FRED Reports

JAPAN'S SALMON CULTURE PROGRAM AND COASTAL SALMON FISHERIES

by
Thomas M. Kron

Number 50

Alaska Department of Fish & Game
Division of Fisheries Rehabilitation,
Enhancement and Development

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Enhancement and Development (FRED)

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ABSTRACT

An all-time record return of 33.3 million chum salmon, *Oncorhynchus keta*, was reported by Japan for the 1983 season. Chum salmon was the dominant species in the salmon return followed by pink, *O. gorbuscha*, cherry, *O. masou*, and sockeye salmon, *O. nerka*. The total return for all species of salmon was estimated at 36 million fish. The chum salmon catch in the coastal fisheries of Hokkaido Island and parts of Honshu Island was twice the peak catch of the late 1800's. Fish traps are the most commonly used gear type employed in Japan's coastal salmon fisheries. Hatcheries produce more than 90% of Japan's adult salmon. Success of the salmon propagation program is credited to the strong support given by the government and fishermen and to the technical expertise achieved by the Japanese in the field of chum salmon enhancement. While chum salmon hatchery programs continue to expand, increasing emphasis will be placed on pink, cherry, and sockeye salmon enhancement as well as on marine net-pen rearing of market-sized coho, *O. kisutch*, and cherry salmon.

KEY WORDS: Japan, salmon culture, salmon fisheries

INTRODUCTION

The Japanese have become very successful at salmon propagation. With salmon returns to Japan increasing, the western world has become more and more interested in Japan's salmon hatchery program. In response to this interest, several recent reviews of the Japanese salmon hatchery program have been published in English (Moberly and Lium 1977; Kobayashi 1980; Kafuku and Ikenoue 1983).

I examined Japan's salmon propagation program and coastal salmon fishery between April 1983 and March 1984. During this year I was fortunate to be able to work alongside salmon hatchery staff, crews taking eggs, and fishermen of Hokkaido Island in five of the prefectures on Northern Honshu Island. I visited 124 salmon hatcheries, 76 egg-stripping stations, and 8 net-pen rearing facilities. This paper summarizes my findings.

SALMON STOCKS AND THE COASTAL FISHERY

Three species of anadromous salmon are native to Japan: Chum salmon, *Oncorhynchus keta*, pink salmon, *O. gorbuscha*, and cherry salmon, *O. masou*. Kokanee, *O. nerka*, which are land-locked sockeye salmon, are also native there. Japan is the southernmost limit for the distribution of these species along the western north Pacific Ocean coast. Attempts to develop self-sustaining runs of coho, *O. kisutch*, and chinook salmon, *O. tshawytscha*, have not been successful.

Chum salmon return in abundance to northern Japan and comprise more than 90% of the catch in the coastal salmon fishery. This species occurs from Tottori Prefecture north along the Japan Sea coast and from Chiba Prefecture north along the Pacific Ocean coast (Figure 1). Historically, chum salmon populations may have occurred as far south as Kyushu Island. Timing of the returning adult salmon varies with stock and extends from August through January.

Chum salmon have been an important food item for the Japanese for more than 2000 years. Early in Japan's history, salmon returning to rivers near large cities on Honshu Island were heavily exploited. Though it is apparent that historic chum salmon production from Honshu Island was high, records of the catch for most areas date back less than 100 years. The chum salmon catch in Honshu's coastal waters has been increasing sharply since 1972; as a result of the expanding hatchery program, it reached 10.0 million fish in 1983 (10.8 million total return). Eighty-two percent of the 1983 catch for Honshu Island was taken at Iwate Prefecture, which is located along Honshu's northeast Pacific Ocean coast. Hokkaido's chum salmon stocks were not exploited heavily until after the Meiji restoration in 1868. The historic peak catch of 10.4 million chum salmon for Hokkaido's coastal fishery was recorded in 1889 (Figure 2). The chum salmon catch in Hokkaido's coastal fishery has been increasing since 1970, and it reached 20.7 million fish in 1983 (22.5 million total return) (C. Iioka,

