved in salmon production. The Hokkaido Salmon Hatchery is actually a complex of 37 hatcheries , a research facility, and administrative and management sections (Figure 3). There are also 6 prefectural fish hatcheries and 90 private hatcheries, most of which are run by fishermen's cooperatives. The private hatcheries tend to be small and account for only about 30% of production. The budget for the JFA salmon culture program in 1984 was 2.07 billion yen for operation of the government hatcheries and 1.17 billion yen for subsidies to the private hatcheries. This totaled about 14 million dollars at the 1984 exchange rate and $22.8 million at today's exchange rate of 140 yen/U.S. dollar.

While in Japan I visited the Chitose Salmon Hatchery, the research laboratory and management section of the Hokkaido Salmon Hatchery in Sapporo, and facilities of salmon restoration groups in Sapporo. I also met with some researchers in other parts of Japan who were studying chum salmon nutrition.

Chitose Salmon Hatchery. The Chitose Salmon Hatchery is the oldest hatchery in Japan. It was built in 1888 and modeled after the Backsport Salmon Hatchery in Maine. The Chitose Salmon Hatchery serves the central section of Hokkaido (Figure 4). In 1986 this hatchery took 122 million eggs from 127,416 spawners. Production figures in recent years are included in Table 2. Many of the eggs are transferred to other hatcheries, but approximately 32 million fry are reared and released into the Chitose River each year.

The hatchery is composed of two sections set along both sides of the Chitose River (Figure 5). The water source is from springs which run at a constant temperature of 8 C. The temperature of the river, at the time I visited, was 3 C. The hatchery contains approximately 1300 square meters of enclosed buildings for egg incubation. The eggs are incubated in 50 liter upwelling boxes which hold 1/2 million eggs each (Figure 6). There are 256 of these located in two sections of the hatchery. I was shown a new upwelling box design which is being tested. It is made of clear plexiglass and had rolls of plastic mesh in the bottom for alevins. It supposedly can rear eggs at even higher densities,but I was told by the assistant hatchery manager, Mr. Akira Nakayama, that so far the results have been only moderately successful. I was also shown two different styles of egg sorting machines. Light sensors are used in these machines to remove dead eggs, which are opaque. The machines can sort 1/2 million eggs in an hour, a task which would normally take a crew two days to perform. The machines are manufactured by Maruichi Bussau Co., Ltd., Tokyo.

Table 1. Changes in return rate of chum salmon released in Hokkaido.
(From Dr. M. Kaeriyama).

	年 級	稚魚放流数 Liberation (thousands)	同 一 年 Returns by brood year (thousands) 帰 率 (千尾) 2 年	3 年	4 年	5 年	6 年	合 計	回帰率 Return rate (%)	
1950	昭25	222,422	38.0	765.0	2,060.0	259.0	7.0	3,129.0	1.41	
	26	189,157	27.0	1,034.0	1,454.0	241.0	14.0	2,770.0	1.46	
	27	159,557	37.0	668.0	934.0	201.0	2.0	1,842.0	1.15	
	28	170,606	32.0	659.0	1,136.0	162.0	1.0	1,990.0	1.17	
	29	269,338	46.0	1,233.0	1,901.0	134.0		3,314.0	1.23	
55	30	247,922	34.0	851.0	1,044.0	77.0	2.0	2,008.0	0.81	
	31	140,454	45.0	572.0	992.0	286.0	12.0	1,907.0	1.36	
	32	361,608	31.0	628.0	1,830.0	555.0	16.0	3,060.0	0.85	
	33	417238	23.0	765.0	1,279.0	165.0		2,232.0	0.54	1.0%
	34	313,549	59.0	896.0	1,829.0	382.0		3,166.0	1.01	
1960	35	203,413	19.0	1,583.0	1,569.0	193.0		3,364.0	1.65	
	36	359,489	147.0	1,817.0	3,429.0	544.0	4.0	5,941.0	1.65	
	37	280,743	14.0	1,064.0	1,547.0	400.0	1.0	3,026.0	1.08	
	38	272,106	44.0	1,701.0	3,018.0	220.0		4,983.0	1.83	
	39	344,463	105.0	1,032.0	877.0	105.0		2,119.0	0.63	
65	40	549,278	17.0	808.0	1,615.0	132.0		2,572.0	0.47	
	41	272,036	191.0	2,346.0	3,155.0	251.0		5,943.0	2.19	
	42	434,729	79.0	1,876.0	5,342.0	813.0		8,110.0	1.87	
	43	207,436	67.0	1,829.0	2,660.0	325.0		4,881.0	2.35	
	44	361,571	180.0	3,324.0	4,589.0	644.0		8,737.0	2.42	
1970	45	442,101	69.0	3,153.0	6,097.0	791.0		10,110.0	2.29	
	46	575,986	102.0	2,640.0	9,350.0	821.0		12,913.0	2.24	
	47	475,805	97.0	5,411.0	5,461.0	940.1		11,909.1	2.50	
	48	445,510	23.0	2,311.0	5,753.7	947.8		9,035.5	2.02	
	49	484,849	63.0	3,177.4	6,683.8	1,147.7		11,341.9	2.34	
75	50	801,991	36.2	5,202.9	13,132.4	2,950.5		21,322.0	2.66	
	51	523,361	62.1	3,813.4	7,276.2	1,935.9		13,087.6	2.50	2-3%
	52	692,601	59.5	4,715.9	13,680.9	2,654.1		21,110.4	3.05	
	53	779,261	191.3	5,826.8	12,904.4	4,903.2	77.2	23,902.9	3.07	
	54	873,489	52.3	3,928.0	12,253.1	2,549.7		18,783.1	2.15	
1980	55	1,146,179	273.3	5,460.2	14,546.2			15,444	2.95	
	56	1,079,893	27.0	4,054.8				21,426	3.17	
	57	1,113,893	34.5					20,040	2.57	
	58	1,146,763						23,013	2.63	
	59	1,147,446						21,572	1.88	
1985	60	1,082,610						31,448	2.95	
	61									
	62									
	63									
	64									
	65									
	66									

NOTE: Handwritten figures are from a more recent table provided by Dr. Kaeriyama showing returns only. Release figures are back-calculated for 1984 and 1985. Release figures do not agree with return rates for 1980-83.

Figure 2. (From Dr. M. Kaeriyama).

FLOW CHART OF SALMON RANCHING IN JAPAN

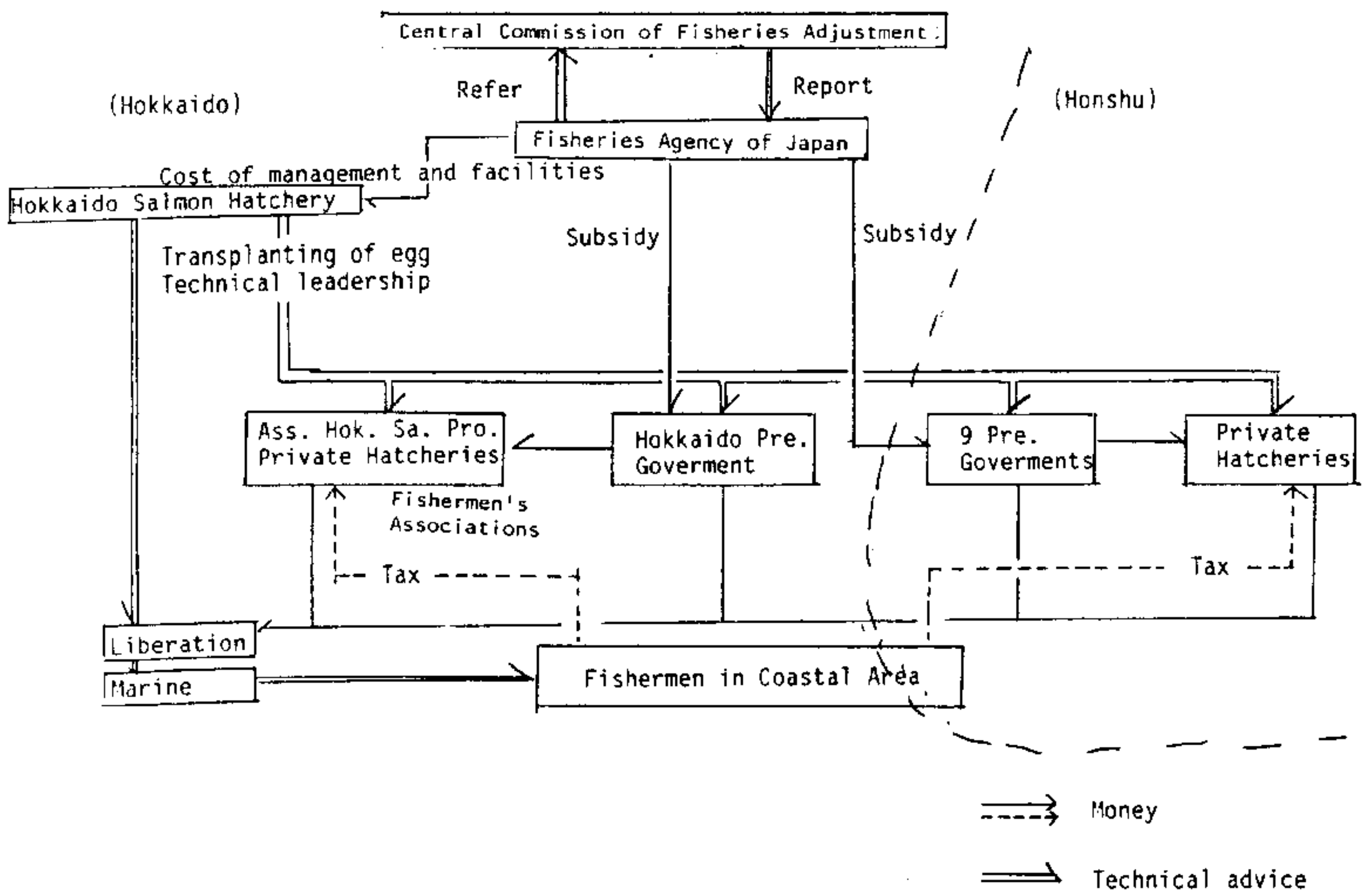


Figure 3 Organization of Hokkaido Salmon Hatchery. (From Dr. Kaeriyama).

