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# Fish Breeding in Nigeria

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**Abstract:** Fish breeding is a very important activity ensuring availability of fingerlings for the stocking of ponds, pens, tanks and cages. The breeding habits of fishes in nature differ from specie to specie Different species of fish choose different places in the aquatic environment for breeding. Most species do not breed when in captivity due to a number of factors. In Nigeria, induced breeding of African mud catfish through injection of ova prim hormone or pituitary gland is the main practice. This article reviews the wild sources of fish seeds, some cultivable fishes. carp breeding, relationship between the endocrine system and gonad development, function of the Central Nervous System (CNS) in propagation, influence of ecological conditions on gonad development, artificial propagation of common carp, natural induced spawning, salmon culture and an innovation in the sea to educate fish breeders, fish genetics and fish culturist in other to facilitate their productivity.

**Key words:** Carp culture, cultivable fishes, fish seed sources, innovation at sea, propagation, salmon culture

## INTRODUCTION

The food and Agricultural Organization of the United Nations (2006) stated that Nigeria is a protein deficient country. The protein deficiency in the diets can be primarily remedied through the consumption of either protein - rich plants or animal food stuffs.

Protein from animal sources is in short supply in Nigeria due to the rapid increase in human population annually a well as the decrease in livestock population du to several factors including diseases, deforestation and drought, scarcity and high cost of quality feeds, poor genetic qualities and limited supply of indigenous breeds and avian flu disease which brought about mass mortality of poultry. These factors combined have raised the cost of animal protein to a level that is almost beyond the reach of the ordinary citizen. This situation has therefore given rise to a considerable increase in the demand for fish to supplement the needed animal protein intake.

The steadily growing importance of fish farming has compelled improvements in the technologies necessary for securing the initial and basic requirements for productive aquaculture; namely the production of fish seed for stocking. Fish culture today is hardly possible without the artificial propagation of fish seeds of preferred cultivable fish species. The need for the production of quality fish seed for stocking the fish ponds and natural water bodies has indeed increased steadily (Brain and Army, 1980). Artificial propagation methods constitute the major practicable means of providing enough quality sed for rearing in confined fish enclosure waters such a fish ponds, reservoirs and lakes (Charo and Oirere, 2000). The production of marketable fish fingerlings or juveniles into rearing environment that assures optimum and rapid growth to allow harvest in the shortest possible time. The fish farmer has to obtain adequate number of young fish to meet his production goals. The possibilities of obtaining fish seed in adequate numbers from natural source is rather limited. Even the spawners which, reproduces successfully n confined enclosures are propagated artificially. Apart from being able to obtain quality seed, the artificial propagation technique can also be used to develop strains superior to their ancestors by the methods of selective breeding and hybridization. Depending on the perfection of the system, at least 65% of the eggs produced can be raised to viable fingerlings as against less than 1% survival rate in natural spawning. It is through this method that out of season supplies of fingerlings are achieved. This article reviews the meaning of fish breeding, wild sources of fish seeds, some cultivable fishes. Carp breeding, relationship between the endocrine system and gonad development, function of the Central Nervous System (CNS) in propagation, influence of ecological conditions on gonad development, artificial propagation of common carp, natural induced spawning, salmon culture and an innovation in the sea to educate

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## MEANING OF FISH BREEDING

Fish breeding is the act of producing young ones from parent brood fish. This ensures species continuity and survival. In aquaculture, fish breeding is a very important activity ensuring availability of fingerlings for the stocking of ponds, pens, tanks and cages. In fishes, reproduction or breeding is controlled by internal and external or environmental factors. The internal factors are controlled by the endocrine system as well as physiological state of the fish. The environmental factors include temperature, salinity, good water quality, adequate food and photoperiod. Fish breeding in hatcheries can be achieved by either natural methods or induced (artificial) breeding.

The breeding habits of fishes in nature differ from specie to specie Different species of fish choose different places in the aquatic environment for breeding. They also breed in different season. For example, Clarias breeds during the flood season while Tarpon breeds during the dry season. Tilapias breed through out the year. In fishponds, natural breeding is achieved, having acquired a thorough knowledge of the reproductive biology and habits of the culture fish. The fish breeder must provide and simulate the natural environment to succeed in the spawning of the species (Adekoya *et al*., 2006).