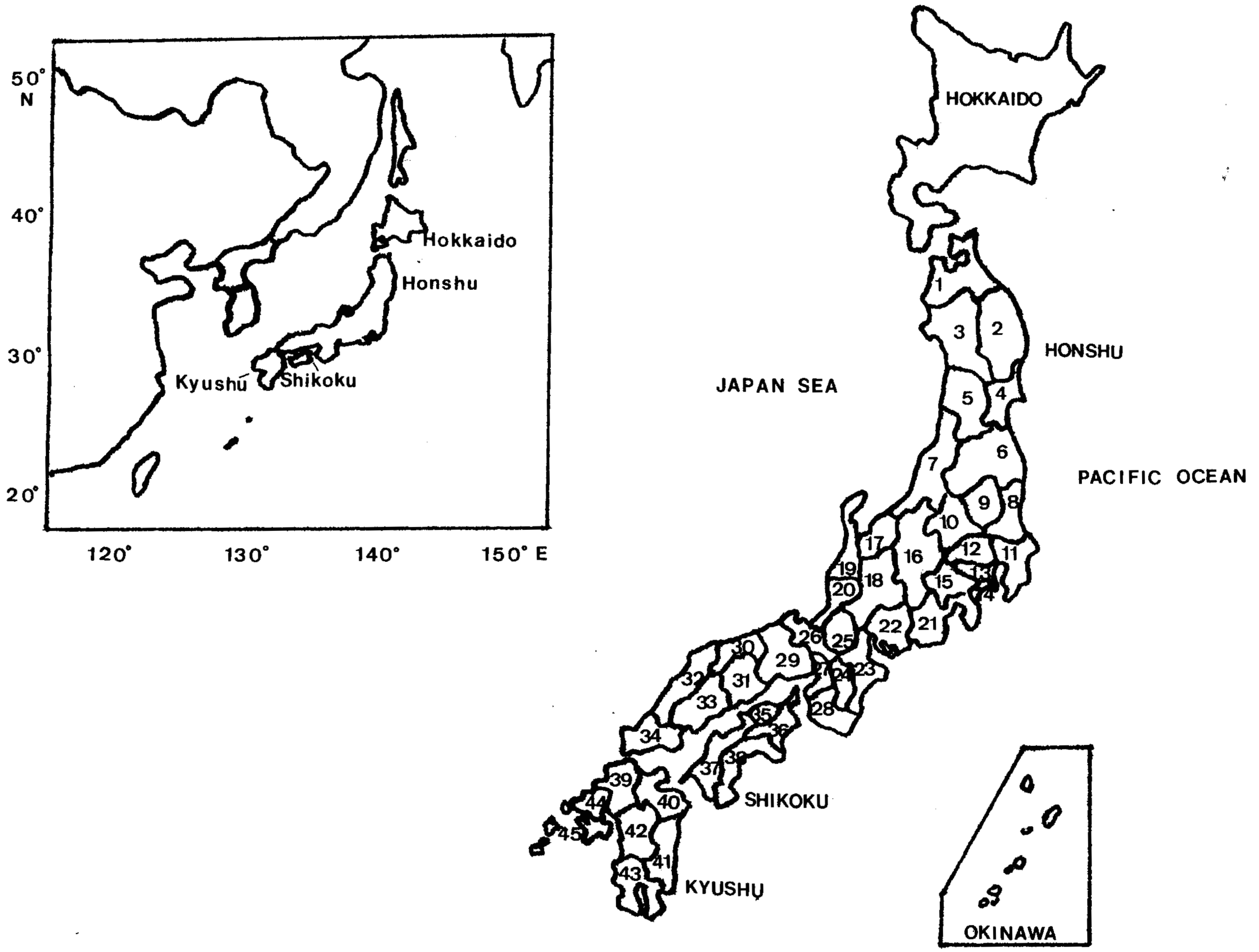

Figure 1. Map of Japan
Prefectures--1, Aomori; 2,Iwate; 3,Akita; 4,Miyagi; 5,Yamagata; 6,Fukushima; 7,Niigata; 8,Ibaragi; 9,Tochigi; 10,Gunma; 11,Chiba; 12,Saitama; 13,Tokyo; 14,Kanagawa; 15,Yamanashi; 16,Nagano; 17,Toyama; 18,Gifu; 19,Ishikawa; 20,Fukui; 21,Shizuoka; 22,Aichi; 23,Mie; 24,Nara; 25,Shiga; 26,Kyoto; 27,Osaka; 28,Wakayama; 29,Hyogo; 30,Tottori; 31,Okayama; 32,Shimane; 33,Hiroshima; 34,Yamaguchi; 35,Kagawa; 36,Tokushima; 37,Ehime; 38,Kochi; 39,Fukuoka; 40,Ohita; 41,Miyazaki; 42,Kumamoto; 43,Kagoshima; 44,Saga; 45,Nagasaki.