- Fisheries Agency of Japan
  - Hokkaido Salmon Hatchery
    - Director
    - Assistant director
    - Research Department
      - Ecology Laboratory
      - Resources Laboratory
      - Environment Laboratory
      - Breeding Laboratory
      - Pathology Laboratory
    - Enterprise and Work Department (Fisheries Management)
      - Planning Section
      - First Work Section
      - Second Wrok Section
    - General Affairs Department
      - General manage Section
      - Accounts manage Section
    - 6 Branches
      Nemuro, Kitami, Tokachi, Chitose, Teshio, Oshima
      - 37 Hatcheries

*Other Organization in Hokkaido

Hokkaido Prefectual Government --- Hokkaido Fish Hatcheries --- 6 Hatcheries

Association of Hokkaido Salmon Prepagation

Private Hatcheries (by Fishermen's Association) --- about 90 Hatcheries

Figure 4. Location and area served by Chitose Salmon Hatchery. Also shows locations of prefectural and private hatcheries in central Hokkaido. (From Mr. Nakayama).

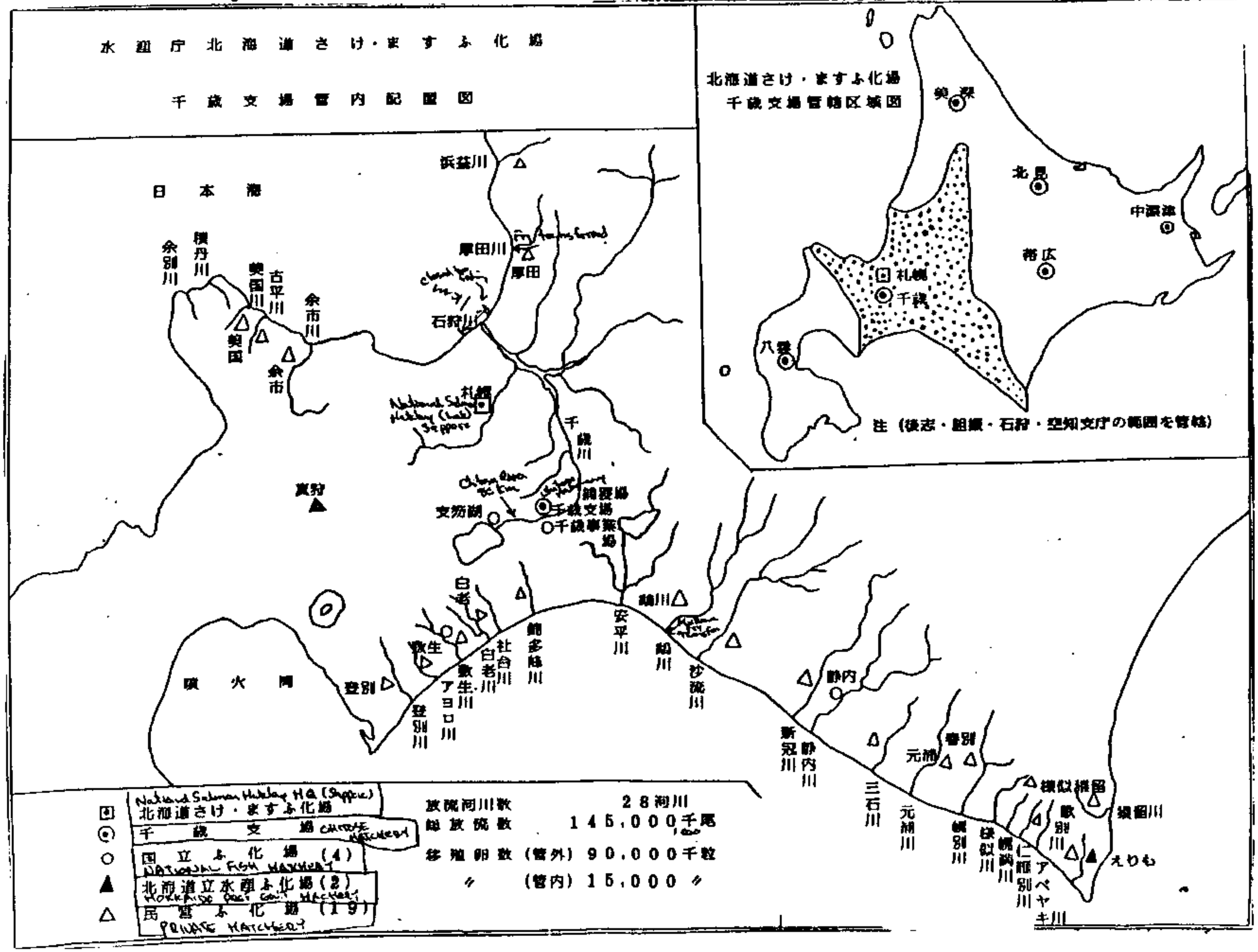


Table 2. Number of spawners and eggs taken from chum salmon at Chitose Salmon Hatchery in recent years (From Mr. Nakayama)

Year	Number of Spawners	Number of Eggs Taken
1980	120,000	113,750,000
1981	240,000	203,487,000
1982	183,000	147,688,000
1983	269,000	217,415,000
1984	136,000	172,381,000
1985	149,000	145,433,000
1986	127,416	121,883,000

NOTE: Approximately 28% of the total number of eggs are reared at Chitose Hatchery and released as fry into the Chitose River. Approximately 10% of the eyed eggs are transferred to other areas in central Hokkaido (stippled area in Figure 3-3). The remaining 62% of eyed eggs are transferred to other areas in Japan as well as to foreign countries such as Korea and Chile.

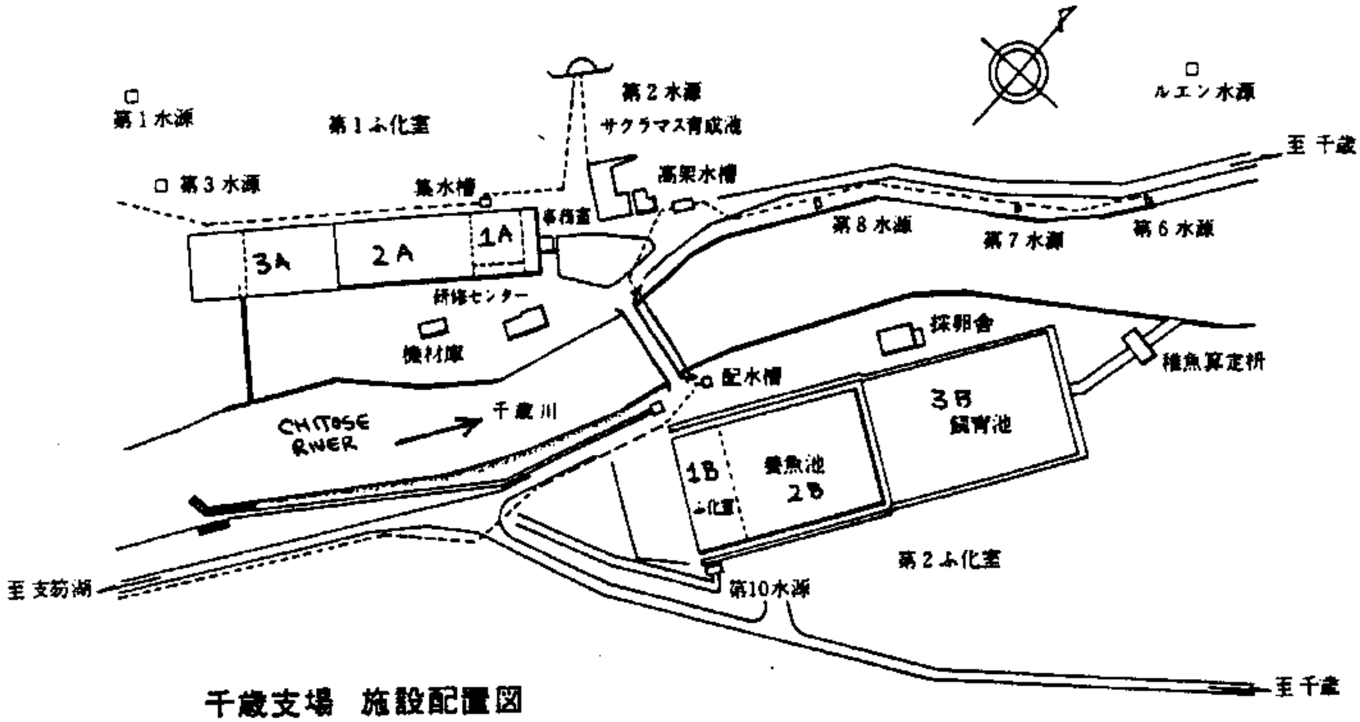


Figure 5. Chitose salmon hatchery. (From pamphlet produced by hatchery).

