# Artificial Propagation of Chum Salmon (*Oncorhynchus keta)* in Korea

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The artificial propagation of salmon in Korea began in 1913. Since 1984, the survival rate and number of juvenile fish released has increased as a result of research and innovations in fish culture methods. As a result, the annual in-river harvest of salmon increased to about 35,000 fish in 1995. In 1996, 16 million juvenile chum salmon (*Oncorhynchus keta*) were released from Korean hatcheries. From 1984 to the present, chum salmon adults have been captured in the Namdae River, Yangyang, Kangwondo. Through this period the captured fish were examined to determine: age, length, weight, sex, and run timing. The study was conducted at the Yangyang Inland Fisheries Research Institute.

## *INTRODUCTION*

Chum salmon are found in streams of the North Pacific and the Arctic Ocean (Chyung *1977).* Though both chum and cherry salmon *(Oncorhynchus masou)* occur in Korean waters, chum salmon are the most common salmon homing to the east coast of Korea (Seong et al. 1992 and 1995). Salmon are considered an important marine resource in many countries adjoining the North Pacific. Fishery scientists in these countries have conducted research into large-scale hatchery production of these fish. The first salmon hatchery in Korea was built in Kowon, Hamkyungnamdo in 1913. Modern fish culture in Korea began when hatcheries were established on the Milyang River of Kyungsangnamdo and on the Osip River in Samchuk City in 1967. The Yangyang Inland Fisheries Research Institute was established in 1984. Hatchery-produced chum salmon are released in 12 streams on the east coast of Korea. Through the period from 1970 to 1995, the number of juvenile chum salmon released from hatchery programs increased from 8,000 to 16,000,000. Through this period the rate of survival of juvenile chum salmon at release to adult has ranged from 0.3% to 1.5% (Seong et al. 1992, 1994 and 1995).

Because of recent advances in fish culture technology in Korea, the number of chum salmon harvested in freshwater has increased from 410 in 1970 to 35,000 in 1995. An average total of 120,000 chum salmon have been harvested in Korean waters annually since 1990, when set nets were first deployed in marine waters to harvest these fish.

The following is a report on chum salmon characteristics, harvest and hatchery performance in the Namdae River, Yangyang, Kangwondo, which has the greatest return of chum salmon among the 12 streams where chum salmon are harvested. The work has been done in an effort to improve the survival rate of juveniles to adult and thereby expand the scale of the project.

## *MATERIALS AND METHODS*

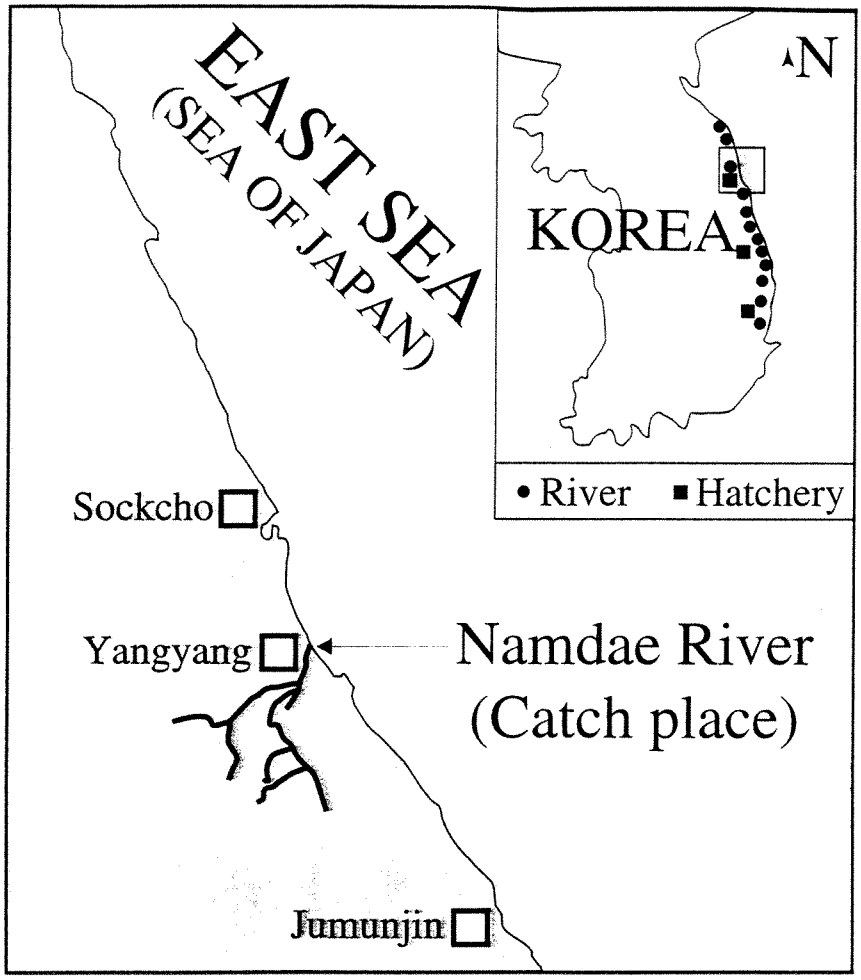
### *Adult Salmon Capture and Measurement*