Tilapia species spawn naturally in fishponds. Natural spawning of tilapia is achieved when mature male and female Tilapia is stocked together in ponds or tanks. Provision of substrates or shallow pond margins enhances natural spawning of tilapia. The tilapia fry are harvested at regular intervals and used for stocking the production ponds. For Clarias, natural spawning can be achieved through simulation of flooding. Increasing and decreasing the volume/level of water in the ponds intermittently may trigger natural spawning in *Clarias gariepinus*.

Most species do not breed when in captivity due to a number of factors. In *Clarias gariepinus*, the eggs enter into a “dormant” phase after accumulation of yolk material (post-vitellogenic oocytes). Final maturation and release of these eggs may not be achieved except the fish is induced to breed through hormone treatment. The success of induced or artificial breeding depends on the state of the post-vitellogenic oocytes in the ovary. The eggs should be ripe before fish can be induced to breed (Charo and Oirere, 2000).

Induced ovulation and spawning is achieved by the administration of either pituitary glands from fish or amphibians (hypophysation), mammalian gonadotropins (HCG), DOCA, ova prim, Luteinizing hormones or other substances.

In Nigeria, induced breeding of African mud catfish through injection of ova prim hormone or pituitary gland is the main practice. The hormone dosage varies from 0.25-0.5 mL of ova prim/kg female; 50 mg/kg for DOCA or 3-5 mg powdered pituitary gland per kg gravid female. Some farmers inject fresh pituitary gland after extraction. The brood fish used in this case are classified as either donors or recipients. The recipients are injected with the extract of fresh pituitary gland from the donors.

Spawning could be natural or artificial. For natural spawning, the male and female spawners are kept together in spawning tanks or containers after hormone injection. The females will release their eggs, which will be fertilized, by the released milt from the males. In artificial spawning, the eggs are stripped out of the females and fertilized with milt collected from the male. The belly of the male is dissected open to obtain the testis. Artificial spawning is mostly practiced by fish farmers in Nigeria and is more reliable than natural spawning.

For an efficient induced fish-breeding programme in hatcheries, the following must be considered:

- Selection of healthy gravid brood stock
- Procurement of gametes
- Fertilization of eggs and incubation
- Larval/fry rearing
- Fingerling production and harvest
- Fish nutrition (larva → fry → fingerlings)
- Water quality control

Fish seeds are very young fishes that are stocked in culture media (ponds, concretes, fiber glass troughs etc). Fish generally being oviparous animals has its earliest stage as fertilized egg/ovum. This is followed by hatchling (hatched larvae) sac fry, swim fry and just feeding fry, which is between 4.5 to 14 mm in length depending on the species.

The fry stage is succeeded by fingerling stages whose length ranges from 50 to 100 mm and of 1-10 g-body weight depending on species. This leads to juvenile stage, which is of between 4 and 8 weeks old and above 10 g body weight. It is bigger and longer than fingerling but smaller and shorter than adult fish. In aquaculture, the life stages usually sourced for as seed is fingerling. Therefore large-scale procurement of fingerlings is a pre requisite to profitable fish culture (Aluko *et al*., 2003).

## WILD SOURCES OF FISH SEEDS

These are natural water bodies, which have been the traditional sources of young fish. These include rivers, natural lakes, lagoons, estuaries, creeks, swamps, pools and seas.

Other wild sources of fish seeds are depressed lands that are frequently flooded especially during raining season. Canals or channels that supply water from big rivers or lagoons also, can be sources of young fish.

Abandoned fishpond is another important source of wild fish seeds.

**Collection materials:** These involve various types of gears, such as dragnets, seine nets, bag nets and scoop nets. Generally these collectors have mesh sizes that are small to retain young fish. These young fish (fingerlings) of the desired species are sorted out of the entire collection while the rest are returned back to the water body. The process of sorting should be mild to avoid stressing of the young fish.

**Collection time:** The period of collection should be early in the morning or early evening. Seeds can also be collected at other time of the day provided there is low water and atmospheric temperatures. Time lag between collection and transportation to culture media should be kept as short as possible.

In brackish water species culture, the larvae can be netted out from the source water body and introduced directly in culture medium, such as already prepared ponds. This is due to the proximity of culture pond to the natural brackish water body.