1A - Incubation room with 100 incubators capable of hatching 47,800,000 eggs.

1B - Incubation room with 156 incubators capable of hatching 78,000,000 eggs.

2A - Enclosed sac-fry raceways. 12 raceways, each 50 m long and 1.65 m wide, capable of producing 15,000,000 alevins.

2B - Enclosed sac-fry raceways. 40 racewyas, each in two sections 26 m and 23 m long, 1.65 m wide, and capable of producing 24,300,000 alevins.

3A - Outdoor fry rearing raceways. 8 raceways, each 15 m long and 5 m wide, capable of producing 6,000,000 fry.

3B - Outdoor fry rearing raceways. 32 raceways, each 16 m long and 5 m wide, capable of producing 26,000,000 fry.

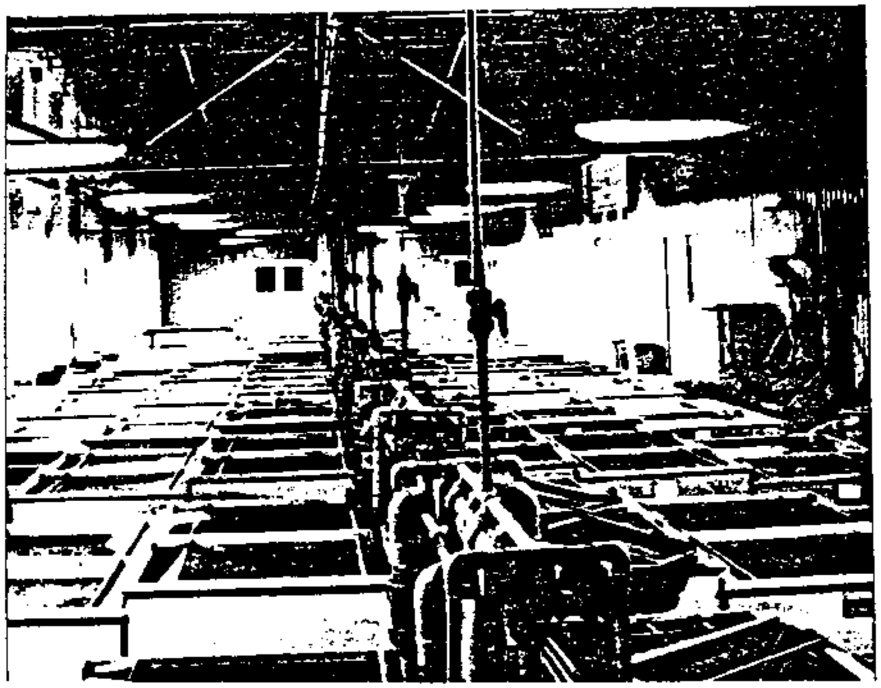


Figure 6 Egg incubation room at Chitose Salmon Hatchery. (From Hatchery pamphlet).

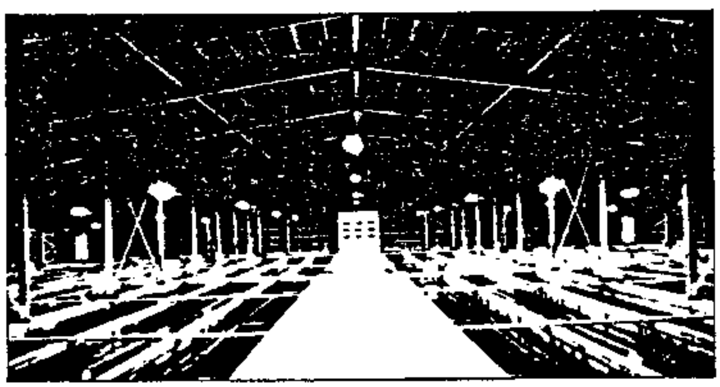


Figure 7. Sac-fry raceways at Chitose Salmon Hatchery. (From Hatchery pamphlet).

Figure 8. Fry raceways at Chitose Salmon Hatchery. (From Hatchery pamphlet).

Eyed eggs are transferred to gravel bottom troughs in enclosed buildings and kept in low light (Figure 7). In the old section of the hatchery the 12 gravel raceways are 1.65 m wide by 50 m long. In the new section of the hatchery there are 40 raceways, 49 m long by 1.65 m wide. Trays containing about 13,000 eyed eggs are placed in raceways. The gravel is 3 cm deep and when the alevins hatch they move out of the trays into the gravel. Water current through the raceways is about 1 cm per second and is provided by an upwelling system. The time to hatching for chum salmon at 8 C is 60 days. After hatching, the flow is increased about 30%

I asked about disease problems and how they could do treatments in a gravel bottom system like this. I was told that usually there are no disease problems. However, occasionally there is an outbreak of Cytophagia, in which case, all fish have to be destroyed.

Dr. Osamu Hiroi was conducting an experiment in the gravel raceways to evaluate the use of river water for rearing instead of spring water. The river water had to be heated from 3 C up to about 8 C and large plate heaters were being placed underneath the gravel to accomplish this. This experiment was not for the benefit of Chitose Hatchery, which has plenty of spring water, but was for the purpose of developing methods that might be used for growout in more marginal areas. Dr. Hiroi did not describe the preliminary results but Dr. Kaeriyama said this was extremely expensive and unlikely to be useful except in a few areas.

After emergence the fry swim downstream to outdoor rearing ponds (Figure 8). In the old section, there are eight 5x15 m raceways and in the new section there are 32 5x16 m raceways. The density of fry at the time I was there was 20 kg of fry per 1000 kg of water. The fish average 0.28 g and it was getting close to the normal release time in late March to mid-April. Optimum release size was described as 0.6 - 0.7 g. All feeding was by hand, and the fish were receiving 2.5% of their weight per day at a water temperature of 6 C. There were no nets for keeping birds out and no electrical wires for mammalian predators. There were pictures of kingfishers and some other predators in the administrative offices but apparently this is not a big enough problem to warrent any preventative measures.

I was not able to visit the fish trapping area but this was described to me and I collected some pictures. Fish are trapped from August through December about 10 km downstream on the Chitose River. There is a large weir placed across the river and a fish wheel is used to collect the fish. This is not only a very effective way of collecting spawners for the hatchery, but it is also one of the major tourist attractions in the Chitose area. There is even a statue of this fish wheel in downtown Chitose and it is on the cover of the local telephone book.

There is also some rearing of other species at Chitose Hatchery. While I was visiting, there were 150,000 masu salmon and 10,000 kokanee salmon in the raceways.

Research and Management. The Sapporo branch of the Hokkaido Salmon Hatchery is the primary research and administrative center. In addition to several buildings housing offices and laboratories, there is also a small hatchery for experimentation. Approximately 20 research projects are currently underway at the hatchery, covering a wide variety of topics (Table 3).

Table 3. Research at the Hokkaido Salmon Hatchery

I. Fundamental Research on Salmon Ranching
   1. Ecology, Ontogeny, Ethology and Physiology of Salmon
      a. Behavior and ecology of escapement and spawning (chum and masu salmon)
      b. Ontogeny of egg development (chum)
      c. Morphology and functional differentiation with development during the early life period (chum, masu and sockeye salmon)
      d. Ecology and physiology during seaward migration of juvenile chum, masu and sockeye salmon

   2. Effective Promotion of Artificial Salmon Reproduction
      a. Biological management in Hatcheries (chum, masu, sockeye and pink salmon)
      b. Rearing methods (chum, masu, sockeye and pink salmon)

   3. Population Dynamics
      a. Statistics of catch and escapement (chum, masu, sockeye and pink salmon)
      b. Tagging and marking experiments (chum and masu salmon)
      c. Population dynamics of kokanee and the ecosystem of Shikotsu Lake

II. Research on Breeding of Salmon
   1. Physiological and ecological characteristics of the race (chum salmon)

   2. Production of superior breeding (chum, pink salmon)

   3. Production of polyploid species (masu salmon)

   4. Sperm storage (chum salmon)

III. Marine Ranching Program for Masu Salmon (Special Project Research)
   1. Ecology and physiology

   2. Production and release of smolts

   3. Control of maturation

IV. Coastal Examination of Salmon
   1. Ecology of juvenile salmon and ecosystems in coastal areas.

   2. Ecology of adults during spawning migration

V. Environmental Examination in the Hatchery
   1. Water quality

   2. Pathology

A number of the studies relate directly to hatchery practices, such as determination of optimum release times for fish. Release is not only determined by size of the fish but also by environmental conditions in the river and ocean. The Environmental Laboratory staff samples both the ocean and river for phytoplankton, zooplankton, and insect production. I met Dr.Shimizu, who studies oceanographic conditions and plankton production, and he discussed the relationship between ocean temperatures and productivity, and growth and survival of salmon fry while in the ocean.

I was impressed by the amount of information the Japanese have accumulated on the fate of their fish once they leave the river system and enter the ocean. Chitose River fry are in Ishikari Bay from April until early June. During this time they grow to a size of 6-8 cm. They stay near shore and migrate clockwise around the island until they get to the Kushiro area in July and August. At this time they are about 12 cm in length. From northeast Hokkaido the fish follow the Kushiro warm ocean current across the North Pacific to the Gulf of Alaska. This is the summer feeding ground and they stay here until late fall, when they are one year old. During the winter they move to the Bering Sea and then go back to the Gulf of Alaska in the summer as two-year-olds. They repeat this again in their third year and then migrate back to Japan, for the most part as four-year-olds. There have been extensive tagging studies and radiotagging experiments to determine these patterns. The radiotagging studies have primarily been done by Tokyo University.