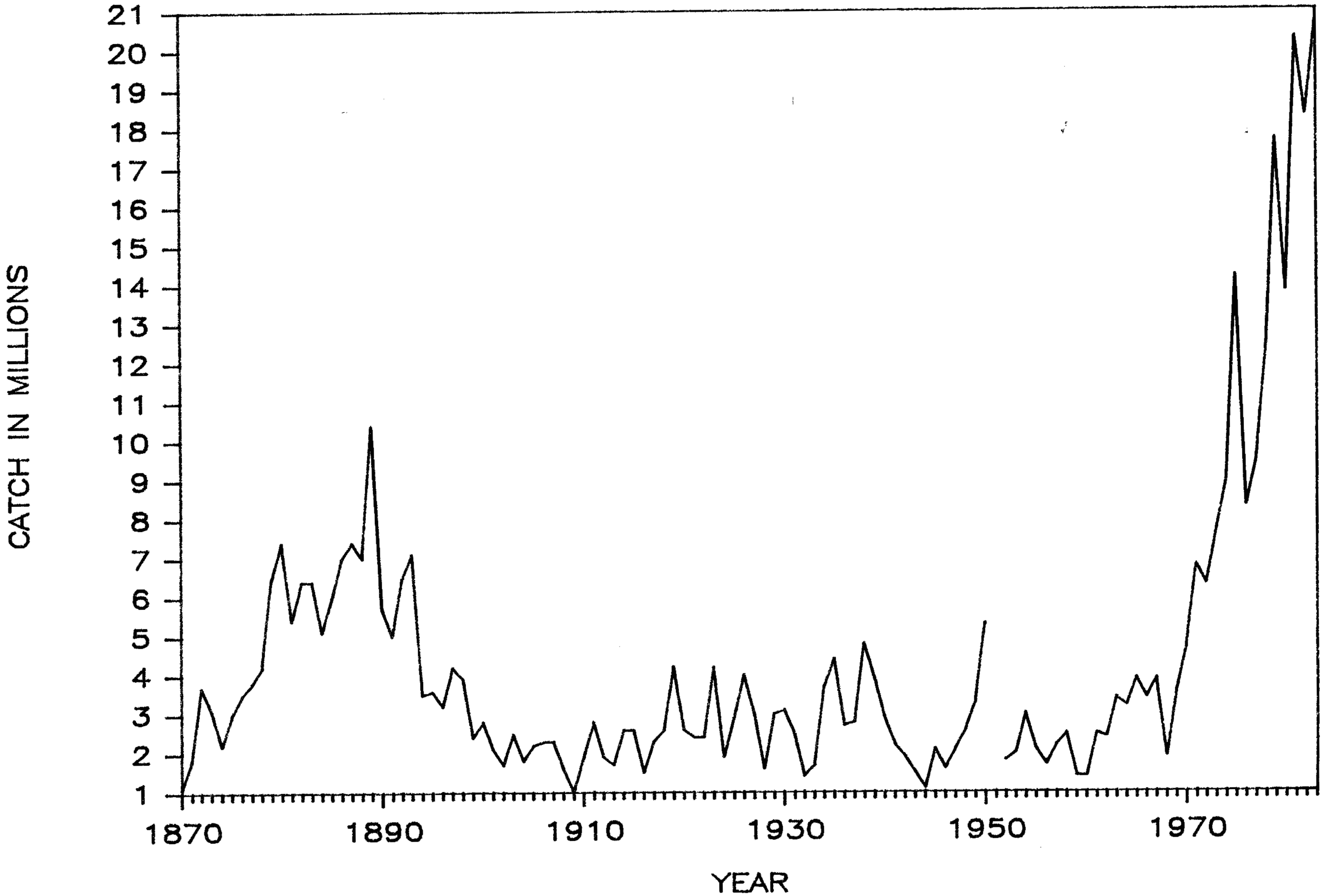

Figure 2. Chum salmon catch in the coastal waters of Hokkaido, Japan (Data are not available for 1951).

Iwate Prefecture Fisheries Department, Morioka, Iwate, personal communication, 1984). Historically, salmon were harvested in the rivers. After 1868, coastal fishing grounds expanded rapidly, gear improved, and the portion of the chum salmon taken in this new fishery dominated the catch (Anonymous 1966). Though gillnets and longlines are also used to catch chum salmon in the coastal waters, approximately 90% of the fish are taken with fish traps. In 1983, Hokkaido's chum salmon fishery started between 5 and 12 September and closed between 10 November and 13 December depending on area. The catch is bimodal with peaks between 20-30 September and 10-20 November (S. Abe, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1983). The coastal fishing season for Honshu's chum salmon varies among prefectures. There was no closed season for chum salmon at Iwate Prefecture in 1983.

Compared with the available historical information for chum salmon, data on pink salmon returns to Japan are limited. Since 1970, returning adult pink salmon have numbered between 0.4 and 2.8 million and have averaged 1.2 million fish annually. Pink salmon returns are limited primarily to northeastern Hokkaido. Fishermen in this area trap pink and cherry salmon and in many cases do not participate in the chum salmon fishery. In 1983 this fishery opened on 1 May and closed 30 September. (S. Abe, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1984).