Disadvantages of collecting fish Seeds from the wild:

- Labor intensive and time consuming; with the possibility of not getting the desired species.
- Seasonality in the availability of fry and fingerlings except for Tilapia, all fishes produce offspring during rainy season.
- Percentage survival from egg to fingerling stage in nature is always less than one percent. This is as a result of relatively low rate of fertilization, predation and unfavorable environmental condition.
- Uncertainty of seed quality. Under nourishment in nature might have accounted for production of offspring of low quality. This is undesirable for a profitability fish culture.
- The possibility of bringing pests such as parasites and predators especially their larvae to culture medium from the wild.
- In ability to raise species of higher growth rate and taste; and market values through genetic manipulation. Heteroclarias is a product of hybridization of *Clarias gariepinus* with *Heterobranchus bidorsalis*.

**Some cultivable fishes:** For maximum yield of the efforts to obtain fish seeds from the wild, it is necessary to have some basic knowledge of their natural history such as habitat, breeding season and ground: and reproductive pattern.

**Clarias:** Belongs to the Claridae family and popularly called mud cat fish. It inhabits freshwater swamps and rivers. The breeding places and season are flowing water, submerged vegetation and during rainy season respectively.

**Heterobranchus:** Belongs to the Claridae family and inhabits swamps and rivers with preference to the former. The breeding place and season are flowing water; on submerge vegetation, between months of June and October.

**Chrysichthys:** Belongs to the Bagridae family and popularly called silver catfish. It inhabits fresh and brackish water swamps and rivers. It breeds in rock and tree holes in flowing fresh water during rainy season. Collection from the wild remains the main source of Chrysichthys seeds due to difficulty in accomplishing its artificial propagation. Collection is accomplished by placing large diameter hollow pipes at the bank of water bodies where the adults are found. This will provide approximation of conditions required for breeding, such as darkness. Fish fingerlings can be collected by, evacuating the pipes.

***Oreochromis niloticus*:** This is a cichlid popularly called Tilapia. It inhabits fresh water swamps and rivers. The female is a mouth brooder and breeds all year round.

***Tilapia guineensis*:** This is also a cichlid and called Tilapia. Its habitat is fresh and brackish water bodies. It is a substrate spawner and breeds all year round.

***Heterotis niloticus*:** Belongs to the Osteoglossidae family. Popularly called bony tongue or slap water. The habitats are swamps, lakes and fresh water creeks with slow currents. It breeds in shallow water filled with weeds with which the couple build nest between June and October. Young form schools.

***Cyprinus carpio*:** This belongs to the family Cyprinidae and popularly called common carp. It is widely distributed, found in rivers lakes and ditches. It prefers bottom layers of the water body because it feeds on benthos.

Being widely distributed, no exact environmental condition is required for gonad development and reproduction. Therefore, it reproduces in still and running water, where there are substrates (e.g., aquatic plants) to which the eggs will adhere. It breeds predominantly during the rainy season (Ayinla and Nwandukwe, 1980).

## CARP BREEDING

There are several species of carp that are cultured in many countries all over the world. These include grass carp (*Ctenophyanyngodon idellus*), bighead carp

(*Aristichtys nobilis*), black carp (*Mylopharyngodon piccus*), silver carp (*Hypophthalmichthys molitrix*), common carp (*Cyrinus carpio*), Catla (*Catla catla*), rohu (*Labeo rolli)* etc. Of all these species, common carp has the longest history of culture, which dates back to more than 2,100 years ago. Presently common carp is one of the most important cultured fish species in the world, occurring in both tropical and temperate zones. The success of the proliferation of common carp is basically due to the fact that it is able to survive and tolerate extremes of temperature in addition to its ability to spawn in captivity (Brain and Army, 1980).

A lot of morphological variations have arisen in common carp due to artificial breeding and natural selection. However, the basic morphology of common carp is a laterally compressed body with the dorsal region projected in an arc shape. The mouth is slightly turned downward with a blunt snout and two pairs of barbells on the upper jaw. Common carp possesses molar like pharyngeal teeth and is an omnivore. However, in the natural environment, common carp tends to be more of a carnivore, feeding on benthic animals such as snails, young clams, chironomid, other insect larvae, zooplankton (e.g., cladocera, copepods) and shrimps. In addition, common carp diet also includes detritus of higher aquatic plants and plant seeds.

Common carp can tolerate a wide range of water temperature ranging from 0.5 to 35ºC. However below 13ºC growth is slowed down; while feeding stops below 5ºC. The optimum water temperature for proper feeding and growth is between 24 and 28ºC. Though a fresh water species *C. carpio* can tolerate salinities up to 20 ppt.

