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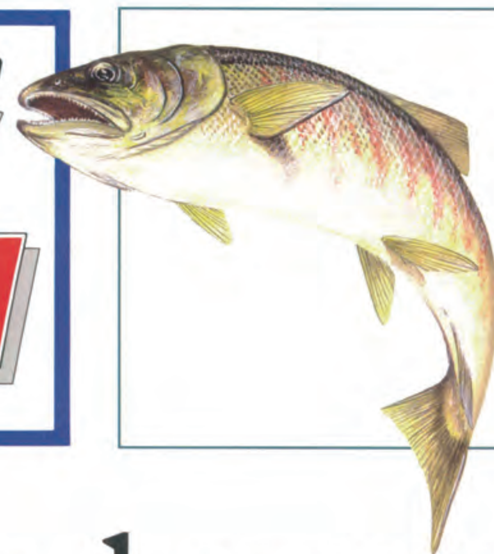


SALMON CULTURE

Production and consumption on a global scale

The native inhabitants of northern Japan, the Ainu, referred to chum salmon by the name "Kamuichep" meaning "Fish of the Gods", and made it an important staple of their winter diet. In northern Japan today it is often referred to by the name "akiaji" meaning "the taste of autumn". Traditionally, chum salmon are salted and used in dishes for the New Year holidays or as seasonal gifts.

Regarding the consumption and production of fish, Japan can be said to claim a unique position among the countries of the world. This position is the result of Japan's large population, its large market demand for fish and the unique price standards that are maintained in that market.

Sharp changes in domestic marine production in the past 10-odd years have led to a dramatic increase in fish imports to Japan. Changes in the world foreign exchange market in recent years have also worked to the benefit of traders exporting to Japan and contributed to an increase in Japanese marine imports. When one gains a clear understanding of Japan's unique position in the world marine products market, however, it becomes clear that it is extremely important not only to the countries which export to Japan but for the Japanese people themselves.

Among marine products, it is certainly salmon that has endured the most profound changes in supply patterns over the years. Since olden times, salmon has been one of the most commonly loved fish by the Japanese. At present, the average Japanese household consumes 44.0kg of fresh fish and 13.9kg of dried and salted fish per year. Of this consumption salmon constitutes on the average 1.1kg of the fresh fish and 3.3kg of the dried and salted fish, for a total of 4.4kg per year. This makes salmon the second largest consumer fish behind squid. According to FAO statistics, the total Pacific and Atlantic production for Salmonid fish (family Salmonidae) in 1987 was 904,000 tons. In that same year, the total amount of salmon supplied to Japan by domestic production and imports was 293,000 tons. This means that Japanese consumption accounted for no less than 32% of the total world production of salmon.

FIG. 1 shows the fluctuations in the supply of salmon to the Japanese since 1960. Up until about the year 1970, most of the salmon consumed in Japan was supplied by the northern sea salmon fishing fleets operating in the North Pacific. With its defeat in World War II, Japan lost its fishing grounds along the coasts of the Kamchatka Peninsula and the northern Kuril Islands, after which it commenced the redevelopment of salmon drift gill net fisheries on the high seas, using either mothership-type or land-based operations. These Northern Pacific high sea fisheries were operated in accordance with a fishery treaty between Japan, the U.S.A. and Canada, and another between Japan and the Soviet Union, and at their peak reached an annual production of about 120,000 tons.

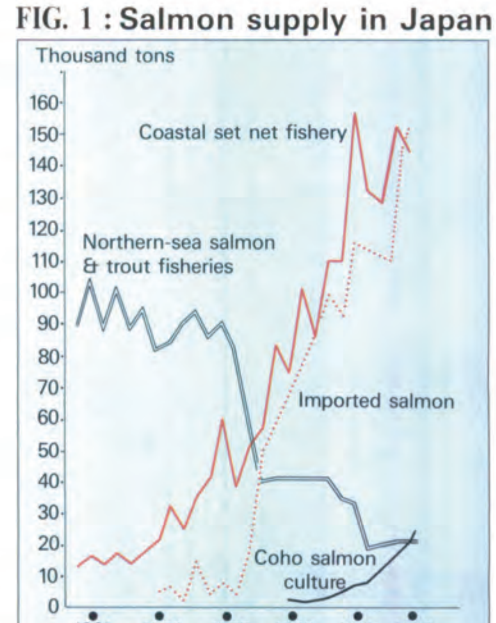
At the 3rd Convention of the United Nations Law of the Sea in 1975, a motion was passed to recognize the primary interest of the country of origin for anadromous fish resources. Then, with the adoption of the "exclusive 200-mile sea areas" in 1977, countries with coastal fishing areas began to tighten their restrictions on salmon fishery. Consequently, Japan's high sea fishery production began to decline.

However, the decrease in northern sea salmon fishery catches was accompanied by an increase in coastal water catches of chum salmon. Many years of research and development of artificial incubation and release operations began to bring fruit in the 1970s and contribute to this trend. Also, imports from the U.S. and Canada have expanded since the adoption of the "exclusive 200-mile sea areas"

By the year 1978, salmon supply to the Japanese people stood at 130,000 tons and was divided almost evenly between supply coming from northern sea salmon fishery, chum salmon caught in coastal waters and imports. In 1989, the salmon supply reached 417,000 tons, with 140,000 tons (34%) coming from coastal chum salmon fishery, 20,000 tons (5%) from Northern Pacific salmon fisheries, 20,000 tons (5%) from Northern Pacific salmon fisheries, 21,000 tons (5%) from domestic coho salmon culture, 150,000 tons (36%) from imports and 86,000 tons (20%) from previous season frozen stock.

These figures speak clearly of the trends toward the internationalization of marine production, the diversification of sources of supply and an overall increase in supply from all the channels. These factors have in turn led to chronic low pricing in Japan's salmon market. At present, Japan's marine industry has begun to tackle the problem of creating a stable, overall system of supply and demand of salmon in Japan in order to secure stable imports while at the same time maintaining stable domestic industries with well-balanced supply and demand.

FIG. 1 : Salmon supply in Japan



Salmon

The life form and development of restocking operations

The family Salmonidae consists of four genera, the genus salmon [*Oncorhynchus*], the genus rainbow trout [*Salmo*], the genus char [*Salvelinus*] and the genus "Itoh" [*Hucho*], among which the genera salmon and rainbow trout are the important objects of commercial fishery. The representative species of this family are shown in **TABLE 1.** Because the genus salmon is distributed along the coastal and offshore waters of the North Pacific, it is commonly referred to as the Pacific salmon. The genus rainbow trout, however, originates in the Atlantic and most of its species are distributed in the Northern Atlantic and the adjacent waters. (It should be noted, however, that rainbow trout [*Salmo gairdnerii*] is also found along the Pacific coast regions of North America from Alaska to Southern California. Rainbow trout, because of its suitability to culture and capturing, was transplanted to the landlocked parts of Europe and Asia in the late 19th century. Today several kinds of rainbow trout live in the waters of Japan.) **(FIG. 2)**

All species of the genus salmon go through a life cycle consisting of three distinctly recognizable stages:

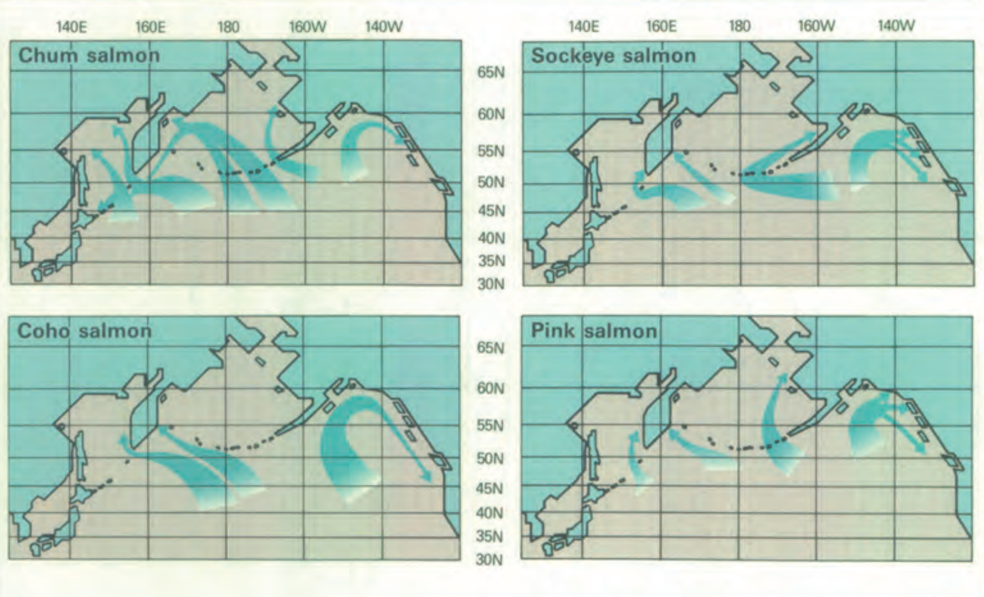
1) The alevin or fry stage which is spent in the river after hatching.

2) The growth stage in which the fish go downstream into the ocean and migrate for feeding.