Anadromous cherry salmon occur from Toyama Prefecture north along the Japan Sea coast and from Iwate Prefecture north along the Pacific Ocean coast. Hokkaido has the largest returns of cherry salmon. Information on the return of anadromous cherry salmon is extremely limited. In 1982 an estimated 1.4 million cherry salmon were harvested in the coastal waters of northern Honshu and Hokkaido. The cherry salmon harvest occurs primarily between January and June, though small numbers of rearing fish are intercepted by the coastal fishery during other months of the year (H. Mayama, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1983). Handlines are commonly used to harvest cherry salmon in late winter and spring. Adult cherry salmon enter fresh water during spring and summer and spawn in early fall. Unlike chum and pink salmon, cherry salmon rear for a year in fresh water before migrating to sea as smolts.

Prefectural governments work in close cooperation with fishermen as well as with federal and municipal officials to manage the salmon harvest. On Hokkaido, major decisions concerning the fisheries are made every 5 years. Annual adjustments may be made concerning the opening and closing dates for the season at each of the 24 management areas that cover the 790 salmon gear (trap & gill net) permits. In the early to mid 1970s, silver-bright fish represented only about 40% of Hokkaido's total coastal chum salmon catch. Regulations were adopted to start certain fisheries later to allow more of the silver brights to contribute their genetic material to the hatcheries. Stocks have responded well to this management strategy, and as a result silver brights currently represent approximately 70% of Hokkaido's coastal chum salmon catch. New regulations aimed at increasing the percentage to 75% to 80% were to be considered in 1984 (S. Abe, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1983). Iwate Prefecture is currently addressing the silver-bright issue as it relates to management of the fishery. At Iwate, silver brights have made up less than 20% of the catch from the 92 fish traps along its coast (C. Iioka, Iwate Fisheries Department, Morioka, Iwate, personal communication, 1983).

Commercial salmon fishermen in Japan are well organized. Fishermen in a given area belong to the local fishermen's cooperative and sell their catch through that cooperative. Many cooperatives operate salmon hatcheries and are involved with taking eggs for those hatcheries. There are separate cooperatives for coastal salmon fishermen and freshwater salmon fishermen at a number of areas on Honshu Island.

Sport fishing for salmon is allowed in salt water in most areas of Japan. Sport fishing for adult salmon in the rivers is prohibited; however, cherry salmon fingerling may be taken by sport fishermen in many areas. Sport fishing effort is relatively low, and the size of the catch is not regulated. Additional restrictions were levied on sport fishermen in 1983 to protect rearing cherry salmon and to keep people off certain rivers during the adult salmon run (G. Kimura, Hokkaido Salmon Hatcheries, Nakashibetsu, Hokkaido, personal communication, 1983). Sport fishing for salmon in Japan is generally viewed as a leisure activity of relatively little importance compared with the commercial fishery. Public interest in sport fishing seems to be increasing in Japan.

SALMON PROPAGATION

Salmon propagation in Japan dates back more than 250 years. The first attempts at salmon propagation involved stream habitat improvement. With the Meiji restoration in 1868, a new epoch of rapid modernization began throughout Japan. Culture of salmon was first applied in 1876 at an agricultural laboratory in a suburb of Tokyo. In 1877 a team of American agricultural specialists were invited to Japan to assist the Meiji government in setting up new programs. One member of this team, Mr. U.S. Treat, taught the Japanese about cannery operations and advised them about salmon hatchery technology. Based on his recommendations, salmon hatching investigations were conducted near Sapporo, Hokkaido. In 1886 the Hokkaido government sent Mr. Kazutaka Ito to the United States to study hatchery technology. After returning to Japan, Ito was instrumental in the development of Hokkaido's hatchery program; the Hokkaido government hatchery at Chitose was completed in 1889 (Anonymous 1966). By the year 1900, 45 salmon hatcheries had been built in Japan.

The success of the hatchery program was limited until the 1960's. Prior to that time, chum salmon emigration timing from the hatcheries was largely a function of the temperature regimes of the hatchery water supplies. In general, fry emigration from hatcheries with spring-water supplies occurred about a month before the peak of natural chum salmon emigration, while fry emigrating from hatcheries with surface-water supplies occurred about a month after natural emigration. Experimental short-term rearing of chum salmon was first conducted in Japan in 1962. Results from the first short-term rearing studies were encouraging. Short-term rearing yielded larger fish at release and, at hatcheries with spring-water supplies, also allowed a release time that was similar to the emigration timing of natural chum salmon populations. Yolk absorption abnormalities were found in chum salmon fry from hatcheries with surface-water supplies, but not at hatcheries with spring-water supplies. These abnormalities were attributed to the sensitivity of developing chum salmon embryos to water temperature fluctuations. Hatcheries with surface-water supplies experienced larger temperature fluctuations than did natural chum salmon spawning areas and hatcheries with spring-water supplies. Virtually all of Japan's chum salmon production is currently limited to facilities that have spring or pumped groundwater supplies (T. Kobayashi, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1983).