Natural spawning of this species in temperate climate is seasonal; while in the tropics it is all year round. The stimulus for spawning is a rise in water temperature to at least 18ºC in addition to flooding.

The age at maturity of common carp in the tropics ranges from 6 to 12 months. Females are highly fecund. The average fecundity of a 3-year old, 44-48 cm, 1.9-2.75 kg, female is approximately 244,000 eggs.

**Relationship between the endocrine system and gonad development:** The physiological activities of carp are regulated and controlled principally, by the nervous system of which, the pituitary (hypophysis), gonad and thyroid glands are closely associated with gonad development (Ezeri *et al*., 2009).

**Hypophysis/pituitary gland:** Follicle Stimulating Hormone (FSH) is a sexual hormone secreted by the adenohypophysis and is responsible for the stimulation of growth, development, maturity and ovulation of eggs. FSH promotes the synthesis and secretion of estrogen in the female or the formation of sperm and the secretion of androgen in the male. Hypophyseal hormones can be utilized to artificially induce estrus cycle in fish species.

**Gonads:** Apart from the production of germs cells (spermatozoa and ova) the gonads also secrete sexual hormones:

Androgen: secreted by the testes.
Estrogen: secreted by the ovary

These hormones are responsible for the initiation of secondary sexual characters and for the sexual behavior of the fish.

**Function of the Central Nervous System (CNS) in propagation:** Successful propagation of fish specie depends on the maintenance of a balance between physiological processes and ecological conditions. The realization of this balance depends on the Central Nervous System (CNS). To a great extent, gonad development is controlled by hypophysis and the activity of hypophysis is in turn controlled by some external ecological factors through the CNS.

For instance, when certain ecological conditions stimulate the external sense organs, impulses are transmitted to the CNS, which induce the hypothalamus in releasing luteinizing hormone releasing hormone (LRH). LRH further stimulates the hypophysis to release luteinizing hormone (LH) and FSH. LH and FSH stimulate the gonads by promoting their growth and development. In addition, the gonads secrete sexual hormone affecting the hypothalamus and hypophysis; and initiating sexual activity or estrus i.e. chasing, natural courtship, spawning and releasing milt.

**Influence of ecological conditions on gonad development:** Favorable ecological conditions enhance normal growth and development of fish gonads. These include availability of food, water temperature, and water current and dissolved oxygen.

**Food:** The nutritional standards are generally higher in ponds than in the natural environment as a result, higher fecundity is expected. If the rearing conditions are good with the provision of sufficient food for the spawners, then the gonads will mature early enough and the fecundity will be high.

Among the required nutrients (proteins, carbohydrates, fats and oils, vitamins and minerals); vitamin E is especially important for gonad development. Therefore, feed rich in vitamin E should be supplied to brood stock (at least 10% increase of the vitamin E content of the feed). Food items rich in vitamin E include soybean, groundnut, lettuce leaves among others. Proper nutrition and favorable ecological conditions are essential for the maturation of the gonads.

**Water temperature:** This is an important significant factor affecting metabolic rate, maturing age and the development rate of the gonads. The ideal temperature for breeding of carps is 22-28ºC.

**Water current:** Good water current or running water is essential is stimulating gonad development. It is necessary therefore to provide running water for about 2-3 h once a week (one month before the fish spawn). Also it is necessary to increase water level in the brood stock pond by 2-3 cm. If there is no running water fertilization rate may drop by 50%.

**Dissolved Oxygen (DO):** The ideal DO level in brood stock pond is 4.5 mg/L. Normal physiological activities are drastically reduced when DO is as low as 2 mg/L. It is therefore important to always maintain DO levels well above 2 mg/L.

**Artificial propagation of common carp:**

**Selection of brooders:** Sex determination of common carp brooders is through the observation of secondary sexual characteristics. However, a sure way of distinguishing sexes is to feel the pectoral fins of brooders between the fingers. The matured females have smooth pectoral fins; while the surface of the pectoral fins of the males are rough to touch (Fagbenro *et al*., 1991).

Selection of brooders can also be based on degree of maturity of the eggs. Collect a small amount of eggs from the genital opening by inserting a spoon in the vent. Place the eggs in a Petri dish and add a mixture of 85 mL of 95% alcohol, 10 mL of 40% formaldehyde and 5 mL of glacial acetic acid. Fix the eggs in this solution for 2-3 minutes. The nucleus becomes opaque while egg yolk and cytoplasm are transparent (Nwadukwe *et al*., 1991).