3) The reproduction stage in which the fish return to their native rivers, seek out mates and lay their eggs.

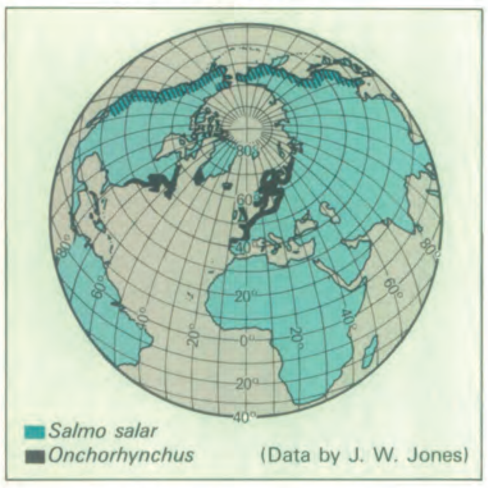
With regard to Pacific salmon, those originating from Asian rivers migrate in the ocean waters on the Asian side of the Pacific, while those originating in North American rivers migrate on the U.S. and Canadian side of the Pacific. Fig. 3 gives a schematic picture of the migration patterns of Pacific salmon. Pink salmon and chum salmon are the dominant species on the Asian side with 60% of their annual harvest being caught by Japanese and Soviet fisheries. In contrast, the sockeye salmon, coho salmon and chinook salmon resources originate mainly on the North American side with between 70 and 85% of the harvest of each species being caught by U.S. and Canadian fisheries, respectively. In 1987, the total catch of Pacific salmon was 630,000 tons (FAO statistics), with pink salmon (218,000 tons) and chum salmon (217,000 tons) being the largest, followed by sockeye salmon (131,000 tons), coho salmon (35,000 tons) and chinook salmon (26,000 tons). Cherry salmon resources are distributed over a fairly restricted area and only a few thousand tons are caught by Japanese and Soviet fisheries.

FIG. 3 : Migrating routes from offshore waters (mature fish)



(Source: Japan Fisheries Resource Conservation Association)

FIG. 2 : Distribution of Atlantic salmon (*Salmo salar*) and members of the Genus *Onchorhynchus*



(Data by J. W. Jones)

TABLE 1 : Main salmon species and their distribution

Common name	Scientific name	Main distribution area
Chum salmon	*Oncorhynchus keta*	USSR, USA, Canada, Japan
Sockeye (Red) salmon	*Oncorhynchus nerka*	USSR, USA, Canada
Coho (Silver) salmon	*Oncorhynchus kisutch*	USSR, USA, Canada
Chinook (King) salmon	*Oncorhynchus tshawytscha*	USSR, USA, Canada
Pink salmon	*Oncorhynchus gorbuscha*	USSR, USA, Canada, Japan
Cherry salmon	*Oncorhynchus masou*	USSR, Japan
Atlantic salmon	*Salmo salar*	Northern Atlantic Ocean
Steelhead	*Salmo gairdnerii*	Northern Atlantic Ocean
Sea trout	*Salmo trutta*	Northern Atlantic Ocean

Note: Steelhead - saltwater form of rainbow trout

As mentioned earlier, the genus salmon shows three distinct biological characteristics.

1) They are born in rivers and mature in the oceans.

2) They always return to the rivers of their birth to lay their eggs.

3) After the reproduction process all members of the parent generation die.

All of these aspects of the life form of salmon served in some way as positive stimuli to efforts to pursue artificial restocking operations in Japan. This is because if on-land economic development is allowed to destroy the rivers that serve as reproduction grounds, it will inevitably lead to a destruction of the reproductive cycle and a devastation of resources. But, if a suitable life environment can be provided for the river phase of the salmon's life cycle by artificial means and even strengthened, the great productive capacity of the ocean can be harnessed to bring about a recovery and increase in salmon resources. Ever since it began on its course of modernization, Japan has in fact been faced with this kind of critical situation.

The inland areas of Hokkaido, where traditionally over 85% of Japan's salmon resources returned, remained in a virtually wild state until the end of the 19th century, a fact which contributed toward the natural increase of salmon resources. Between the years 1878 and 1893, old records show catches of 6 ~ 8 million fish, and in 1889 an especially large catch of 11 million. However, excessive catching by dragnet and set net at the river mouths and the negative effects of inland development on the river environment eventually had a bad effect on the reproduction of the salmon stocks and catches began to decrease in size. Despite continued artificial hatching and releasing operations the size of returning salmon decreased constantly. Around 1965 the returning fish had fallen to a level of about 3 million fish. **(FIG. 4)**

The eggs and fry of salmon require large volumes of clean spring water. Japan, by nature, has short rivers and is lacking in the long river stretches through unspoiled wilderness that are suited to salmon's going upstream for spawning. In addition, the modern social and economic development of inland Japan has led to such phenomena as the containment and redirection of rivers, dam construction and deforesting while increasing population has led to the growth of cities. All of these factors have contributed to the deterioration of the water quality of its rivers making the number of water systems suitable for salmon running extremely few.

Artificial hatching and release for salmon got its start in Japan in 1877 based on the technology acquired by an official sent to America by the Meiji Government to study trout culture at a fishery center in New Hampshire. Since then, nearly a century of trial and error have produced the unique salmon restocking techniques found in Japan today.

At present, almost all of the chum salmon caught by Japan's coastal fisheries are the product of artificial restocking operations, while the recruit of salmon resulting from naturally hatched stock can be dismissed as negligible. The situation in Japan virtually requires a complete dependence on artificial restocking for its salmon resources.

The species of salmon that are cultivated in Japan are the three genera, chum salmon, pink salmon and cherry salmon only. Among these, the distribution of pink salmon and cherry salmon are restricted to a few areas. Chum salmon, on the other hand, is distributed over a wide area and has the largest production potential. For these reasons, chum salmon has long been the most valued and fetched a high market value. Since the 18th century some regions of the country adopted a "Spawning River" ordinance to protect the natural spawning grounds of salmon in the upper stretches of many rivers. And since the beginning of research on artificial hatching and release technology in the Meiji Period until the present, chum salmon has always been given the most importance.

In addition to the above-mentioned advantages of abundant resources and socio/economic value, chum salmon also possesses several biological and life-form characteristics that make it especially suitable to artificial restocking operations.

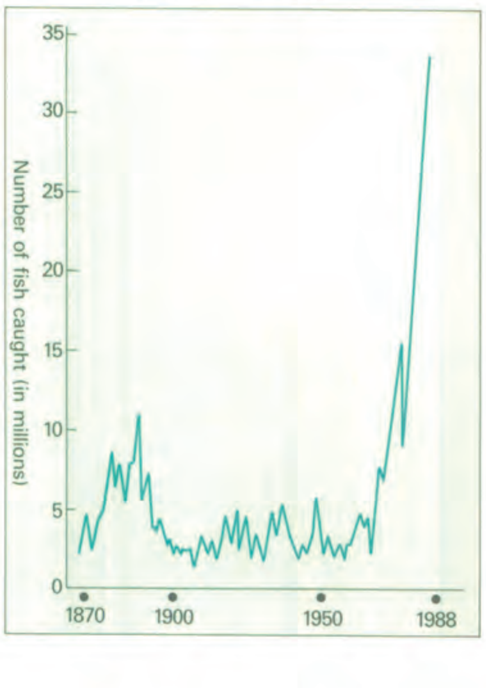
1) With chum salmon, the fish that return to the rivers for spawning range widely from age-2 to age-6, with the largest proportion being ages 3 ~ 4. As a result the average migrating school will consist of individuals of different ages. This fact means that the number of fish returning to spawn each year is fairly constant. (By contrast, returning fish in the pink salmon are always age-2. Thus, environmental changes tend to cause drastic cyclic changes in the number of returning fish in alternate years.)

2) Chum salmon tend to migrate back to their rivers of birth in a fairly concentrated period of the year, and the maturation of their reproductive functions commences as soon as they begin to ascend their rivers. This means that it is comparatively easy to catch parent fish and rear them. (Pink salmon, on the other hand, begin their river ascent sporadically over a longer period from spring into summer and mature sexually while residing in the middle and upper waters of the river before laying their eggs in the fall.)

3) The eggs of chum salmon measure from 5 ~ 9.5mm, making them second in size only to chinook salmon among the species of the salmon family. This fact makes them easy to handle during the hatching operation. Furthermore, the alevin reach a body length of 2 ~ 3cm while feeding on the nutrients of their egg yoke in the shelter of pebbles on the river bottom. And when they emerge into the waters they already have developed mouths and digestive systems as well as considerable swimming capability. This means they tend to have a high survival rate and are easy to feed.

4) Chum salmon descend their rivers to the ocean within a few months of hatching. This gives them access to the abundant food plankton of the sea waters and contributes to rapid growth. (Cherry salmon, in contrast, habitually spend their first one or even two years after birth in the relatively unproductive waters of their native river. This makes them vastly less productive as a species than chum salmon or pink salmon.)