In 1983 there were 301 salmon hatcheries in Japan. Of these, 37 are operated by the national government, 15 are operated by prefectural governments, and the remainder are operated by fishermen's cooperatives or local governments. All of the national hatcheries are located on Hokkaido. The budget for the national hatcheries was approximately 9.4 million dollars in 1983. The benefit-cost ratio for chum salmon hatchery programs on Hokkaido is estimated at between 16:1 and 33:1 (Kobayashi 1980). Though new national hatcheries are not being constructed, the national government has spent an average of approximately 5 million dollars annually on improvements and expansion of their facilities between 1979 and 1983. During that same period, the national government spent approximately the same amount annually subsidizing fry releases from private hatcheries on Honshu Island (S. Abe, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1984).

The number of hatcheries in Japan has been increasing. New facilities are being built by fishermen's cooperatives as well as prefectural and local governments. Of the 102 fishermen's cooperative and local or prefectural governmental hatcheries on Hokkaido in 1983, 44 have been constructed during the five-year period between 1978 and 1983. New construction and expansion of fishermen's cooperative facilities is subsidized by the government. Decisions to implement new hatchery construction and expansion in Japan are based primarily on the availability of pumped groundwater for incubation as well as supplemental river water for short-term rearing.

The present production level of anadromous salmon in Japan is the direct result of their aggressive hatchery programs. Of the returning chum salmon that escape the coastal fishery in Japan, more than 90% are collected for spawning at hatcheries. About 50% of the pink salmon are collected from the rivers for their eggs and sperm. The cherry salmon resource is supported primarily by natural spawning.

Various types of weirs are used to collect adult salmon returning to the rivers. In 1983 there were more than 170 weirs operating on Hokkaido alone. Weir design varies from area to area; picket weirs are most common in Japan. A number of picket weirs are wired to operate as electric weirs during periods of high water. Picket panels are either fixed in place against supports in the river or are hinged at the bottom edge to a cable or rod so that the pickets swing up and down on the hinges as the water level varies. Either buoys or trim-tab boards are used to hold the top of the hinged pickets above the water. A special modification of the picket weir has been developed for weirs with unstable bottom substrate. Weirs constructed from netting are commonly used at Iwate Prefecture and other areas where the river waters are deep and slow moving.

In response to increasing adult returns, procedures for handling fish at the weirs have been streamlined and mechanized. Large scoop nets are lifted by power winches that move the fish to platforms where the fish are sorted by species, sex, and stage of ripeness by workers using wooden rakes. Fish are funneled into pipes that carry them to various pens or return them to the weir. At many adult salmon capture facilities, the holding space is limited, so fish must be moved to holding ponds elsewhere. Various types of tanks are used for the overland transport of adults. The most common design consists of a metal frame that supports a 2-m^3 capacity waterproof fabric bag with air stones for oxygen release affixed to the bottom. The amount of salmon transported in the tank varies as a function of water temperature (Table 1).

Transport time is usually short, but transports of up to 2 hours do occur. Mortalities during the transports are rare. Upon arrival at the holding ponds, the fish and water in the tank are released through a fabric tube at the back of the tank and into an open chute by which they reach the desired holding pond. The density of adult chum salmon within the holding areas is maintained at six to seven fish/m^2 (based on a water depth of 70 cm). Minimal water flow requirements vary as a function of water temperature (T. Kobayashi, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1983):

8°C - 1.0 m^3 water/min/1000 fish
10°C - 1.4 m^3 water/min/1000 fish
12°C - 2.0 m^3 water/min/1000 fish

Prior to taking eggs, fish are crowded in holding ponds. Assorted rolling crowders and crowding nets are used to concentrate the fish for sorting. Workers then sort the fish for spawning. Ripe fish are transported to the stripping facility by conveyor belt, chute, or bridge crane. In the normal spawning operation, female salmon are routed down to the head of the spawning line; males are funneled to a separate table near the end of that line. The Japanese do not bleed the fish prior to spawning. Instead they use a special device that removes the blood from the eggs by

Table 1. Specifications for adult salmon transported at four water temperature strata at Hokkaido Salmon Hatcheries.

Water Temp °C	Fish(kg):Water(kg)
Over 16	no transport
16	100:900
14	150:850
12 and below	200:800

gravity immediately after the eggs are stripped from a female. Using one spawning line (one person stripping eggs from females), 300 to 600 females are spawned per hour; sperm from the males is added, and eggs and sperm are mixed by hand. The gentle mixing process is often facilitated by placing the pan on a turntable mounted at the end of the spawning table. Next, eggs are normally poured directly into large troughs with upwelling water where they rinse and water harden. Where the hatchery adjoins the egg-take facilities, eggs are water hardened in the incubators. Carcasses are usually moved out of the spawning facility by conveyor belt. When fish are spawned at a facility that is remote from the hatchery, the eggs are moved to the hatchery after they have water hardened. The eggs are ladled from the water-hardening trough and placed in muslin or net-lined rigid containers. The egg mass is then compressed (water drained away) by approximately 5 percent, thereby ensuring that no movement within the egg mass occurs during the transport. Slightly less pressure is used when water temperatures are below 6°C. A banding tool is commonly used to pull the lid down on the egg-transport container to compress the egg mass.