Three possibilities may occur:

- The nucleus is seen in the center of the egg, which indicates that the egg has not matured, and the fish is not ready for induction.
- The nucleus is eccentric (at the animal pole), meaning the egg is mature and the fish is ready to spawn.
- The nucleus is vague or cannot be seen, which means that the egg is over mature or degraded and the fish should not be induced.

**Collection:** Brood stock may be bought from a reputable farm or reared in one's own farm from fry stage to adult.

Transportation: Brood stock may be transported in wooden or plastic barrel or in plastic bags with oxygenated water. There should be 10 L of water for every 1 kg of parent fish.

**Induced spawning of common carp:** Principles: Artificial breeding (induced spawning) is simply supplementing the insufficient hormones (Richter and Van Der Hurk, 1982), which due to poor ecological conditions that would not make the fish spawn under culture conditions to do so. Otherwise, for efficiency of fertilization and to ensure greater survival of fry, common carp is induced to spawn by the administration of hormones (inducing agents) such as:

- Luteinizing hormone releasing hormone analogue (LRH - A)
- Human chronic gonadotropin (HCG)
- Carp pituitary extract (CPE)
- Ova prim

**Dosage for carp pituitary:** The pituitary gland of donors of mature common carp can be collected irrespective of their sex. Mature carp donor of 0.5 kg weight will have approximately 1 mg of pituitary gland.

The dose for CPE is usually 4 mg/kg body weight of female; males are given one-half of the female dose. On the other hand, split doses can be administered to the females. The first or preparatory dose is given (0.5 mg/kg. body weight of female) and then after 6-8 h the second dose or decisive dose is administered (4 mg/kg body weight); at which time the males are given the remaining dose (2 mg/kg body weight of male) or half of the decisive dose administered to female.

**Preparation and administration of CPE solution:** Pulverize the CPE and mix with normal saline (0.9% NaCl solution). Extract the supernatant with a syringe. Inject the contents into the muscle at the base of the pectoral fin with the needle pointing towards the head region at an angle of 45ºC. Based on the weight and sex of each recipient, the required dose of CPE is calculated and given as a ml solution in normal saline.

**Stripping:** About 15 min after the onset of estrus, the brood fish are captured and stripped. The eggs are collected in a dry basin. The milt is squeezed into the eggs. The mixture is then stirred gently with a feather for 1 min. The eggs of common carp are adhesive and stickiness can be removed by adding a solution of 0.4% NaCl and 0.3% urea to the eggs, immediately following mixing of eggs and milt during stripping. After this, the fertilized eggs may be washed in 0.15% tannin to remove any traces of adhesive material before transferring eggs to the incubation tank (Hogendoorn, 1981).

On the other hand, adhesiveness of the eggs may be removed by adding a mixture of mud/clay and water (in a ratio of 1:5).

**Natural induced spawning:** After injection, the brooders are placed in the spawning pond/tank to spawn/exude milt and complete the fertilization process. The spawning tank should be provided with kaka bans so that, the sticky eggs

Table 1: Main salmon species and their distribution

| Common name | Scientific name | Min 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 gorbuschar* | USSR, USA, Canada, Japan |
| Cherry Salmon | *Oncorhynchus masou* | USSR, Japan |
| Atlantic Salmon | *Salmo salar* | Northern Atlantic Ocean |
| Steel head | *Salmon gairdnerii* | Northern Atlantic Ocean |
| Sea trout | *Salmon trusty* | Northern Atlantic ocean |

FAO (2006); Steel head is saltwater form of rainbow trout

may attach to these kaka bans. Local materials like palm tree roots can be used; old nets are also good enough. The kaka bans should be suspended in flowing water. Prior to use, the kaka bans should be disinfected in 7 ppm $KMnO_4$ (potassium permanganate) (Makinde, 2001).

**Incubation:** This involves not only brining the egg through embryonic development to hatching out but also includes all the management work from hatching to stocking ponds.

In other to prevent fertilized eggs from sinking to the bottom of the incubation tank, the water flow should be regulated. The speed of water flow should be high enough to keep eggs floating in the water column. The fertilized eggs may be disinfected with $KMnO_4$ (7 ppm) to prevent microbial infection.