FIG. 4 : Salmon catches in coastal and river waters of Hokkaido from 1870 ~ 1988



A Grand Challenge

Salmon returning rivers are found only in coastal regions touched by cold currents. In the Japanese Islands, the Kamo River in Chiba Pref. on the Pacific coast and the Onga River in Fukuoka Pref. on the Japan Sea coast represent the southernmost boundaries of the biological distribution of chum salmon. At present chum salmon restocking is being conducted on a commercial scale in Hokkaido and 10 prefectures on Honshu, and on an experimental basis in 11 other areas. As of 1987 there were 143 artificial hatching operations in Hokkaido and 191 in Honshu, for a total of 334 facilities. And, the number of rivers in which young salmon are released was 174 in Hokkaido and 163 on Honshu, for a total of 337 water systems. **(FIG. 5)**

In recent years, approximately 2 billion fry are released annually and about 50 million fish (equivalent to a catch of 150 ~ 160,000 tons) return each year. The total cost involved in the entire restocking process, from the obtaining of parent fish to the release of the fry, including production costs, facility costs, monitoring costs, etc., reached a total of ¥10.6 billion for the year 1986. Of this total, the national government paid 27.8%. Hokkaido and the other Prefectures paid 15.4% and the fishermen paid 56.8%. The total coastal chum salmon production in recent years is believed to be valued at about ¥100 billion.
Therefore, the economic yield of the restocking operations for chum salmon is evaluated to be about 10 times the initial cost.

The restocking system

Full-scale hatching and release operations for chum salmon in Japan began with the establishment of a government-run hatching facility on the Chitose River in Hokkaido in 1888. In the wake of this, three more government-run and about 50 privately-run hatching facilities were soon established throughout Hokkaido. In 1951, with the passing of Japan's "Fishery Resources Conservation Law", all hatching and release operations were nationalized, resulting in the present system of management. Under this system national authorities are responsible for the seed gathering, hatching, fry raising and release phases of the restocking process, while the private sector is responsible for obtaining and keeping of the parent fish.

FIG. 5: Regions engaged in salmon restocking

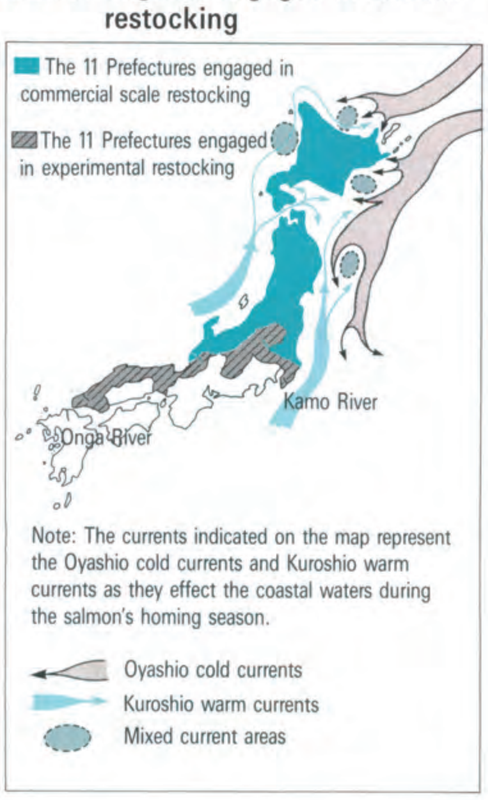
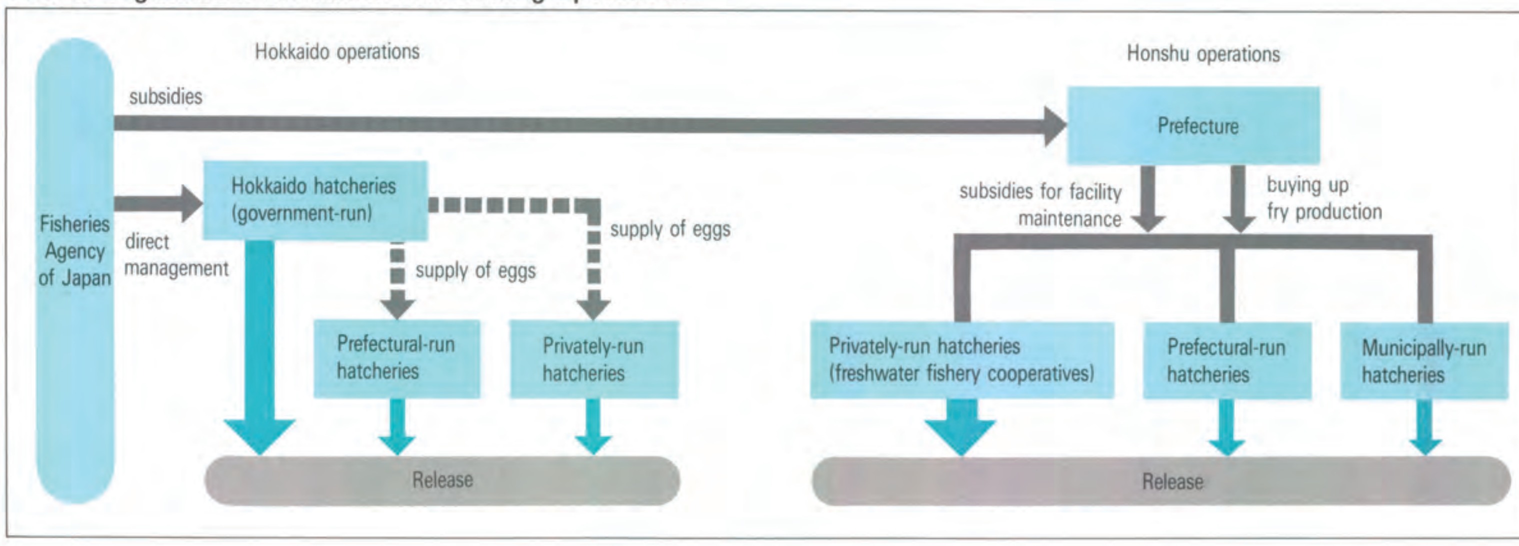


FIG. 6: Organization of salmon restocking operations



On Honshu, on the other hand, artificial hatching and release of chum salmon has been conducted by private operators on certain rivers in the Northeast region since olden times. Here, a system has existed whereby the national government provides financial support to the prefectural governments which, in turn, provide the privately-run hatcheries with funds for facility maintenance and then buy up the fry produced by the operations.
FIG. 6 shows the system of chum salmon restocking operations. The operators of private sector hatcheries are mainly the local freshwater or saltwater fishery cooperatives.

The development of restocking practices

Since around the year 1970, there has been a dramatic increase in the number of salmon migrating back to Hokkaido. This phenomenon is the result of improvements in release technologies and a resulting increase in the return rate. Another increase since 1975 is a reflection of an increase in the number of young being released. As a result of these successes there has been wide recognition of the great significance of artificial hatching and release practices. In Iwate Prefecture on Honshu among other places research was undertaken to improve the release techniques beginning around 1977, and since 1980 we have begun to see positive results from these efforts. **(FIG. 7 and FIG. 8)**

The Salmon Resources Enhancement Program

The fact that Japan is lacking in the natural environmental conditions favorable for salmon resources turned out to be a positive factor in terms of encouraging research and development on artificial hatching and release technology and creation of a system to employ this technology. The practice of artificial restocking has the following three main advantages:
1) Maintenance and expansion of facilities can lead directly to an increase in the number of eggs that can be processed.
2) The fry can be fed and released in a healthy state at a strategically chosen time of year.
3) Seed eggs can be moved to other regions to increase the number of potential home rivers.
Fisheries Agency of Japan undertook a "Salmon Resourses Expansion Program" in three 4-year stages between the years 1971 and 1983. This was a large-scale undertaking that involved unified efforts by the nationwide network of local fishery experimental stations. In terms of content, the program involved the following types of projects.

- Obtaining a sufficient number of parent fish to satisfy production goals through the establishment of proper catching standards and enlarging and improving the holding and feeding facilities.
- Improving and expanding hatchery facilities. Also, improving maintenance efforts concerning hatchery equipment.
- Standardizing technology for the raising of healthy seeds and achieving optimal release timing; thereby achieving more efficient restocking.
- Building new resources by moving stock to rivers in lower latitudes and increasing the number of rivers where restocking is practiced in existing regions.
- Encouraging debate about ways to protect the river environment.
- Researching better survey methods and strengthening resource monitoring methods.

Pursuing these policies on a nationwide basis in the end brought about the establishment the "2 billion released, 50 million returning" restocking system in effect today for chum salmon.
In 1985, The Fishery Agency announced yet another policy concerning salmon restocking operations. This policy stated that any further increase in the volume of restocking operations to be difficult both from a government funding and from a technological standpoint, and encouraged consideration of the following three alternatives as the directions for future development; **(1)** improved return rate for Japan Sea chum salmon, **(2)** promotion of pink salmon restocking operations in Hokkaido, and **(3)** experimentation in restocking for new species such as coho salmon, sockeye salmon and cherry salmon.