The escapement period for spawners returning to Hokkaido rivers is between September and December. The coastal fisheries primarily use set nets or seines near the mouths of rivers. There is generally a protective area of one square km around each river. There is both a time and catch limit set on the fisheries to insure optimum escapement. To set early, mid- and late season escapement goals, there is constant monitoring of the fisheries, by the Work Sections of the laboratory and the Research Department. Dr. Abe is the chief forecaster for the escapement goals. Apparently it is very easy to predict the early and late portions of the run and to control those, but the middle of the run is very difficult because of the large number of fish migrating into the rivers at this time.

There is little natural spawning of chum salmon in Japan due to loss of much of their habitat. Flat land in Japan is very limited, so most of the land along the lower reaches of rivers is heavily populated. As a result, rivers have been channelized and pollution is common. In the upper reaches, many dams have been built for hydroelectric generation, water supply, and flood control. I was very happy to see, however, that there is ongoing research into the natural history of chum salmon. Dr. Kariyama, in particular, was working on studies of protected areas of rivers where there is natural spawning and I was able to visit one of his study sites. Other members of the Ecology Laboratory were also working on different phases of this project.

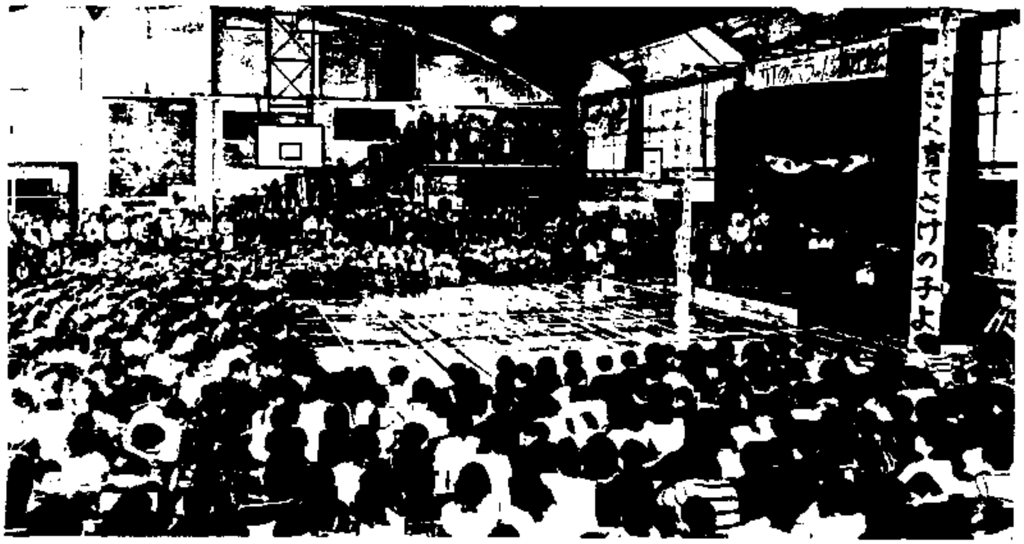
Chum Salmon Nutrition Research At Other National Laboratories. While at the National Research Institute of Aquaculture in Mie Prefecture, I met with three researchers who had been working on development of formulated diets for chum salmon fry: Dr. Tohsio Akiyama, Dr. Takeshi Murai, and Dr. Katsuyoshi Mori. I was given several papers which describe the development of a formulated diet for chum salmon fry which was worked on by these and other researchers. It turned out that the nutritional requirements of chum salmon fry are not significantly different from requirements of rainbow trout fry. Most hatcheries in Japan are not feeding the special diet designed for chum salmon but instead are using the EBOS diet from Scandinavia or an equivalent.

Dr. Akiyama is now working on nutritional studies related to prevention of scoliosis and cataracts in chum salmon fry. He believes these problems are caused by a nutritional deficiency of the amino acid tryptophan. He has done a number of studies which show that by increasing the amount of tryptophan in the diet, scoliosis and cataracts in chum salmon fry can be prevented. I also received a number of papers on this subject which are listed in Appendix 1.

Public Involvement Programs. I visited two educational facilities that were involved in programs to increase public awareness about salmon. The first was the Salmonidae Science Museum in Sapporo, which is quite a large and popular attraction. I met with Dr. Hisashi Shibata, director of the museum, who described it's operation and background. One building is primarily filled with displays and photographs showing the different salmon species in Japan, their fisheries, and their life histories and environmental requirements. Attached to this building is a small hatchery and tanks with examples of all salmonid species found in Japan. There is also a ladder and spawning channel which leads from the Toyohira River behind the laboratory. People can watch the salmon returning and watch the spawning activities. In addition to the museum and hatchery, there is a separate building which is available for classroom use. After touring the main museum classes can go back to this teaching building, which contains a library and a large tank designed as a model stream.

This museum is the focal point for the Hokkaido Salmon Assocation, which is a coalition of different public groups and fishermen's associations interested in restoring salmon runs to the Sapproro area. This is also called the "Come Back Salmon" movement. This group has been restockng the Toyohira River for the last several years and has been successful in increasing the spawning run from 6 salmon in 1953 to 1500 salmon in 1981. Fry releases are a huge public event for which thousands of people turn out. School children and interested adults are given small buckets of fry which they release into the river by hand. Judging from the photographs, this event has tremendous media coverage and a tremendous outpouring of participants. During the fall many people now come to view the returning salmon spawning along the banks of the river. One of the major projects proposed by the Hokkaido Salmon Association is development of a Salmon Park alongside the river in an area where large numbers of adults have been seen spawning.

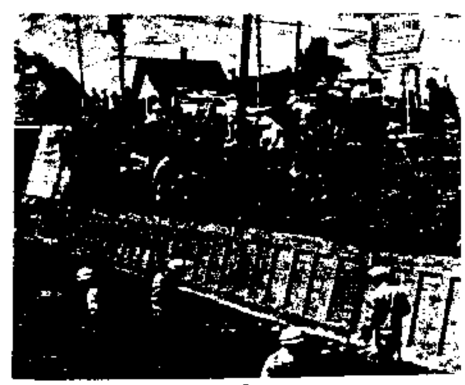
Sapporo is the sister city of Vancouver, British Columbia, and there are many activities between the school system in British Columbia, which is involved in the salmonid enhancement program there, and the school system in Hokkaido. There have been student enchanges and lots of literature passed back and forth between the two areas. The Snohomish County Adopt a Stream Program in Everett Washington also has very strong ties with the Hokkaido Salmon Association and their activities are reported in magazines that are produced by the Japanese association. Figure 9, A-D is excerpted from literature I received from Hokkaido Salmon Association.