On Hokkaido, the adult-capture and spawning operations at all except two stations are under the jurisdiction of a fishermen's organization: Hokkaido Salmon Propagation Cooperative Association. This association was formed in 1976 in response to public concern over the level of government funding for the hatchery program. Through this organization, fishermen bear most of the costs of adult capture (weir operations, etc.) and egg stripping while working closely with hatchery staff. To help defray these costs, the association is allowed to sell a portion of the male fish (50-60%) at the time of initial capture in the river, and it also sells the salmon carcasses after spawning. There is a 2% tax on the fishery to cover the remainder of the association's costs (G. Kimura, Hokkaido Salmon Hatcheries, Nakashibetsu, Hokkaido, personal communication, 1983).

Atkins incubators for eyeing eggs and raceways for alevin incubation have been used in Japan for nearly 100 years. During the past quarter century, however, a large number of changes and procedural improvements have been made in the incubation process. Modified Atkins, vertical tray, and free-style incubators were introduced in 1960, 1962, and 1965, respectively. These incubators are described by Kafuku and Ikenoue (1983) and Moberly and Lium (1977). Even though malachite green was prohibited for hatchery use in 1982 by the national government, it is still being used for fungus control during egg incubation. Under normal conditions, live eggs are seeded above gravel in shallow raceways just prior to hatching. On Hokkaido, most facilities have separate raceways for rearing, while at Iwate Prefecture salmon are normally reared in the same raceways where they were incubated.

Chum salmon are usually reared in fresh water to a minimal weight of 0.5-0.6 g. The release strategy is to have the first fish arrive at salt water at the start of the spring zooplankton bloom. At most hatcheries on Hokkaido and a number of the facilities on Honshu, chum fry are allowed to emigrate from the hatchery volitionally when the two above criteria have been satisfied. The hatchery chum salmon emigration normally occurs over a 30-60 day period.

In recent construction of freshwater chum salmon rearing ponds in Japan, the specifications called for a water depth of 0.4 m, a water exchange rate of 1 exchange/2.5 hours, and a designed loading density of 10,000 chum fry (0.6-0.8 g fish)/m^2. A more rapid exchange rate (up to 1 exchange/hour) is better if there is water available. The need for higher velocities to exercise the fish is being emphasized. Calculations are based on surface area (m^2) rather than volume (m^3) because of chum salmon distribution patterns in the water column (T. Kobayashi, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1983).

Short-term saltwater rearing of chum salmon is applied throughout the area of Japan where chum salmon occur. The technique is applied most extensively at Iwate Prefecture where 17.6% of the

339 million chum salmon released in 1983 were short-term saltwater reared. In contrast, only 2.6% of the 1.08 billion chum salmon released from Hokkaido were short-term saltwater reared. Iioka (1982) found no difference between the adult return rate of chum salmon that had been short-term reared in salt water and those that had been short-term reared in fresh water. Short term rearing in salt water is seen as a technique that accomplishes the following:

1. expands rearing capacity;
2. takes advantage of temperature differences between salt water and fresh water for best growth;
3. expands hatchery production in excess of the carrying capacity of the zooplankton resources of coastal waters; and,
4. establishes returns to areas that do not have hatcheries and/or do not have the freshwater resources to support hatcheries.

When stocking the pens with 0.5- to 0.6-g chum salmon, netting with 1 knot/cm and an actual opening size in the mesh of about 5 mm is normally used. The recommended final saltwater-pen loading density in Iwate Prefecture is 10 kg of chum salmon/m^2. Pen depth varies from 3 to 12 m. Fish are reared in salt water until they reach an average weight of 8.0 g or until seawater temperatures reach 10° to 11°C. Problems with *Vibrio* have been encountered when pen rearing was continued at temperatures in excess of 10°C (Anonymous 1983a).