FIG. 7: Number of returning chum salmon

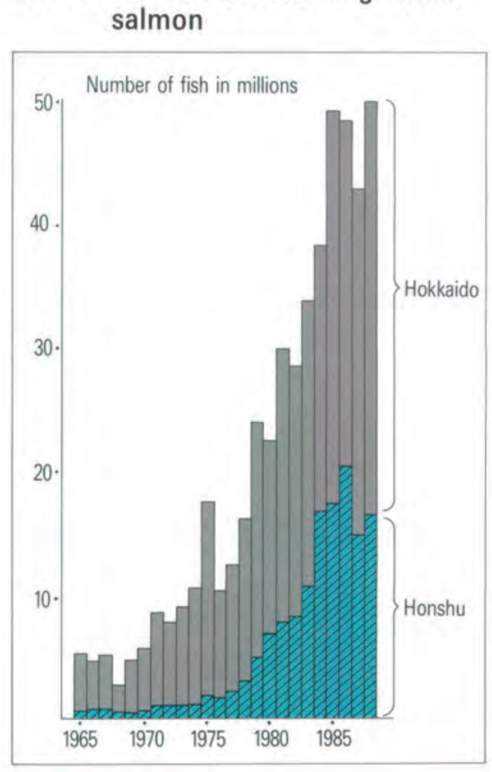
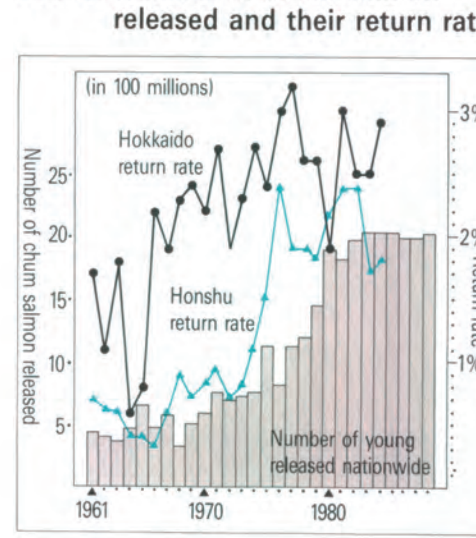
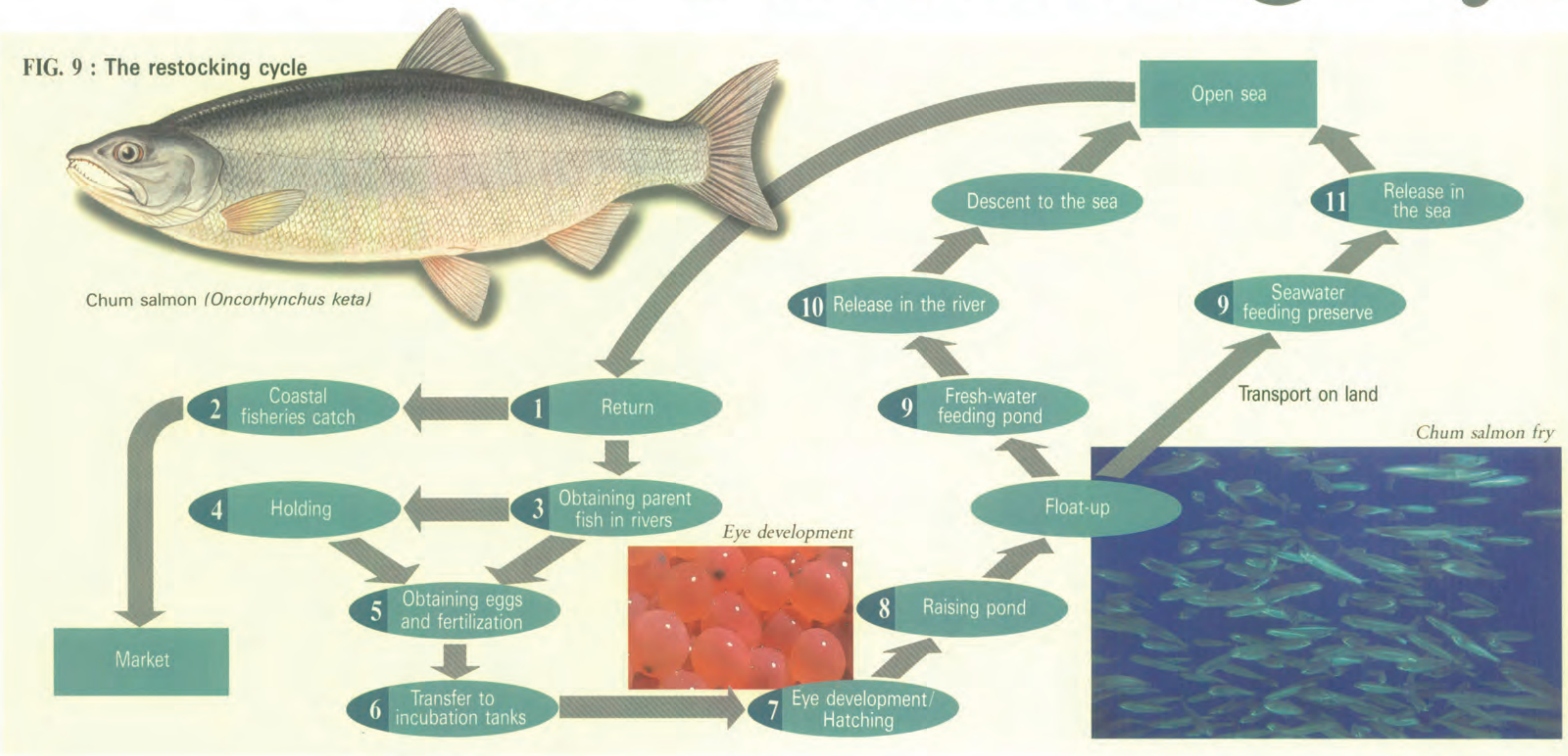


FIG. 8: Number of chum salmon released and their return rate



The Restocking Cycl

FIG. 9 : The restocking cycle



1 Return

Japanese chum salmon return to the coasts and begin to ascend their mother rivers for spawning between the months of September and December when the coastal water temperature has dropped to between 3 ~ 19 °C and the river waters between 1 ~ 15°C.

2 Coastal fisheries catch

Coastal salmon are caught by large-scale and small-scale set net fisheries that have been licensed by the fishery authorities. With the increase in returning salmon in recent years, some parts of Honshu have also begun to license small-scale longline fisheries.

3 Obtaining parent fish in the rivers

Catching salmon that are ascending rivers where restocking is going on is generally prohibited. The only licensed catchers are the fisheries cooperatives, and they utilize either dragnets or a kind of trap called an "urai" set in the river for this purpose.

4 Holding

Premature salmon are kept in a holding pond of spring water at a suitable temperature of 8 ~ 12°C where maturity is induced by creating the feel of the final stage of river ascent.

5 Obtaining eggs and fertilization

Eggs are obtained by cutting open the belly section of mature females. Sperm from two or more males are stirred into the eggs and then water added to induce fertilization.

6 Transfer to incubation tanks

After the eggs absorb water and thicken to the point where they can sufficiently withstand pressure, the fertilized eggs are put into the incubation tank, where they are kept in flowing water at a temperature of about 8°C. Since fertilized eggs are susceptible to damage when shocked, special care must be taken when introducing them to the tank.

7 Eye development and hatching

Within 9 ~ 11 hours after fertilization, cell division in the nucleus begins and within about 30 days eye development begins. Hatching begins about 30 days after eye development.
(accumulated temperature: 480°C)
Note: Accumulated temperature = average water temperature × number of days

8 The rearing pond

After hatching, the young are moved to a raising pond, the bottom of which is covered with small pebbles. After about 50 days the young fish have ingested all of their egg nutrients and begin to emerge from the shelter of the bottom pebbles and swim around.

9 Rearing in freshwater/seawater

In the past, the young were released into the river environment as soon as they reached the swimming stage, but today the young are moved from the rearing pond to a fry pond where they are fed for an additional 30 ~ 60 days to allow further growth. In some cases, the young may also be transported overland to the river mouth and reared for a while in seawater feeding preserve. As will be explained later, in periods of large natural population decrease, the young are kept under human care for a while before being released to the natural environment with the aim of increasing the production.

10 Release in the river

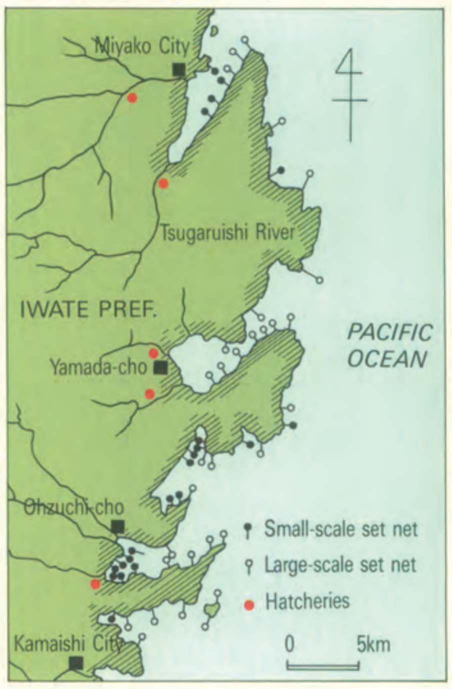
When the fry reach a body length of 4 ~ 5 cm, they are taken from the hatchery and released into the river. The number of days required for descent to the sea varies due to water and feeding conditions and, in the case of chum salmon, may take from a few days to 2 or 3 months.