A

B

D

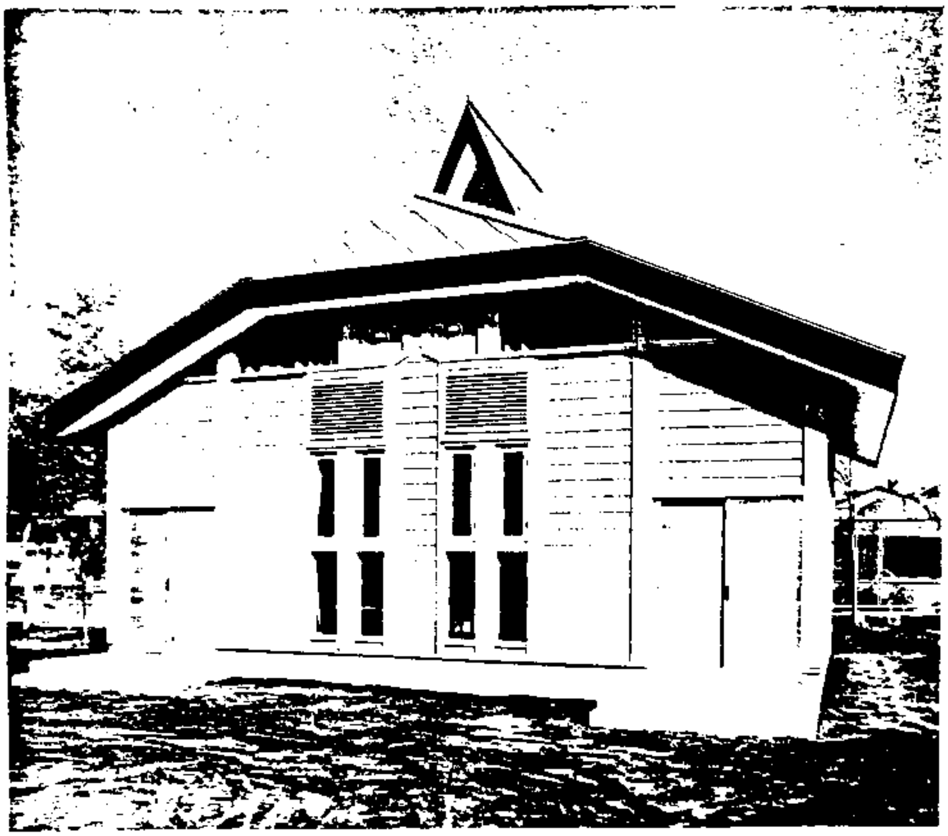


C

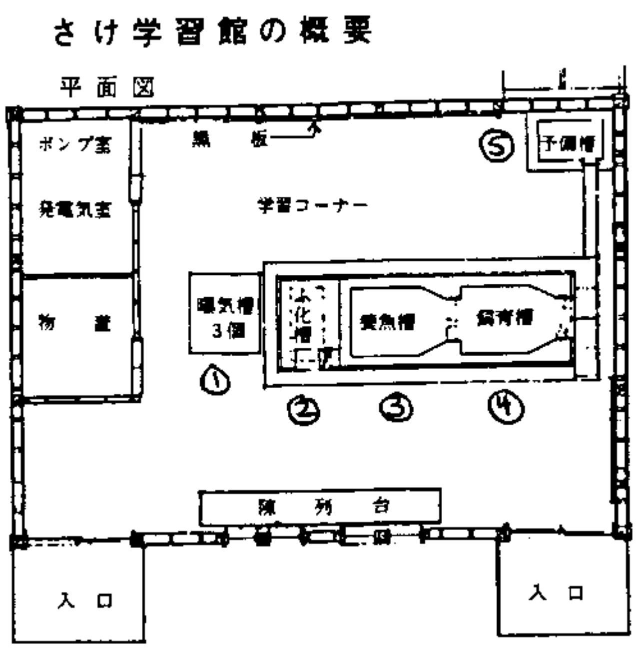
Figure 9. A. Assembly prior to salmon release at elementary school in Sapporo.
B. Salmon release
C. Clean-up party along the heavily channelized Toyohira River.
D. Proposed salmon park along Toyohira River in Sapporo.
(From Hokkaido Salmon Association).

I also visited a hatchery built next to the recreation yard of the Higashi-Shiroishi Elementary School in Sapporo (Figure 10A). This school used to operate a small hatchery at a shrine with a spring but the water source was only marginal. Using donations from all over Japan the present hatchery was built at a cost of 300 million yen (about $200,000). The hatchery uses well water, which is pumped and gravity fed through four vertical tanks for aeration and denitrification, into a two-stage raceway. The upper stage is filled with gravel, in which the eggs are hatched. After the fry emerge, they move into the second tank where they are fed and reared for about 2 months until they are 5cm. The first stage is 1.5m x 1.0m x 0.2m deep, and the second is the same outer dimension but 0.5 m deep (Figure 10B).

I met with two instructors and the principal of the school. They pointed out that there is a well-developed curriculum which goes along with this project. The curiculum not only emphasizes the ecology of chum salmon and the fish's environmental needs, but integrates an overall environmental perspective into the curriculum. The hope is that the students will grow up with a dedication to fighting pollution and trying to restore natural habitat regardless of what species are affected.



A.



1) Three verticle tanks 1x1x1m for oxygenating and denitrifying well water

2) Forebay 1.1x0.44x0.4 m.

3) First stage of raceway 1.5x1x0.2 m for incubation

4) Second stage of raceway (fry rearing) 1.5x1x0.5 m.

5) Holding tank 1.0x0.6x0.7 m

B.

Figure 10. A. Hatchery building at Higashi-Shiroishi Elementary School.
B. Diagram of hatchery layout.
(From Higashi-Shiroishi Elementary School).

Coho Salmon Net Pen Culture

(*Oncorhynchus kisutch*)

During my trip to Japan, I visited a coho salmon incubation and freshwater rearing station near Shizugawa, a seawater net pen culture operation in Shizugawa Bay, and the Miyagi Prefectural Freshwater Fisheries Laboratory in the Dai-wa-cho area. At the Prefectural laboratory I met with Dr. Gen-ichi Hoshiai, who had just written a handbook for coho salmon culture. He presented a slide show on coho net pen culture and comments in this section will be a combination of information I received from him as well as from Mr. Kanji Takahashi, from the Kesennuma Prefectural Experimental Station, who took me to the culture operations, and Mr. Seichi Sudo, director of the Shizugawa Sea Coast High Utilization Center.

Coho salmon production in Japan started in 1975 in Shizugawa Bay when 2.4 tons of coho salmon were produced. In 1986, production was 6600 tons of coho salmon (Figure 11, 12). For the 1987 brood year 1100 tons of fingerlings were put into seawater pens and, if the mortality and growth figures for this year are similar to those in the past, a crop of about 12,000 tons is expected in 1987.

This increase in production has created some problems with marketing. The cost per kg to the consumer has gone down as the supply has increased. Before 1981 the unit selling price was 1000-1200 yen per kg. It has been below 1000 yen since that time and last year the unit price was 693 yen per kg (Table 1). (This compares to 500-1000 yen/kg for female chum salmon and 200-300 yen/kg for male chum salmon.) While this lowering price has helped to increase demand, the problem is that fishermen have a break-even point of about 800 yen per kg. Last year I was told that fishermen lost money raising coho salmon and they are very concerned about the large crop that is planned for this year.

The recommendation from fisheries biologists to the cooperatives to improve the market situation is to change the time of entry into the marketplace. Last year almost all the fish glutted the market during mid- to late summer. Now they are trying to get as much of the production sold as possible in late spring and early summer. There are no other salmon in the market in Japan between April and May so the price is very high. Fishermen can still get over 1000 yen per kg for coho salmon if they market them during these months. The Prefectural Fisheries Agency has recommended that 5% of the harvest be marketed in April, 20% in May, 30% in June, 30% in July and 15% in August. If the marketing is handled in this manner they should maintain a high price throughout the year.

One item to note for American producers is that the demand for coho salmon in Japan has stayed fairly constant at about 300,000 salmon per year recently. Last year the supply was about 400,000 salmon and this year it should be considerable higher than that, which I think has implications not only for US exports of coho salmon to Japan but also for the possibility that coho salmon may be exported from Japan at some point.

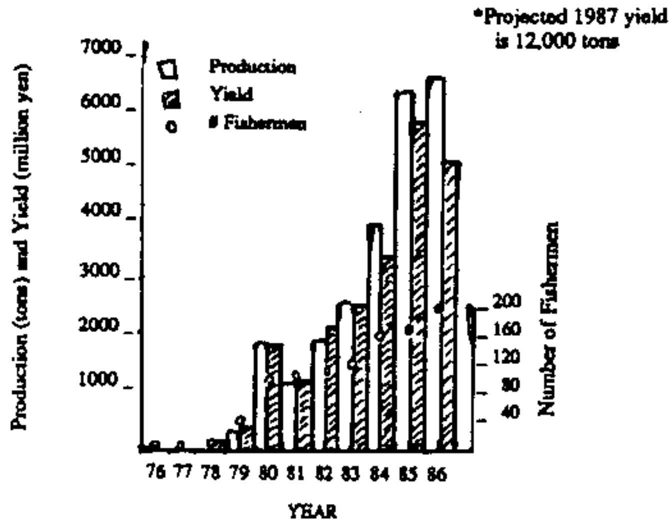


Figure 11. Coho salmon production, yield (value), and number of producers in Miyagi Prefecture. (From Yoshida and Hoshiai 1987).

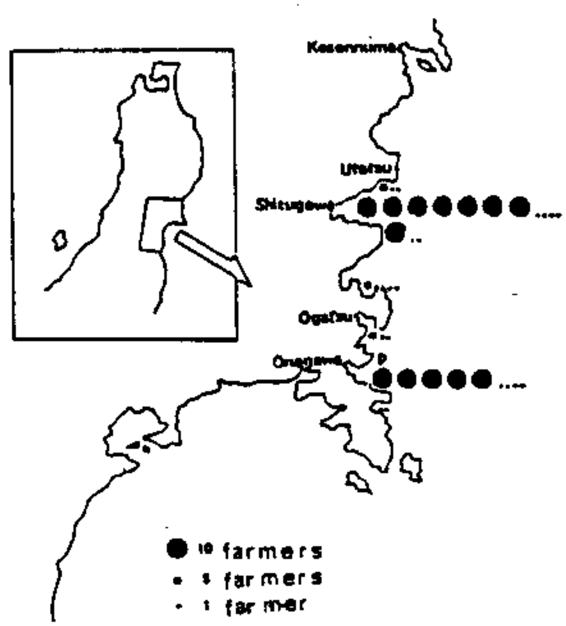


Figure 12. Producing centers of coho salmon in Miyagi Prefecture. (From Yoshida 1985).

A B C

	4月 APRIL	5月 MAY	6月 JUNE	7月 JULY	8月 AUGUST	Total 平均, 総量
S58年 1983	1,200円 10.8 t 0.76%	989 153.7 10.86	864 495.9 35.04	833 713.5 50.42	947 41.2 2.91	867 1,415.1
59年 1984	—	891 83.0 4.9	798 506.4 29.7	802 785.8 46.07	749 330.2 19.36	794 1,705.5
60年 1985	—	985 51.8 2.11	911 808.1 32.89	827 1,452.5 59.11	900 144.8 5.89	862 2,457.1
61年 1986	—	927 24.1 1.24	802 534.8 27.45	643 1,112.0 57.09	665 276.9 14.21	693 1,947.9

A = Price (yen per kg) B = Tons of salmon sold C = Percentage of annual production sold

Circuled values are prices that fell below the break-even point of 800 yen/kg. (From Yoshida and Hoshiai 1987).