The optimum range of water temperature in the tank should be between 25 and 27ºC; DO level should be up to 4-5 mg/L; below 2 mg/L, the embryo will develop abnormally; hatching time is about 48 h after fertilization.

**Stocking:** About 4-5 days after hatching out, the fry swim away from the kaka bans. Fry can now be transferred to nursery ponds where they will begin feeding. The stocking density of fry is estimated at 1 million/ha, and can be maintained for 2 weeks before restocking in fingerling ponds or grow out ponds.

**Feeding:** Suggested feed for fry (at this early developmental stage):

- Natural food organisms: mainly zooplankton
- Soya bean milk.

**Estimation of fertilization rate:**

$$\text{Fertilization rate (\%)} = \frac{\text{No. of fertilized eggs}}{\text{Total no. of eggs}} \times 100$$

**Procedure:** 6-8 h after fertilization, 100 eggs should be randomly collected with a scoop net and placed in a white dish. Unfertilized eggs (while, empty or rotten eggs) should be selected and removed; the number noted and fertilization can then be calculated.

**Salmon culture:** The family salmonidae consists of four genera: Salmon (Onchorhynchus), rainbow trout (Salmon), cha (Salvelinus) and Itoh (Hucho). The genera Salmon and rainbow trout are 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 from 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 girdnerii* 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 land locked parts of Europe and Asia in the late 19th century. Today several kinds of rainbow trout live in several water bodies.

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

- The alevin or fry stage which is spent in the river after hatching.
- The growth stages in which the fish go down stream into the ocean and migrate for feeding.
- The reproductive stage in which the fish return to their native rivers, source for mates and lay their eggs.

With regard to pacific salmon, those originating from Asian rivers, migrate to 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. 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, 2006) 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 Japanese and Soviet fisheries catch a few thousand tons.

The genus salmon shows three distinct biological characteristics:

- They are born in rivers and mature in the oceans.
- They always return to the rivers of their birth to lay their eggs.
- After the reproduction process all members of the parent generation die.

All these aspects of the life form of salmon served in some way as positive stimuli for efforts to pursue artificial restocking operations in Japan. This was because if on-land economic development was 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 reproductive 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 world 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.

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 wildness that are suited to salmons 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 contributed to the deteriorations 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 technique 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 required 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 the most important. 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 for artificial restocking operations.

- With Chum salmon, the fish that returns to the river for spawning ranges widely from two years to six years, with the largest proportion being 3-4 years. As a result the average migrating school consisted of individuals of different ages. This fact meant that, the number of fish returning to spawn each year is fairly constant. By contrast, returning fish in the pink salmon are always two years. Thus, environmental changes tend to cause drastic cyclic changes in the number of returning fish in alternate years.
- Chum salmon tends to migrate back to their rivers of birth in a fairly concentrated period of the year, and the maturation of their reproductive function 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.
- The eggs of Chum salmon measure from 5-9.5 mm, 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 2-3 cm while feeding on nutrients from 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.

- 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 seawaters and contributes to rapid growth. Cherry salmon, in contrast, habitually spend their first one or 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.

**Restocking for chum salmon:** 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 seacoast, 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 in Honshu, for a total of 337 water systems.

**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 50 private run hatching facilities were established throughout Hokkaido. In 1951, with the passing of Japans 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. On Honshu, on the other hand, private operators on certain rivers in the northeast region have conducted artificial hatching and release of chum salmon since olden times.

Here, a system has existed whereby the national government provides financial support to the prefecture governments, which, in turn, provide the private run hatcheries with funds for facility maintenance and then buy up the fry produced by the operations.

**The salmon resources enchantment 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:

- Maintenance and expansion of facilities can lead directly to an increase in the number of eggs that can be processed.
- The fry can be fed and released in a healthy state at a strategically chosen time of the year.
- Seed eggs can be moved to other regions to increase the number of potential home rivers.

Fisheries Agency of Japan undertook a “Salmon Resource 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, 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 timings, 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 of the “2 billion released, 50 million returning” restocking system in effect 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 encourage consideration of the following three alternatives as the directions of future development.

- Salmon
- Promotion of pink salmon restocking operations

- Experimentation in restocking new species such as Coho salmon, sockeye salmon and Cherry salmon.