11 Release in the sea

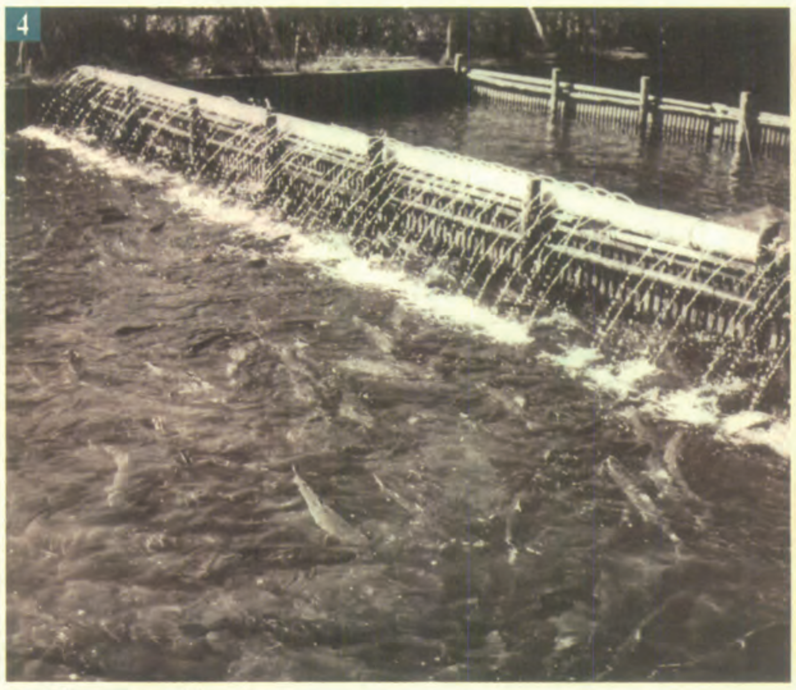
Fry which have been reared temporarily in seawater holding ponds are released at a time deemed appropriate by the movement of the cold currents.

FIG. 10 : Set net fishery distribution in the central Sanriku coast region

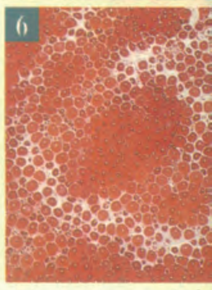
(Iwate Pref. Fisheries Dept. data/1974)



Catching by



Holding parent fish.



Obtaining eggs (Ab
and fertilization.

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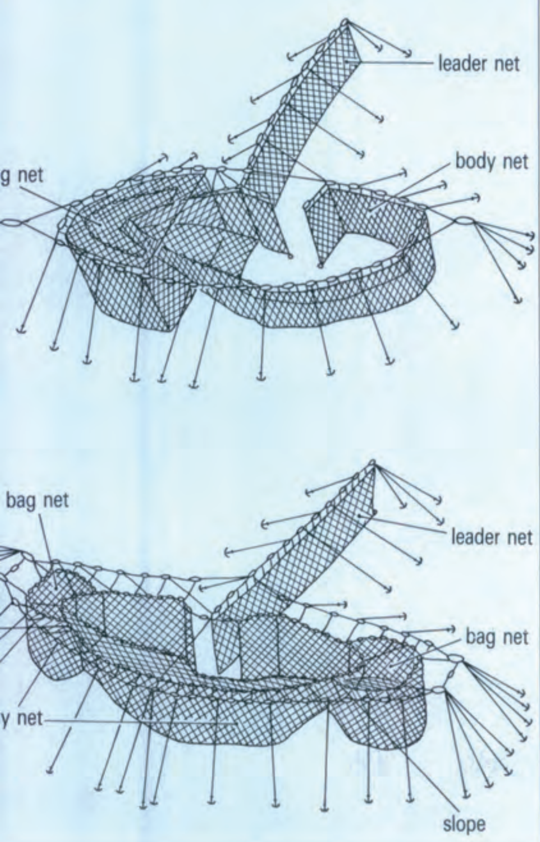
FIG. 11 : Large-scale salmon set net



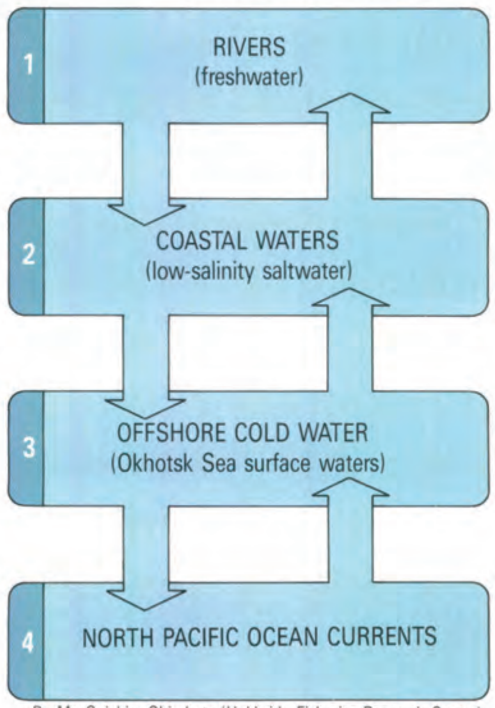
Catching by large-scale set net.

rai" in river waters.

Introducing eggs into the incubation tank.

Rearing ponds.

FIG. 12 : Progression of the environment for salmon



By Mr. Soichiro Shirohata (Hokkaido Fisheries Research Center)

Chum salmon fry just after incubation

An Innovation in the Sea

Looking back on the resource expansion program for chum salmon that was pursued in Japan in the 1970s, we realize that it was in fact a grand "innovation" taking place in the rivers and vast expanses of seas. In much the same way that economists define an "innovation" in the business world, the conditions for its development converged from the **(1) biological, (2) technological, (3) economic** and **(4) social** sectors to create results that grew geometrically.

(1) Biological:
Revealing the life cycle

Salmons which descend to the seas sometime during their life cycle, grow while migrating through four substantially different types of water environments. **(FIG. 12)** Fry which have descended a river first live in river mouths or inlets which are under the influence of the river waters. Then they move on to the low-salinity waters along the coasts. During this period the young become acclimated to the saltwater while feeding to advantage on the abundant plankton in the coastal waters. As they enter the juvenile stage in which their body shape takes on the characteristics of a mature fish, the young fish begin to venture out farther into the colder offshore waters and finally they disappear completely from the coastal environment. **FIG. 13** shows the steps of this process regarding chum salmon resources originating in Japan.

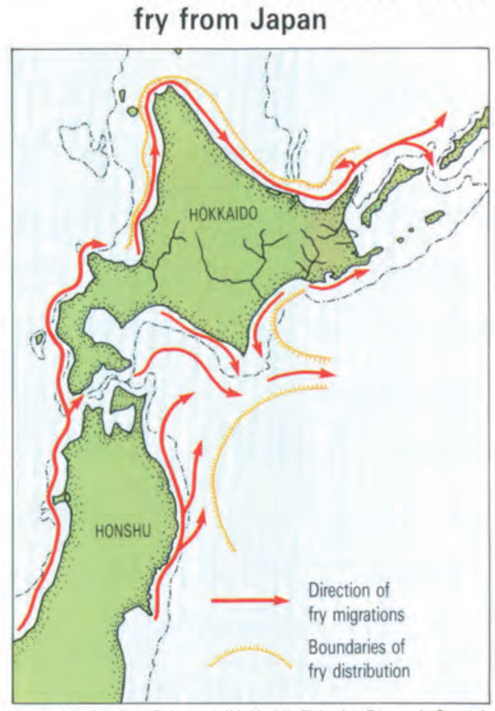
Because the effectiveness of restocking is measured in terms of the sum of the survival rates in all the different life cycle stages, research clarifying the entire life cycle is a critical part of the undertaking that cannot be omitted. In Japanese salmon restocking research, particular efforts have been made to clarify the relationship between the fish and its environment at each stage of its life cycle. Scientific factors such as water temperature and salinity and biological factors such as food sources and predators that threaten the salmon have been researched in order to prevent decrease in stock abundance as much as possible.

(2) Technological:
Improving hatching and release technology

The purpose of these efforts is to improve the final return rate. In the case of natural eggs, the mortality during the fertilization and hatching stages and until the young enter the free-swimming stage is very high, resulting in a survival rate of only about 10%. Artificial restocking eliminates population decrease almost completely during this period. From the time the fertilized eggs are initially incubated until the young are released into the river, a survival rate of between 80 ~ 90% is said to be maintained. During this stage the following points become the object of technical concern:

- Securing mature parent fish and obtaining eggs that have begun to mature.
- Egg obtaining and fertilization techniques and points of concern when moving and handling the fertilized eggs.
- Proper incubation of the eggs from the time of eye development until hatching (maintaining a state of rest in a darkened place, providing a sufficient supply of oxygen, supplying sufficient water, preventing the growth of marine bacteria, disease prevention, etc.)