Table 4. Production of coho salmon from Miyagi Prefecture by month, 1983-1986

All of the eggs for production are imported from the United States, primarily from Oregon but also from Washington. In 1986 the total number of eggs imported was 28 million. Most of the eggs are incubated and reared in freshwater hatcheries in Tochigi Prefecture, but about 6 million eggs are also reared in Miyagi Prefecture and another 6 million in Iwate Prefecture. The hatchery that I visited in Otatsu near Shizugawa purchased 240,000 eggs for incubation. These eggs apparently were originally purchased from the United States by Nichiro Fish Company or Taiyo Fish Company and then were sold to small private firms and fishermen's cooperatives for rearing. The hatchery I visited received its eggs in early December. After receiving the eggs it took about 3-10 days for them to hatch, and after a month they began feeding. Fish were held in raceways or portable plastic circular ponds. Some were covered with plastic greenhouses to increase the water temperature. The fry are raised until late October, at which time they average 150 g. They are then sold to the fishermen's cooperative. The hatchery that I visited purchases eggs for 6.5 yen per egg and the fry are sold for 1200 yen per kg of fish. The water temperature at the hatchery I visited in Miyagi was only 5 C during most of the year, although during the summer it goes up to 18 C, when by far the majority of growth takes place. The reason Tochigi Prefecture is preferred is becuase the water temperature is between 10-15 C even during the winter months.

One comment that I received everywhere while traveling in Japan was how upset the Japanese are with the quality of eggs received from the United States, in particular from the state of Washington. They have had very serious problems with bacterial kidney disease (BKD) in recent years. When the Japanese receive the eggs they dip them in a 50-100 ppm iodine solution to try and prevent BKD that is external to the egg. However, they have found nothing that works for bacteria that is internal to the egg. They mentioned a method that a US researcher developed to prevent the disease, but they found that this method did not work for them. The Japanese also use the fluorescent antibody technique (FAT) for egg inspection. They try to discard as many eggs with BKD as possible but they still say this is an extremely serious problem.

I was told that the Japanese could produce their own coho salmon eggs if they needed to, but it was considerably cheaper to import them from the United States. They have developed a method for raising coho to reproductive maturity within 2 years, after which they are able to obtain eggs. If they culture the fish in sea water for one year and then put them back in freshwater they will mature. I did not obtain any details regarding this method.

When the fry are ready to be transferred from freshwater to the net pens they are acclimatized. First, they are put into tanks filled with freshwater and 20% seawater. The next day the seawater level is raised to 40% and then it is raised 20% per day until they reach 100% seawater in four days. This works for fish 100 g or larger. For smaller fish, it takes 7 days to acclimatize them. Fish are starved in both cases. Oxygen is supplied and the water is recirculated in the acclimatization tanks. A lot of foam is created during this process and this is removed. I did not see the method they used to do this but foam removal is apparently very important during the acclimatization period.

Once the fish have been adapted to saltwater they are moved into net cages. The most popular size is 13 x 13 m at the surface by 10 m deep. This size net pen can hold between 7000 - 10,000 fish. In Shizugawa Bay most of the net pens are smaller than this. They are 10x10 by either 7 or 10 m in depth and hold 5-6000 fish per pen. At the time I saw them, at the beginning of April, the fish were 500-800 g. They had been in the pens since October or November. One problem the biologists kept mentioning was that fishermen tend to crowd their nets too much. While the recommended number of fish is what I just described, there are some fishermen who will put up to 1500 fish too many in each pen.

During the winter they are fed once per day and during the summer after the seawater temperature is above 9 C, they are fed twice per day. The feeding method that I observed was to prepare the food onboard the boat which services the pens. There was a grinder in the bow of the boat and frozen sardines, mackeral, and small shrimp were ground along with a bag of prepared dry fish diet. This diet is a combination binder and nutritional supplement. The bag of dry feed and the frozen fresh fish were ground together and extruded onto the deck, and the fisherman shoveled this into the pens on either side of the boat.

The fish feed was 70% fresh fish and 30% dry feed compound. The dry feed compound is composed of 45% cod fish meal, 28% soy bean, 14% rice, 13% binder, and vitamins. Color in the fish comes from carotenoid pigment, which is in the meal and in fresh shrimp which are fed to them as they get older. They don't start to give fish the shrimp for color until early March. They then start to subsample the fish in order to check meat color. Starting in April they look at color about every 2 weeks and adjust the shrimp or astaxanthin supplement in the diet as necessary. The feeding rate is 2% of body weight per day during the cold period and 3-4% during the warm season. At temperatures above 15 C, which sometime occur in Shizugawa Bay, feeding rates go up to 5%.

I heard two different versions of the role of natural feed from the bay in the diet of the fish. When I visited Shizugawa Bay I was told that 1 kg of natural food from the water moving through the pens is eaten by the fish for each 4 kg of diet which is fed to them. However, when I was at the Prefectural Laboratory discussing this with biologists, I was told that they do not eat any natural feed at all and that their entire diet is supplied by supplemental feeding.

When I visited the net pens in Shizugawa Bay I observed a number of mortalities, apparently caused by a combination of overcrowding and overfeeding. One of the manifestations is an enlarged, fatty liver, but the exact nature of the disease is not presently understood. Dr. Hoshia explained that saturation feeding occurs at 5% of body weight during most months; however, many fishermen feed at rates well above this. How this related to hepatic enlargement was not made clear to me and it appears to be a major area of research for biologists in Miyagi Prefecture. Next to BKD, it is the major source of mortality for coho salmon in Japan.

While the relation between overfeeding and an enlarged kidney was not obvious to me, the relation between overfeeding and pollution in Shizugawa Bay was. In addition to overfeeding a major problem is that net pens are too close together. Biologists recommend that the pens be placed 30 m apart, but all the pens I saw were separated by only 5 m or so. The reason for this spacing was obvious - it was almost the exact width of a boat, so fishermen could pull between two pens and feed them simultaneously. Apparently, low dissolved oxygen from buildup of metabolites and uneaten feed on the bottom of the bay is becoming a major concern.

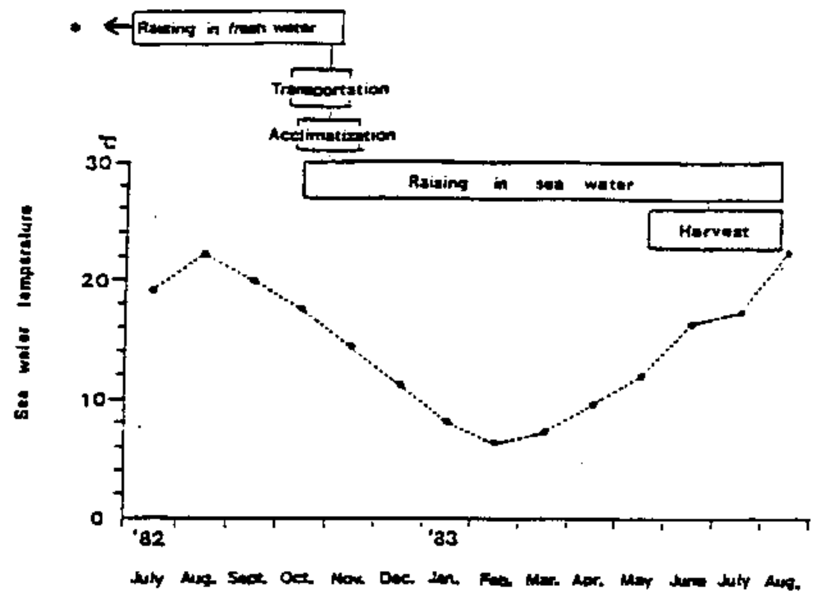
Growth rates of coho salmon are extremely rapid in this environment (Figure 13 and 14). Conversion rates are as high as 5:1 to 7:1. Some fish are ready for harvest as early as April or May, when they are about 2 kg and all are harvested by the fall, when they are about 4 kg. As mentioned earlier, fishermen are trying to even out the harvest rate to keep prices higher throughout the season. One point about harvesting is that the appearance of the fish is critical in determining the market price. It is important not to have any scale loss when harvesting the fish. In Shizugawa Bay the primary method of harvesting is to crowd the fish together into one side of the net pen and slip a sheet of vinyl aroung them to prevent water exchange. Oxygen is quickly depleted and the fish suffocate in about 15 minutes. They are packed in boxes and sent directly to the auction. They are neither gutted or filleted.

In Shizugawa Bay the fishermen are organized into two associations that account for most of the pen culture. The Shizugawa Corp., whose operations I visited, is made up of about 70 families. The Togura Corp. is made up of about 10 families, but each family has a larger operation than those in the Shizugawa Corp. Togura Corp. families use 30 x 30 m net pens instead of 10 x 10 m pens.

Dr. Hoshiai discussed diseases and other sources of mortality affecting each stage of coho salmon pen rearing in Japan in great detail. A flow chart which summarizes this information is included as Figure 15. Dr. Hoshiai also gave me a copy of the chapter of his handbook on coho salmon pen culture, which covers diseases. It is all in Japanese but is available from me if anyone cares to read it. The cost of the entire handbook is 10,000 yen.

Dr. Akiyama at the National Institute of Aquaculture in Mie discussed the diet of coho salmon in net pens with me. The dry diet used is specially formulated for salmon. They first did studies using 100% raw fish then 100% dry diet. They found the best results were with a 50:50 mixture of the two. However, fishermen want to save money so they only use 10-30% dry diet in the mixture. According to Dr. Akiyama, only about 50% of the raw fish is eaten. There is a tremendous drip loss and the fish pellets fall apart in water creating a great pollution problem. He recommends a 50:50 mixture in order to reduce pollution in the bays around net pens and to get the best feeding efficiency.

Figure 13. (From Yoshida 1985).