**The restocking cycle:** Japan Chum salmon return to the coasts and begin to ascend their mother river for spawning between the months of September and December when the coastal water temperature has dropped to between 3-19ºC and the river waters between 1-15ºC. Large-scale and small-scale set net fisheries that have been licensed by the fishery authorities catch coastal salmon. With the increase in returning salmon in recent years, some fishers have also begun license small-scale long line fisheries.

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

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.

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 8ºC. Since fertilized eggs are susceptible to damage when stocked, special care must be taken when introducing them to the tank. Within 9-11 h after fertilization, cell division in the nucleus begins and within 30 days eye development begins. Hatching begins 30 days after eye development (accumulated temperature: 480ºC). Accumulated temperature equals average water temperature multiplying number of days.

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

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 over land to the river mouth and reared for a while in seawater. 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.

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 to 3 months. Fry, which have been reared temporarily in seawater holding ponds are released at a time, deemed appropriate by the movement of the cold currents.

**An innovation in the sea:** The economists define an innovation" in the business world, the conditions for its development covered from the biological, technological, economic and social sectors to create result that grew geometrically.

**Biological:** This involves 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. Fry, which have descended a river, first live in river, mouths or inlets, which are under the influence of the river waters. They move on to the low-salinity waters along the coasts. During this period, the young become acclimated to the saltwater while feeding 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 disappear completely from the coastal environment. 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 under stocking 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.

**Technological:** This is 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 except the young enter the free-swimming stage is very high, resulting in a survival rate of only 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).

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 was:

- 7.8% for the river life stage from the egg to the fry.
- 5.4% for the spent in the coastal waters
- 56.4% during the stage spent in offshore ocean waters; and
- 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 and the seawater raising and release technique.

**Fresh water feeding and raising:** Alevin, which have risen after ingesting all of their yolk, are moved to a fresh water-raising pond, which they are fed for 30-60 days and released, into the river after reaching a body weight of 1-2 g.

**Seawater rearing and release:** Fry that have reached a weight of 0.6-1 g and acquired the capacity to acclimate to salt water are placed in a net-enclosed area in the surface layer of the sea, fed and reared until the coastal water temperature rises to 13ºC, at which time young fish which have reached a body weight of 4-10 g 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. 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 snowmelt. This is also the reason for plankton growth acceleration in the coastal waters. So, the two factors compliment each other. 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, fresh water feeding and rearing, and seawater rearing and release, are conducted mutually. And, because of such varied factors as river conditions, coastal water condition, 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.

**Economic:** This involves improving product quality and the early formation of catch able schools. Chum salmon reach sexual maturity and return to the coastal water for spawning purposes either at age-3 or age-5. In the case of Japanese Chum Salmon resources, they return to the eastern coasts from October into January. Coastal fishers catch these returning schools either with large-scale set net, small-scale set net or long line.

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 silver color 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 water marked 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 water mark being 20% less and fully-matured fish 50-60% less. Since salmon began to return and be caught in larger number, the product quality of the catches has taken on much more importance.

Two important characteristics of coastal salmon fisheries are:

- For any given region, the fishing season will come at a specific time of the year
- For different regions, or even within the same region, the percentages of silver-skinned/water marked fishes within the returning schools will be different depending on the timing of the return. This fact is explained in the following ways:
  - 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 trait passed on from parent to offspring for the preservation of the species, and, at the same time, gives the schools from different rivers their destructive 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, as 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.

◦ Chum salmon originating in Japan return to the coasts in the reverse direction along the same courses shown for leaving the coastal waters. 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 catchers" 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 same 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;

- Raising the product value of chum salmon caught in their area by increasing the percentage of silver-skinned fish, and
- 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.

**Social:** These are effects extending to the local society. Many 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 benefits are derived from 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 there is success 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.

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 carryout 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 group of fishers, other rallied to insisting on cleaning up the rivers to the point that salmon will return.

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 fishers 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 fishers but also society as a whole, then it is expected to see a new common consensus 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 recreational programs are surely serving to spread consciousness about environmental protection.

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 genetic 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.

## CONCLUSION

Wild sources of fish seeds, some cultivable fishes. carp breeding, relationship between the endocrine system and gonad development, function of the Central Nervous

System (CNS) in propagation, influence of ecological conditions on gonad development, artificial propagation of common carp, natural induced spawning, salmon culture and an innovation in the sea are important aspects of fish breeding, fish breeders, fish genetics and fish culturist need to understand in other to facilitate their productivity.

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