FIG. 13 : Migrational routes and distribution of chum salmon fry from Japan



By Mr. Soichiro Shirohata (Hokkaido Fisheries Research Center)

The subject of concern is the survival rate after release. In 1964 a Canadian researcher calculated the survival rate during each stage of the life cycle of pink salmon. When each stage is begun with a population of 100, the rate is **(1)** 7.8% for the river life stage from the egg to the fry, **(2)** 5.4% for the stage spent in the coastal waters, **(3)** 56.4% during the stage spent in offshore ocean waters and **(4)** 93.4% for the period in which they return to the coastal waters. The above fact characterizes that anadromous salmons have to go through extremely severe living conditions in terms of the very high mortality during their early life stages in rivers and coastal zones.

In order to deal with these circumstances, two different kinds of release techniques have been developed in Japan. These are the freshwater feeding and rearing of fry begun in Hokkaido in 1961 and the seawater raising and release technique first tried in Iwate Prefecture in 1970 and later adopted widely in the other regions.

- **Freshwater feeding and raising:** Alevin which have risen after ingesting all of their yolk are moved to a freshwater raising pond where they are fed for 30 ~ 60 days and released into the river after reaching a body weight of 1 ~ 2g.
- **Seawater rearing and release:** Fry that have reached a weight of 0.6 ~ 1g and acquired the capacity to acclimate to saltwater are placed in a net-enclosed area in the surface layer of the sea and fed and reared until the coastal water temperature rises to 13°C, at which time young which have reached a body weight of 4 ~ 10g are released.

In both cases, these are techniques which seek to increase the return rate of mature salmon by obtaining "healthy seeds" whose basic body strength has been fortified. And both have brought definite results. But, survival during the critical periods of river and coastal water life depends on more the seasonal changes in living circumstances including changes in water temperature, availability of food, water salinity, sea current, etc than just the health of the seeds. With naturally born fish, the timing of descent to the sea peaks during the rise in water level due to snow melt. This is also the season when plankton growth accelerates in the coastal waters, so the two factors compliment each other.

(Continued on next pages)


Parent fish are being taken out of the rearing pond of a hatchery.

(Continued from previous pages)

In artificial restocking operations, choosing the right time for release is an extremely important point. The methods and duration of the feeding and rearing of the fry is also closely related to the chosen timing of release. At present, these two different kinds of techniques, freshwater feeding and rearing and seawater rearing and release, are conducted mutually in Hokkaido and in Honshu. And, because of such varied factors as river conditions, coastal water conditions, facility conditions and feeding costs, it is hard to make a definite decision as to which of these two techniques will be the best choice.

(3) Economic:

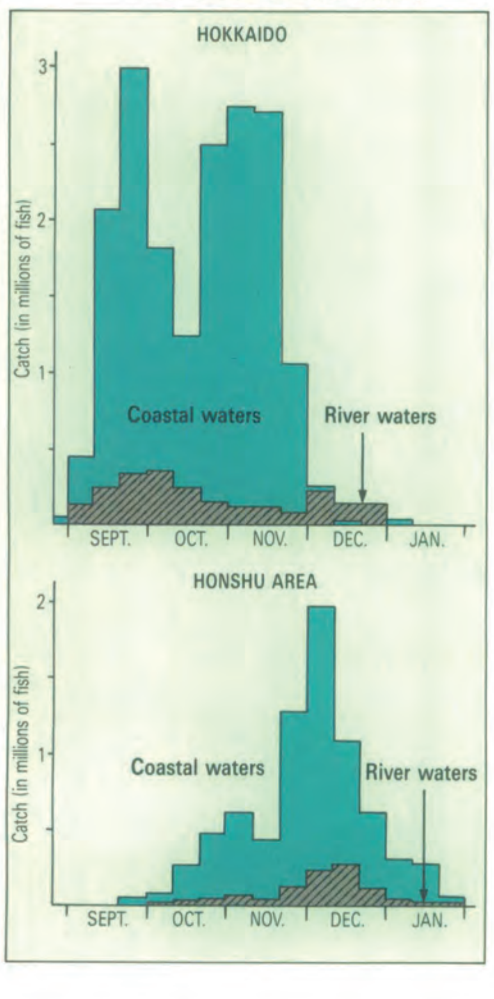
Improving product quality and the early formation of catchable schools

Chum salmon reach sexual maturity and return to the coastal waters for spawning purposes either as age-3 or age-5. In the case of Japanese chum salmon resources, they return to the eastern coasts of Hokkaido from October into December and to the coasts of Honshu from November into January. Coastal fishermen catch these returning schools either with large-scale set net, small-scale set net or longline.

The peak fishing seasons vary with each region as shown in **FIG. 14.**

While migrating in the open seas, the scales of chum salmon show a bright silver color but, by the time they have returned to the river mouth for their spawning run, both the male and female take on a colored watermark related to mating. When still silverish in appearance the meat of the salmon has a deep reddish coloring and carries a large amount of fat, but by the time the watermark appears the meat becomes pale pink and the fat content low. Silver-skinned salmon is traded at high prices for use as fresh fish or for salting, while watermarked salmon has poorer meat quality that has long made it undesirable as fresh meat as well as for use in most kinds of processed products. The standard price of chum salmon is set in terms of silver-skinned fish, with the product value of fish that have begun to show the mating watermark being 20% less and fully-matured fish 50 ~ 60% less. Since fall salmon began to return and be caught in larger number, the product quality of the catches has taken on much more importance.

FIG. 15 : Catches of chum salmon in coastal and river waters (1982)



Two important characteristics of coastal salmon fisheries are that **(1)** for any given region, under natural conditions the fishing season will come at a specific time of year and **(2)** for different regions, or even within the same region the percentages of silver-skinned/watermarked fishes within the returning schools will be different depending on the timing of the return. This fact is explained in the following way:

(i) Salmon have the habit of returning to their native rivers for spawning at the same time of year as they themselves were spawned. This is an important heredity passed on from parent to offspring for the preservation of the species, and, at the same time, gives the schools from different rivers their distinctive behavioral characteristics. In order to arrive at their native spawning grounds at the time dictated by their biological clocks, salmon "pass time" in the cold offshore waters or in the middle or upper reaches of their home rivers short of the spawning grounds. Therefore, at the time the schools return to the coastal waters the degree of sexual maturity is not consistent, but varies with the schools of different rivers. Schools which still have a long way to go to reach their native spawning grounds, are still immature and silver-skinned when they first reach the coastal waters. For example, the salmon schools originating in Hokkaido's Tokachi River, Kushiro River, Shibetsu River and Ishikari River return to the coasts early and have a high percentage of silver-skinned fish.

(ii) Chum salmon originating in Japan return to the coasts in the reverse direction along the same courses shown for leaving the coastal waters in **FIG. 13** on Page 5. Then they disperse and return to their native rivers along these same coastal "corridors". The "entrance points" for schools returning from the North Pacific and Okhotsk Sea on the eastern coast of Hokkaido offer a chance to make "early catches" of schools bound for coastal areas in southern Hokkaido and Honshu. As a result, catches here tend to have a high percentage of silver-skinned fish.

Once the fact is realized that each individual salmon has its own distinct spawning period and returning period imprinted in its genes, it is possible to conceive of taking eggs from Hokkaido-born chum salmon with an early returning period, and therefore a high percentage of silver-skinned fish at the time of return, and move them for restocking use in other regions that have a habitually late returning period, thereby deliberately creating more early-returning resources. Today, restocking operators in Iwate and other Prefectures of Honshu have directed their efforts to this kind of improvement of their local resources. The economic advantages of creating this kind of early-returning resources are; **(1)** raising the product value of chum salmon caught in their area by increasing the percentage of silver-skinned fish, and **(2)** stretching out the peak period of this inherently concentrated, short-seasoned fishery over a larger part of the catching season in order to equalize shipments of the catch throughout the season.

(4) Social:

Effects extending to the local society

Twenty-some years ago, many Japanese were dubious about the prospects of increasing salmon resources by releasing fry. Today, however, no one questions the fact that every year we are taking the "earnings" from a stock that has grown due to an "investment" into the natural life environment and using them for human benefit. In short, with chum salmon restocking we have succeeded in taking a "created resource" and using it to the following types of economic advantages:

- Vitalization of the productivity of small-scale coastal fisheries.
- Creating fish markets in the catching areas and contributing to the development of marine processing industries.
- Supporting related industries such as transport and fishery equipment suppliers.

And that is not all. An action of such a productive nature as restocking has brought people together in a process that encourages a previously unknown goal-oriented spirit that has a great carry-over effect on the local society as a whole. A good example is "Come Back Salmon" community movements that have sprung up around the country since 1970. While some complained that tax monies used for salmon restocking benefited only a select group of fishermen, others rallied to insist; "We should clean up our rivers to the point that salmon will return. That is our right as citizens". The amazing sight of great schools of salmon returning upstream has given many people a new appreciation and understanding of marine resources.

Often it seems that the interests of fishermen and those of the common citizen are diametrically opposed and irresolvable. But if the society at large can be made to recognize that, in the end, salmon restocking benefits not only the fishermen but society as a whole, then we can expect to see a new common concensus regarding chum salmon restocking practices. In reality, salmon restocking is irrevocably linked to the inland water resources and cannot exist without the kind of environmental protection that only the society as a whole can give. The type of efforts that some local governments are making to create a link between salmon and tourism or regional recreation programs are surely serving to spread consciousness about environmental protection. One researcher told us that the spread of salmon restocking operations can bring about a revival of the "salmon-related cultural heritage" that long existed in Northern Japan.