Outline of Coho salmon mariculture in Miyagi Prefecture

* NOTE: My observations indicated that freshwater rearing began in December, six months prior to the start of freshwater rearing shown on this figure.

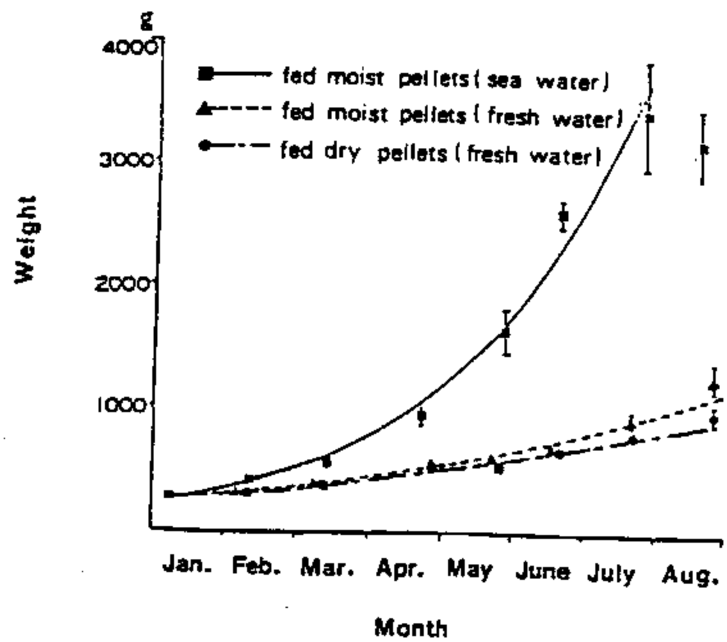


Figure 14. Growth of coho salmon in Miyagi Prefecture during final 8 months of rearing.
(From Yoshida 1985).

CULTURE STAGE	DISEASES AND OTHER SOURCES OF MORTALITY EXPERIENCED IN JAPAN	OTHER POSSIBLE DISEASES AND SOURCES OF MORTALITY INVESTIGATED
IMPORT OF EGGS	BKD	IPN, IHN, VHS
FRESHWATER REARING	IHN, BACTERIAL GILL DISEASE, AEROMONAS, A. SALMONIDAE, VIBRIO, BKD, COLUMNARIS, STAPHYLOCOCCUS, FUNGUS, "ICH", PARASITES	IPN, (3 Other problems listed but not translated for me)
TRANSFER TO SEAWATER		
ACCLIMATIZATION	LACK OF O_2 FROM OVERCROWDING, AEROMONAS SALMONIDAE, "FAILURE TO ACCLIMATIZE CAUSED BY PHYSIOLOGICAL PROBLEMS"	
SEAWATER REARING	VIBRIO, A. SALMONIDAE, BKD, NUTRITIONAL PROBLEM (HEPATIC ENLARGEMENT AND LESIONS), VIRUS DISEASE	PSEUDOMONAS

Figure 15. Diseases and other sources of mortality affecting various stages of coho salmon production in Miyagi Prefecture.
(From Yoshida and Hoshiai 1987)

Masu Salmon
(*Oncorhynchus masou*)

Production of masu, or cherry, salmon is very low but, because it carries a relatively high unit price, there is a great deal of interest in this species. Research on this species was being conducted at most freshwater laboratories I visited.

Masu salmon is an interesting species because it has a complex life history. It is an anadromous species that is found from the Tohoku Region north to Hokkaido. Adults spawn from October to early December and hatch in February. The following autumn the fish divide between stream residents and pre-smolts. Pre-smolts move downstream primarily in March and April, although some also migrate downstream in autumn. Of the remaining fish which over-winter in the stream, some will smolt the following autumn and the others will remain freshwater residents. Therefore, fish may move into saltwater at 1, 1-1/2, or 2-1/2 years or remain in freshwater for life.

Smolted fish live in estuaries and nearshore oceanic areas for 2-3 months. When the ocean temperature reaches 15 C they migrate north to the Okhotsk Sea, where they spend the summer. In the fall they move back towards Hokkaido and work their way southward along the Pacific coast. They winter south of Shiogama in 5 C water. Similar winter grounds occur on the Japan Sea side, where there is a larger population which includes fish from Russian streams. In the ocean there are varied sizes of fish depending on how long they stayed in freshwater before going to the ocean. Regardless of how long they spent in freshwater, masu salmon spend only one year in the ocean before returning to freshwater. The maximum-sized fish are 5-6 kg and 50 cm fork length, while small fish measure about 30 cm.

Masu salmon primarily move into rivers from March through July, although some return as late as September. The summer fish stay in deep pools and near falls, since river temperatures may reach 17 C during the summer in the Tohoku Region. One thing that is particularly interesting about masu salmon is that their life history changes with latitude. The rate of anadromous fish is 10-20% in the Tohoku area and 80-90% are freshwater residents. About 95% of the fish that do smolt become females. However in Hokkaido about 70% of the population is anadromous and 30% are freshwater residents. Hokkaido anadromous masu salmon sex ratios are about 2:1 female to male.

The spawning population in the Tohoku area is composed of large females and small males. There is about one female for every 5-20 males. In Hokkaido, the anadromous females mate almost exclusively with anadromous males, which are also large. Resident fish spawn 2-3 times while anadromous fish spawn only once and die. In Miyagi Prefecture resident males first mature at 10 cm as age one fish. The maximum size of older male spawners is 29-30 cm. Resident female spawners are 35-65 cm in size.

At just about every research facility I visited in Japan there was at least one person and often several people working on masu salmon. Most of the work involved trying to speed up the rate of smolting, to increase the percent of fish that smolted, and to increase growth rate. In this section I will outline a few of the research projects that were described to me.

In Miyagi Prefecture at the JFA Tohoku Regional Laboratory Dr. Katsuhiro Kiso was doing basic ecological research on masu salmon. Most of the background information I received on this species came from Dr. Kiso.

In Sapporo at the Hokkaido Salmon Hatchery there was an entire section working on marine ranching programs for masu salmon. This group was working on ecology and physiology, production and release of smolts and control of maturation. In particular, I talked to Dr. Hiroshi Mayama about his research which concerned movements of masu salmon in rivers. Dr. Mayama had recently completed a paper on fish passage of masu salmon around fish ladders and other obstructions in Hokkaido rivers.

At the Nikko Branch of the National Research Institute of Aquaculture Mr. Kazumasa Ikuta was studying the endocrinology of smolting in masu salmon, especially for precocious males. His studies indicated that sex hormones inhibited smoltification and he was administering different hormones to observe their effects on smolting. Smoltification is controled by the growth hormone thyroxin. He found that estradial inhibited thyroxin but progesterone stimulated thyroxin levels. He gave me several papers regarding his studies. At the same laboratory Dr. Ryozo Sato was studying smolting in masu salmon and its dependency on temperature and light. By mimicking Hokkaido temperature regimes, he has been able to get high percentages of smolts among Tohoku masu salmon. These smolts are also produced earlier in the year than usual for the Tohoku region. Also at the laboratory Dr. N. Okumoto was doing experiments on the relationship between photoperiod and smolting. He found that, although fish usually smolt after 1-1/2 to 2 years, this can be shortened to just over one year by controling photoperiod. The most effective method was to alter long and short daily light regimes. The radical changes in diurnal periodicity "fool" the fish's metabolism into developing as if the seasons had gone by much faster than they acutally have. His method also results in fewer precocious males. Dr. Okumoto has also been studying the ecology of masu salmon in Lake Chugenzi and has been looking at migration and homing behavior of the fish as they move between stream and lake habitats.

In Mie Prefecture at the Freshwater Station of the National Institute of Aquaculture, Dr. H. Ogata was studying smoltification of masu salmon as it relates to diet. He found that diet was extremely important at the time of spawning and that there is a higher smolting rate in masu salmon which have high amounts of lipids in their diet for energy. He stressed his belief that the ideal method to promote smolting of masu salmon is to combine the light and temperature regimes that were being worked on in Nikko and include a different feeding regime with a higher concentration of lipids in the diet. By combining all three methods he claimed that you could speed up maturation in masu salmon by one year or more. At that same laboratory I met with Dr. Onozake who was working on genetic manipulation, in particular, androgenesis. He suceeded in producing androgenic diploids in masu salmon a few years ago. These are fish with two Y chromosomes which are refered to as "super males". When these are bred with females, which he did in another experiment, all the offspring come out XY males. The purpose in doing this is to speed up growth since, for many species, males grow faster than females. A second reason is that you can preserve sperm from males but you cannot preserve eggs from females so, it is possible to maninpulate different genetic lines with androgenic males. A third reason is that he is interested in experimenting with hybrids, which involves using a sperm nucleus from one species and the egg cytoplasm from another species. Dr. Onozako will be experimenting with this soon.

Other Salmonid Species

I observed kokanee salmon (Oncorhynchus nerka) at the Lake Shikotsu Hatchery in Hokkaido near Chitosai. This is a small hatchery built approximately 40 years ago and operated by one person to raise kokanee salmon for stocking into Lake Shikotsu. Dr. Kaeriyama was studying kokanee salmon in that lake as one of his tasks and was trying to determine the cause of their decline in Lake Shikotsu in recent years. In Nikko, Dr. Okumoto was also studying kokanee salmon as one of his tasks. His experiment was determining migration and movement of kokanee salmon within Lake Chugenzi. He was also working with kokanee salmon to create triploids. He was using the heat shock method at 28 C for 6-10 minutes about 10 minutes after fertilization.