Figure 3 shows the average percentage of released fry returning as adult chum salmon (1973 - 1977 brood years) for various areas of Japan (S. Abe, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1983). Lowest return rates occurred along the west coast while highest returns occurred along the north-eastern coast. Overall, 2.2% of released fry returned as adults. Differences in survival by area are thought to be a function of the quality of the nearshore, ocean-rearing areas and, to a

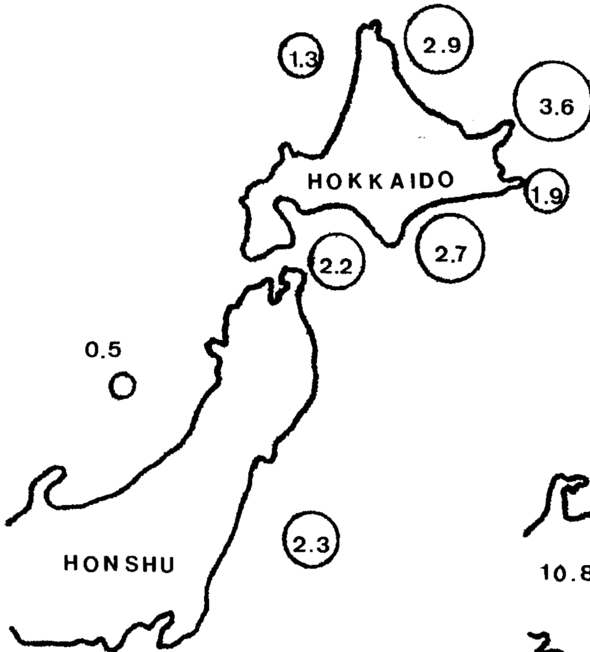

Figure 3. Estimated average percent survival from fry release to adult return for chum salmon of brood years 1973 through 1977 for various areas of Japan.

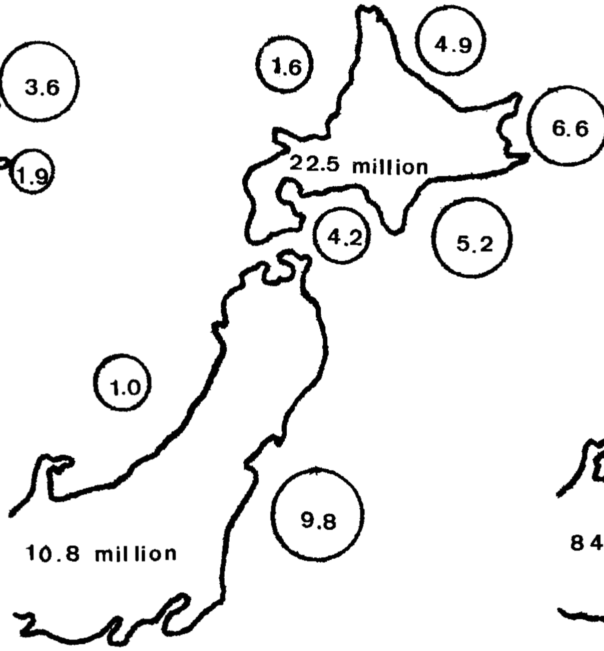

Figure 4. Estimated adult chum salmon return (millions of fish) by area in 1983. The top five circles represent respective areas of Hokkaido Island.

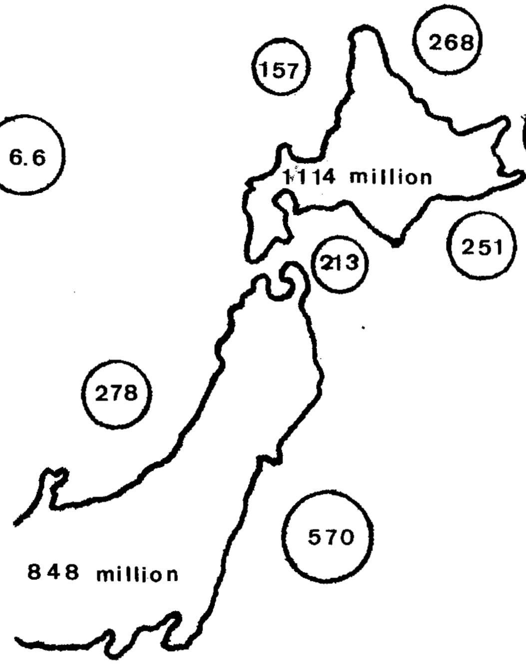

Figure 5. Estimated chum salmon fry release (millions of fish) by area in 1983. The top five circles represent respective areas of Hokkaido Island.

certain extent, the quality of hatcheries and salmon culture procedures in those areas. Survival of fish from the eastern coast of Hokkaido is split north and south for this analysis. The northern part of this particular area had an average of 3.6% survival and is characterized by good ocean circulation and relatively high, nearshore zooplankton numbers in the spring at time of fry emigration. In contrast, the southern part of this area had an average survival of 1.9%. Nearshore ocean waters have poor circulation and relatively low zooplankton numbers in spring (G. Kimura, Hokkaido Salmon Hatcheries, Nakashibetsu, Hokkaido, personal communication, 1984). Adult return values were adjusted on an area-by-area basis and were based on interception rates as determined through tagging studies.