There are still many challenges remaining for salmon restocking operations in Japan. Restocking operators are anxious to see continued research in the following areas:

- Improvement of seed raising and product quality of chum salmon.
- Preservation and effective use of genetical resources.
- Development of techniques for new types of food processing for chum salmon.
- Reevaluation and coordination of fishing regulations.
- Clarification of the offshore ocean life mode and the carrying capacity of the offshore environment.
- Promotion of mutual cooperation on an international basis.

Culture Activates the Village's Economy

At present there are 4 species of salmon that are the object of cage-culture; namely Atlantic salmon, seawater rainbow trout, coho salmon and chinook salmon. The major producing nations are Norway, Finland, Sweden, Ireland, Great Britain, Canada and the U.S.A. The total production for the 1988 ~ 89 season was 180,000 tons, and is expected to reach 300,000 tons for the '89 ~ '90 season.

In 1974, the Japanese company Nichiro Corp. imported coho salmon eggs which had reached eye development and began rearing them in freshwater. Then, the following year, 1975, in a tie-up with the Shizukawa Fisheries Cooperative Association of Miyagi Prefecture, undertook the commercial mari-culture of the smolt. This experiment proved to be successful and resulted in the establishment of a division-of-labor enterprise in which **(1)** Nichiro Corp. conducted hatching and fry rearing operations, **(2)** coastal fishermen bought the fry and reared them in sea waters, and **(3)** Nichiro bought up their production of mature fish and marketed them.

Culture operation began full-scale about 1980, and production has been increasing year by year.

Encouraged by these events, coho salmon culture operations spread from Shizukawa to neighboring Onagawa, Ojika and Ayukawa, and an area of waters was designated for coho salmon culture by the prefectural authorities. Eventually culture operations spread to Niigata, Mie, Tottori, Fukui, Ishikawa and Kagawa Prefectures. By 1988, national production had reached 16,500 tons and in 1989 totalled 21,000 tons. And, in addition to Nichiro Corp., other companies including Taiyo Fishery Co., Ltd. Nichimo, National Federation of Fisheries Cooperative Unions and Nippon Suisan Kaisha, Ltd. have begun seed production operations.

There are four principal reasons why coho salmon was chosen as the object of seawater cage-culture fisheries:

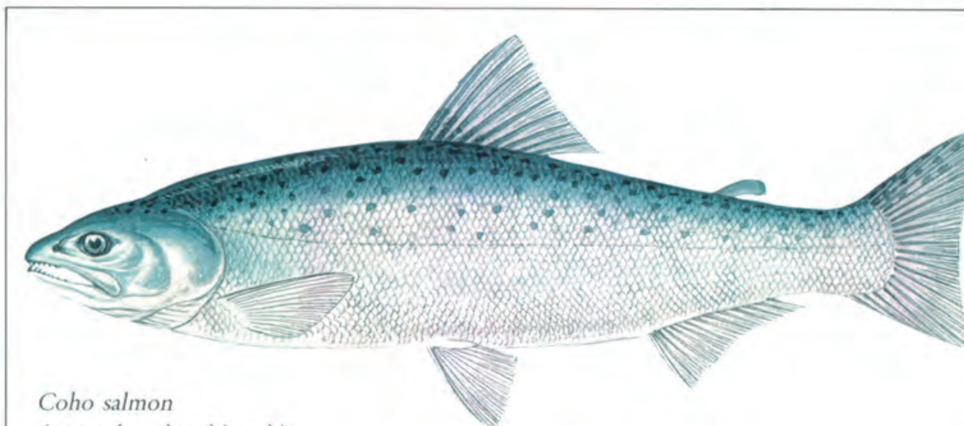
(1) Because their freshwater life period is naturally short, they are easy to acclimate artificially to the saltwater environment.

(2) The preferred water temperature for coho salmon is 7 ~ 12°C and their potential distribution range is between 5 ~ 15°C. Among the species of salmon they have good tolerance of temperature and can be reared even in the temperate zone during certain seasons.

(3) After descending to the sea the coho salmon's growth rate is exceptional. Since it reaches a body weight of 2 ~ 3kg within one year of descent to the sea, its growth rate during the first year of sea life is 3 times that of red salmon and twice that of pink salmon.

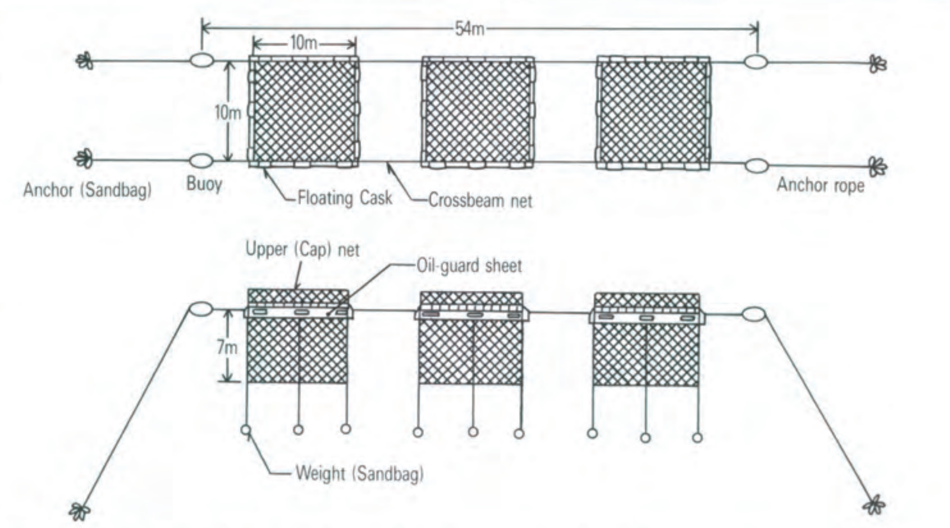
(4) Coho salmon feed largely on squids, but they also eat anchovy, sardine, saurey, mackerel and lantern fish, making them easy for man to feed.

Imported eggs that have reached eye development are delivered to the inland culture facilities in December each year. Hatching in January, they are fed and reared in freshwater until October. By this time the body weight reaches 120 ~ 250g and body length reaches 20 ~ 23cm. In mid-October, when the water temperature in the coastal culture grounds drops below 18°C, the fry are sent to the grounds by means of a live-fish transport truck. Placed in a collapsible-type water tank set up in the shore waters, the fry are acclimated to saltwater by being periodically sprayed with sea water over a 3 to 4-day period before being moved to the culture cages set up in bay waters. Here, the fish are fed for about seven months before the first shipments begin around May of the following year. All the fish are harvested and shipped by the time the water temperature climbs above 20°C in late July. By the time of shipment the fish have reached a weight of 2 ~ 3kg.



Coho salmon
(on corhynchus kisutch)

FIG. 15 : Coho salmon culture facilities (Courtesy of the Shizukawa Fisheries Cooperative Association)



Culture grounds are chosen in areas with good current flow and a bottom of rough sand. The cages are 10m square and 7 ~ 8m in depth, and are hung three in a row. The nets are made of "tetoron" (synthetic fiber) with a mesh size of 33.6 ~ 43.3mm. The nets are changed 3 ~ 4 times during the culture period depending on the degree of clogging in order to maintain good current flow through the cages.

The pioneering operators of coho salmon culture in Japan from the Shizukawa Fisheries Cooperative landed a total harvest of 2,300 tons of cultured coho salmon in 1987. The harvest was valued at ¥1.74 billion and accounted for 81% of the Cooperative's gross production. Of the 413 full-members of the Cooperative who engage in some form of fishery, 93 are operating coho salmon culture fisheries.

The town of Shizukawa is located on the inner part of a bay in a rias coast region, and until 1975 it was a low-production fishing village engaged in laver, kelp, oyster and sea cucumber culture and shellfish gathering. But now, thanks to the adventurous efforts of some of its fishermen and the apt leadership of the Fisheries Cooperative, coho salmon culture has flourished to become the foundation of the area's fishing industry. With the growth of culture production, purchases of fishing equipment and feed have increased, enabling the Cooperative's collective buying, refrigeration and credit businesses to grow in scale to 3 or 4 times their previous level and thereby rebuild the foundation of the Cooperative's business activities. In order to ensure the economic stability of the fishing families and the overall prosperity of the area's fisheries, the Cooperative has stressed three points in its instruction of its members; **(1)** that silver salmon culture operations be kept within the limits managable by family labor, with a limit of 10,000 fish raised per household; **(2)** to prevent pollution of the culture environment by such elements as excessive feeding wastes through proper culture practices; and **(3)** to operate two types of fisheries, the one which provides the core of the household's income and a supplementary one from the conventional fisheries of the area.

The feed used is a combination of fish meat and composite feeds in a moist pellet form. Basically, feeding is performed twice a day, but when the water temperature drops to 5 ~ 6°C in winter the fish exhibit poor feeding habits and the interval is dropped to once a day. When the temperature rises above 8°C in spring feeding habits improve dramatically and once again feeding is conducted twice a day to accelerate growth.

Salmon fry feeding inside the culture cage.