At the Miyagi Prefectural Freshwater Fisheries Station, in addition to coho salmon, there were also rainbow trout, masu salmon and various species of Salvelinus on hand. Most of the studies underway at the laboratory seemed related to disease problems and pathology.

At the National Institute of Aquaculture - Nikko Branch Hatchery, there were many species of salmon and trout on hand including kokanee salmon, masu salmon, amago salmon, rainbow trout, brown trout, lake trout, steelhead, biwa trout, brook trout and different species of charr. In addition to his studies on masu salmon, Dr. Sato was also looking at genetics of several other species. In one study he was estimating heretability of coho salmon and amago salmon. In another study he had developed a triploid hybrid between female rainbow trout and male brown trout. He said this was a particularly good cross because they are very delicious and have a high fat content, so they seem to be excellent for the sashimi market. No special techniques are required to hybridize these species - it's a natural hybrid, but the survival rate is very low. Hybrids have also been produced between rainbow trout females and amago salmon males. For these Dr. Sato uses heat shock 10 minutes after fertilization at 30 C for 10 minutes and this produces heterotriploid fish. He also uses hydropressure 10 minutes after fertilization for 6 minutes at 650 kg per sq. cm. In some cases there is a high survival rate and in others there is not. The survival rate may be dependent on egg quality, as eggs may be over-ripe in cases where this does not work. He has also been working to produce triploid rainbow trout using polyethylene glycol to fuse sperm together. Another study involves cryopreservation of sperm from amago salmon for 1-3 months, then fertilization of rainbow trout from the amago salmon sperm. He got 50-65% survival to the eyed egg stage, which he considers high.

At the Mie Freshwater Facility at the National Institute of Aquaculture, Dr. Arai talked to me about rainbow trout production, particularly about production of rainbow trout with pink colored flesh. He said that some culturists feed them krill oil or shrimp for colorization and this is used for sashimi. However, there is a problem because the freshwater fish tend to have more parasites and they must be frozen before being eaten. He believes also that color of the flesh is related to maturation. He has attempted to feed rainbow trout and coho salmon a diet to give them red-colored flesh when raised in freshwater, and found that unless they were near the age of maturation, he had a very difficult time getting the flesh to take on the red color.

APPENDIX 1

List of salmonid aquaculture and fisheries
reprints obtained on study trip to Japan

Copies are available at cost from C. Toole

1. Akiyama, T., S. Arai, T. Murai, and T. Nose. 1985. Theonine, histidine, and lysine requirements of chum salmon fry. Bull. Jap. Soc. Sci. Fish. 51(4): 635-639. (English).

2. Akiyama, T., S. Arai, T. Murai, and T. Nose. 1985. Tryptophan requirements of chum salmon fry. Bull. Jap. Soc. Sci. Fish. 51(6): 1005-1008. (English).

3. Murai, T., Y. Hirasawa, T. Akiyama, and T. Nose. 1983. Effects of previous dietary history on the mortality and changes in body composition of chum salmon fry during starvation in seawater. Bull. Nat. Res. Inst. Aq. 4: 79-86. (English abstract and figure captions).

4. Akiyama, T., K. Mori, and T. Murai. 1986. Effects of temperature on the incidence of scoliosis and cataract in chum salmon fry caused by tryptophan deficiency. Bull. Jap. Soc. Sci. Fish. 52(11): 2039. (English).

5. Akiyama, T., T. Murai, and K. Mori. 1986. Role of tryptophan metabolites in inhibition of spinal deformity of chum salmon fry caused by tryptophan deficiency. Bull. Jap. Soc. Sci. Fish. 52(7): 1255-1259. (English).

6. Akiyama, T., T. Murai, and T. Nose. 1983. Fluctuations in some body components of fingerling chum salmon after release. Bull Nat. Res. Inst. Aq. 4: 107-112. (English abstract and figure captions).

7. Akiyama, T., T. Murai, and T. Nose. 1984. Composition of fatty acids and free amino acids in whole body of chum salmon fry at various stages. Bull. Nat. Res. Inst. Aq. 6: 51-57. (English).

8. Akiyama, T., T. Murai, and T. Nose. 1986. Oral administration of serotonin against spinal deformity of chum salmon fry induced by tryptophan deficiency. Bull. Jap. Soc. Sci. Fish. 52(7): 1249-1254. (English).

9. Akiyama, T., and T. Nose. 1980. Changes in body weight, condition factor, and body composition of fingerling chum salmon of various sizes during starvation. Bull. Nat. Res. Inst. Aq. 1: 71-78. (English).

10. Murai, T., I. Yagisawa, Y. Hirasawa, T. Akiyama, and T. Nose. 1980. Protein, fat, and carbohydrate sources of practical diet for fingerling chum salmon, Oncorhynchus keta. Bull. Nat. Res. Inst. Aq. 1: 79-86. (English abstract and figure captions).

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APPENDIX 2

Scientists and people in fishing industry met
while on study trip to Japan, 1987.

NAME	AFFILIATION	COMMENTS
Masahide KAERIYAMA	Hokkaido Salmon Hatchery Japan Fisheries Agency 202 Nakanoshima, Toyohiraku Sapporo, Hokkaido 062, JAPAN	Ecology Laboratory; studying chum salmon ecology
Kazumasa OHKUMA	"	Research Department
Gi-ichi KIMURA	"	Director of Second Work Section
Gen-ichiro SAWAYANAGI	"	Director of First Work Section
Shinichi ABE	"	Director of Research Division
Osamu HIROI	"	Resources Laboratory; Experimenting with heated river water for chum salmon incubator
Katsuhiro OHNISHI	"	Director of Planning Section
Hiroshi MAYAMA	"	Ecology Laboratory; Studying masu salmon behavior around fish ladders
Ikutaro SHIMIZU	"	Studying oceanographic effects on salmon survival
Hiroshi KAWAMURA	Hokkaido Prefectural Fish Hatchery Sohya Branch Wakkanai City, Hokkaido 098-66, JAPAN	Northermost salmon hatchery in Japan Didn't visit hatchery met him in Sapporo.
Hisashi SHIBATA	Salmonidae Science Center Makomanai Koen 2-1 Minami-ku, Sapporo, Hokkaido 005, JAPAN	Director of Museum & teaching facility. Seat of main salmon restoration organizatn "Come Back Salmon"
(Director and two instructors)	Higashi-shiroishi Elementary School (Address in Japanese only) Sapporo, Hokkaido, JAPAN	School has a $200,000 salmon hatchery in it.

NAME	AFFILIATION	COMMENTS
Takeshi NOSE	Hokkaido Regional Fisheries Research Laboratory Japan Fisheries Agency 116 Katsurakoi Kushiro, Hokkaido 085, JAPAN	Director of Laboratory; Salmonid Researcher
Teiichi KATO	"	Salmonid nutrition
Akira NAKAYAMA	Chitose Branch of Hokkaido Salmon Hatchery Japan Fisheries Agency Ran Koshi, Chitose Hokkaido 066, JAPAN	Assistant Director of chum salmon hatchery
Masahiro AIDA	Shikotsu Hatchery Chitose Branch of Hokkaido Salmon Hatchery Japan Fisheries Agency Kohan Chitose, Hokkaido 066-02, JAPAN	Director of kokanee salmon hatchery
Kanji TAKAHASHI	Miyagi Prefectural Marine Experimental Station (Kesennuma Branch) Hajikami Kesennuma, Miyagi 988-02, JAPAN	Chief of algae section; also research on juvenile flatfish and coho salmon culture
Mr. CHIBA	(No address) Otatsu, Miyagi, JAPAN	Owner of private salmon hatchery
Seichi SUDO	Shizugawa Seacoast High Utilization Center (address in Japanese) Shizugawa, Miyagi, JAPAN	Director of fishermen's cooperative involved in coho salmon pen rearing, and culture of abalone, <u>Undaria</u>, other species
Katshuiro KISO	Tohoku Regional Fisheries Research Laboratory Japan Fisheries Agency 3-27-5 Shinhamacho Shiogama, Miyagi 985, JAPAN	Studying masu salmon
Gen-ichi HOSHIAI	Miyagi Prefectural Freshwater Fisheries Laboratory Hatazaka, Yoshioka, Daiwa-cho Kurukawa, Miyagi, JAPAN	Fish pathologist; wrote coho pen culture manual
Nobuhiko KATO	"	Director of Laboratory
Nobuki WATANABE	"	Director

NAME	AFFILIATION	COMMENTS
N. OKUMOTO	Fisheries Research Institute of Aquaculture-Nikko Branch Japan Fisheries Agency 2482-3 Chugushi, Nikko-shi Tochigi-ken 321-16, JAPAN	Salmonid researcher -smoltification
Ryozo SATO	"	Chief of Fish Breeding Sec.-genetic research
Kazumasa IKUTA	"	Physiology of smolting
Tamezo MARUYAMA	"	Chief of Branch
Akihiko HARA	National Research Institute of Aquaculture Marine Laboratory Japan Fisheries Agency 422-1 Nakatsu-Hamaura Nansei-cho, Watarai-gun Mie 516-01, JAPAN	Fish Nutrition
Katsuyoshi MORI	"	Chief Fish Feed Sec.
Dr. AKIYAMA	"	Salmonid Nutrition
Takeshi MURAI	National Research Institute of Aquaculture Freshwater Laboratory Hiruta, Tamaki-cho, Watarai-gun Mie 519-04, JAPAN	Fish nutrition
Hiroshi OGATA	"	Masu salmon nutrition
Dr. ONOZAKO	"	Trout genetics