Hokkaido produced 67.5% of the chum salmon returning to Japan in the 1983 season (Figure 4); however, their annual contributions have been gradually declining as a result of accelerated hatchery programs on Honshu Island (C. Iioka, Iwate Fisheries Department Morioka, Iwate, personal communication, 1984).

In spring 1983, an estimated 1.9 billion chum salmon fry were released from Japanese hatcheries (Figure 5). An estimated 57.3 million pink salmon, 2.3 million cherry salmon, 1.5 million kokanee, and 0.1 million sockeye salmon were also released from Hokkaido facilities (Anonymous 1983b).

The hatchery strategy for pink salmon is similar to that used for chum salmon. Short-term rearing in fresh water has not been overly successful with pink salmon in Japan. An accelerated enhancement program is now being developed for this species.

More than 95% of Japan's hatchery production of cherry salmon involves fingerling releases into the rivers; the remainder are smolt releases. Smolt releases have resulted in an 8% survival rate, while fingerling releases have resulted in a slightly more than 1% survival rate. The Japanese are currently involved in a careful evaluation of their cherry salmon program and are developing plans for an accelerated enhancement effort with this species; potentially, this will include the expansion of the smolt production program (H. Mayama, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1983).

Sockeye salmon are in high demand in Japan though the anadromous members of this species are not native there. National hatchery staff at Hokkaido is attempting to develop an anadromous sockeye salmon utilizing eggs from kokanee. They started transporting Shikotsuko Hatchery kokanee eggs to Nijibetsu Hatchery in 1961 for this project. To fortify the developing sockeye salmon run at Nijibetsu, sockeye salmon eggs were brought in from Alaska in 1970. In 1971, 4,539 adult sockeye returned to Nijibetsu. In 1972 there was an *Infectious Hematopoietic Necrosis* (IHN) virus outbreak that destroyed the juvenile sockeye in the hatchery. In 1977 the sockeye program at Nijibetsu was started over again. Recent returns of adult salmon to Nijibetsu have been poor.

The biggest disease problem that the Japanese face with chum and pink salmon culture is bacterial gill disease during the fry rearing stage. *Vibrio* is a problem for saltwater-rearing ventures, while furunculosis is a problem at the adult stage if the fish are held for a long period of time. The biggest problem they face with cherry salmon culture is IHN during the fry rearing stage. Bacterial kidney disease, *Oncorhynchus masou* virus (OMV), and furunculosis are also problems in cherry salmon culture. IHN is the biggest problem in their sockeye salmon program (T. Kobayashi, Hokkaido Salmon Hatcheries, Sapporo, Hokkaido, personal communication, 1983).

In addition to hatcheries, there are several other types of salmon propagation work under way in Japan. Salmon eggs are being planted in natural spawning areas, and incubation channels are being constructed. Stream rehabilitation and cleanup is conducted in a number of areas. In 1981 there were 144 fish ladders on Hokkaido. The ladders were all constructed to provide passage for upstream-migrating adult cherry salmon around man-made dams. The dams vary in height from 1 m to 16 m and average 5 m.

Under a recent agreement, the Japanese provided the USSR with materials for construction and operation of salmon hatcheries. In 1983 the USSR tax on the Japanese high seas gillnet fishery in Russian waters totaled approximately 17 million dollars. The gillnetters were allowed to take 42,500 metric tons of salmon; the percentage makeup of the catch by species was regulated. Starting in 1982 the Russians used the tax revenues to buy salmon hatcheries and hatchery technology from the Japanese. Under an agreement between the two countries in 1982 and 1983, four hatcheries to release 20 million fry were to be built (G. Kimura, Hokkaido Salmon Hatcheries, Nakashibetsu, Hokkaido, personal communication, 1983).

The Japanese are involved in saltwater net-pen rearing of coho and cherry salmon to market size. This work is done from southern Honshu to Hokkaido and is presently centered at Miyagi Prefecture. Production of pen-reared coho salmon increased from 72 tons in 1978 to 2,900 tons in 1983. Rearing coho salmon in net pens in the south is limited to cooler months when coastal water temperatures are within the tolerance range for salmon. Fresh salmon from net-pen rearing facilities are in strong demand in Japan, because fish can be marketed during spring and summer before the glut of the Pacific salmon catch reaches the market. Coho salmon eggs are imported from the west coast of North America for this program. The coho salmon are cultured in fresh water until they reach an average size of 180 g when they are placed in saltwater net pens. At Miyagi Prefecture, 180-g coho salmon normally go into the net pens in October and November and reach an average of 2 kg by the following July or early August. At Miyagi Prefecture the coastal surface-water temperatures exceed salmon tolerance limits during late August and September. Rearing in net pens in Japan is expected to grow rapidly in response to available Japanese markets. The program may be shifting part of its emphasis to cherry salmon production as well as production of larger fish with year-round rearing in marine net pens.

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