A sheet-type water tank used for acclimating the young to seawater. At first the acclimation process was carried out over 7 days, but recently it has been shortened to 3 ~ 4 days.

A view of the harbor of Shizukawa.

Japan's Salmon Market

Although salmon is classified as a mass-catch fish, demand for it is large in Japan and it ranks among the high-class fish in the market. As a result, it has been treated as an important commercial commodity that has a leading role in determining fish market conditions.

In the Japanese fish market a "yearly pattern" has established itself with regard to salmon. As we enter the spring of each year we see the first landings of Japan Sea coastal cherry salmon and pink salmon. From May into June, catches of "tokishirazu" [*spring chum salmon*] caught in the offshore coastal waters of the Pacific, followed by catches of various species of salmon by the northern sea fleets, compete in the market throughout the summer. Then, in late September, shipments of coastal "akizake" (fall salmon) begin. The fall salmon season continues on to the end of the year. This yearly schedule has produced a pattern in the distribution system by which the "salmon in season" dictates price changes during the course of the year. **(FIG. 16)**

The factors by which the price of salmon catches are determined include **(1)** the color of the meat (Japanese prefer red meat), **(2)** whether or not the fish is carrying a good amount of fat and **(3)** the size and shape of the fish body. Furthermore, each of the different species of salmon has its own "accepted price level" depending on the way it is sold (as fresh, salted or frozen fish), and competes with other species based on a specific market pattern of seasonal demand.

Traditionally, chinook salmon, sockeye salmon and coho salmon have been treated as the higher-classed salmons and salted products made from fall salmon, known as "aramaki" have been used as preferred gifts for the year-end holiday season and as a New Year's food. **(FIG. 17)**

At present, we must add, there are big changes occurring in the supply and demand patterns of the Japanese salmon market:

(1) In recent years, shipments of domestic coho salmon and imported salmon from various countries have grown and, as shown in **TABLE 2** and **FIG. 16**, have served to fill in the off-season gaps in the traditional "seasonal pattern" of the salmon market.

(2) Increased supply of fall salmon in recent years has changed it from its traditional position as a seasonal product to one that can be obtained year-round. Also, the domestic consuming areas are now expanding from the predominant eastern Japan markets of the past to a more nationwide distribution.

(3) Traditionally, the Japanese have preferred to grill cuts of salt-preserved salmon. But recently, there is a trend toward less salty dishes which has led to an increased use of frozen salmon in cooking **(FIG. 18)**

(4) As the Japanese become more "gourmet conscious", there has been an increasing demand for fresh salmon. In recent years shipments of Norwegian cultured Atlantic salmon are reaching the Japanese market year-round as fresh fish. In answer to this trend, the number of domestically produced cultured coho salmon and fall salmon being processed as salt-preserved fish is decreasing and more are being shipped to the market as fresh fish.

As the supply of salmon grows in volume and number of sources, the Japanese consumption is rapidly evolving away from salt-preserved products and toward a mass-consumption market. At the same time, the industry is searching for a means by which the salmon can retain its position as a high class sea-food that is high in protein and low in calories.

TABLE 2 : Salmon imports (1988)

Product type	Product	Amount (tons)	Main export countries
Fresh or refrigerated	Atlantic salmon Danube salmon Pacific salmon	3,816	Norway, Canada, U.S.A., New Zealand
	Trout	81	Australia, Norway
	Other species of salmon	8	U.S.A., Australia
Frozen	Pacific salmon	116,611	U.S.A., Canada
	Trout	11,375	Sweden, Denmark, Norway
	Atlantic salmon	1,019	Norway
	Other species of salmon	248	Denmark
Salt-preserved, salmons in saltwater brine	Salmon species	777	Canada, U.S.A.
Smoked (Dried, salt-preserved salmons, in saltwater brine)	Pacific salmon Atlantic salmon Danube salmon	137	Canada, Norway
Fillets	Salmon species	33	Canada
Fish eggs (caviar)	Salmon species	8,683	U.S.A., Canada

FIG. 16 : Yearly patterns in the Japanese salmon/trout market

	Product	Producing area	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Japanese domestic produce	Pink salmon, cherry salmon (Japan Sea)	Japan Sea coastal regions	■	■	■	■	■							
	Spring chum salmon	Pacific-side offshore waters				■	■	■	■	■				
	Northern Sea salmons (Sockeye salmon, coho salmon, pink salmon, chinook salmon, chum salmon)	North & Central Pacific					■	■	■	■				
	Fall chum salmon	Hokkaido and Honshu coastal regions	■								■	■	■	■
	Cultured coho salmon	Honshu coastal regions					■	■	■	■				
Imports	Sockeye salmon, chum salmon	Alaska, U.S.A						■	■	■	■			
	Pink salmon Sockeye salmon, coho salmon Chinook salmon, chum salmon	Alaska, U.S.A Canada Oregon, U.S.A							■	■	■	■		
	Cultured chinook salmon Cultured Atlantic salmon	Australia New Zealand	■	■								■	■	■
	Cultured coho salmon	Chile	■	■									■	■
	Cultured Atlantic salmon	Norway	■	■	■	■	■	■	■	■	■	■	■	■
	Cultured rainbow trout	Norway, Sweden Denmark, Finland	■	■	■								■	■

(Market season)

FIG. 17 : Salmon prices by species

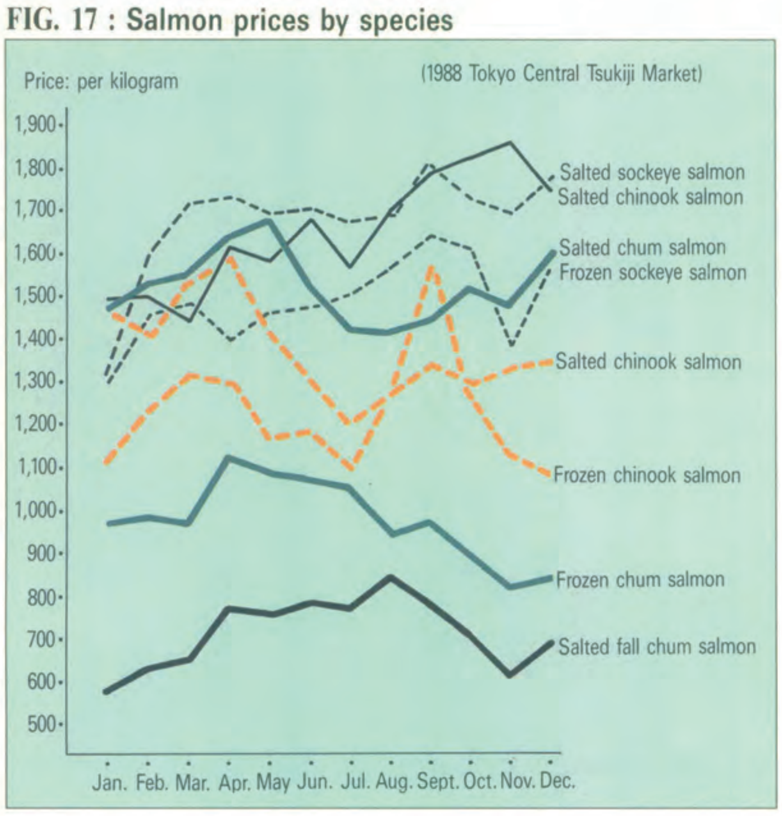
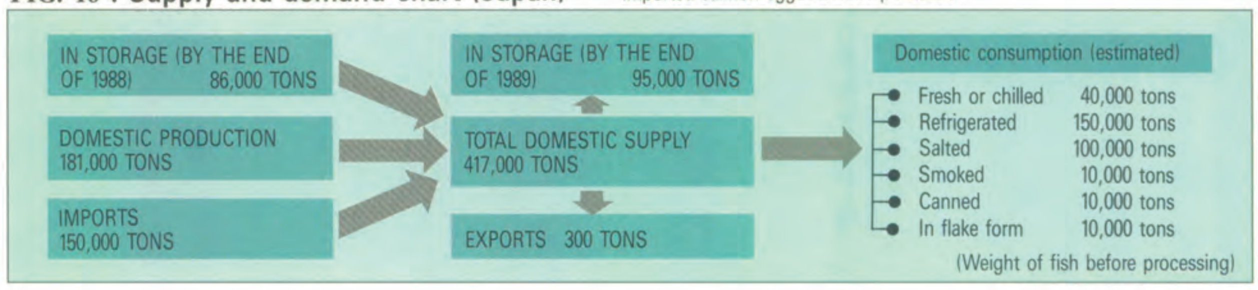


FIG. 18 : Supply and demand chart (Japan)

Note: In addition to the products below, about 17,000 tons of domestic and imported salmon eggs are also produced.



The most common shipping form for fall salmon is as salt-preserved fish, accounting for nearly 2/3 of the total. The fish are dressed and salt applied lightly to the outer skin and gut section, then packed in boxes.

For the Japanese, chum salmon eggs eaten as "ikura" (mature eggs) or as "sujiko" (immature eggs) are a delicacy of the highest class. In the fish market it draws prices as high as ¥10,000 per kilo. About 3,000 tons are produced in Hokkaido and Honshu and another 8,000 tons imported from Canada and the U.S.A.