Adult salmon for the study were captured in river-blocking nets deployed 1.5 km away from the mouth of Namdae River (Fig. 1) as well as in other rivers on the east coast of Korea. Adult chum salmon were captured from mid-September through mid-December of each year from 1984 through 1995. After capture, male and female fish were sorted and sacrificed with a blow to the head. We then determined the fork length (nearest 0.1 cm) and body weight (nearest 0.1 g) of each fish.

### *Assessment of Age*

Scales were collected from each fish to assess their age. In order to more easily determine age, the scales were magnified 20 times on a profile projector and the number of annuli counted.

**Fig. 1 A map showing the catch and releasing places in the river of Korea. Solid circles represent the locations of catching place and solid squares indicate hatchery place.**




*Egg Stripping and Fertilization*

One person held the fish while a second person opened the female by incision and removed the eggs. Conspicuously dead eggs were removed and discarded. Sperm from one or two males was added to the eggs from three or four females. The eggs and sperm were gently mixed prior to adding water. The fertilized eggs were then gently rinsed to remove excess sperm and any other contaminants. The eggs were then placed in an egg washing tank (55x80x63 cm) and exposed to gently flowing water for one hour, after which they are considered water hardened. At this point fertilized eggs are ready for transport to the hatchery. The eggs were removed from the water and placed in wooden boxes with about 10% additional pressure to reduce the impact during transport. The wooden boxes of eggs were then moved to the hatchery in the Yangyang Inland Fisheries Research Institute.

*Incubation and fry emergence*

When the eggs arrived at the hatchery they were disinfected with iodine (1/200 dilution) for 15 minutes and placed in incubators.

Adkins type incubators (295x35x30 cm), cylinder type (66x30 cm), and boxes (55x80x63 cm) are used for incubation. Incubators were loaded with 300,000 eggs for Adkins-type, 90,000 for cylinders and from 400,000 to 500,000 per box-type incubator.

Well water was used for incubation. Incubation water was first passed through high-pressure filters and then depurated with an ultraviolet running water sterilizer. A flow rate of from 20 to 30 liters per minute was used for each incubator. The eggs were bathed in malachite green (3 ppm) at three day intervals to control the growth of fungus on dead eggs (Leitritz and Lewis 1980). Since the fertilized eggs are easily killed by even moderate shock, malachite green was used until the eggs were eyed

and the dead eggs could be physically removed. Live eggs were sorted from the dead eggs with an automatic egg sorter when they had accumulated 420 C temperature units and were strongly eyed. Eggs that died after sorting were removed from the incubators using tweezers.

At about three days before hatching, the eyed eggs were disinfected with iodine and moved from incubators to the indoor pebbly breeding pond. The eggs were placed on hatch nets in a single or double layer at a density of approximately 15,000 eggs per $m^2$. After hatching sac fry swam down through the hatching net and into the spaces between the pebbles until later emergence. When hatching was complete, at from 480 to 520 C temperature units, the nets were removed. Water flow was maintained at about 1 to 2 centimeters per second through the pebbly pond.

*Rearing*

Sac fry finished absorbing their yolks at from 820 to 900 C temperature units. At this point the fry emerged and were free swimming and needed to be fed. Fry were initially started on feed with rainbow trout mash. As the fry grew the size of the mash and pellets was increased up to No. 2 pellets. We used the following schedule for change in feed size: fry below 0.3g were fed mash; from 0.3 to 0.5 g, No. 1 pellets; and, from 0.5 g until release at about 1 g, No. 2 pellets. The fry were fed a measured amount of feed, 3% to 5% of the average body weight per day (Hashimoto 1982-a).

The commercial feed used for rearing contained 2% fat. Feed oil was added to the commercial feed to increase the fat content to 10%. The intent of the added fat was to increase the growth rate. In addition, a variety of vitamins (2% to 3% of the feed) and antibiotics were added with the fat. The fingerlings were kept free of external parasites and bacteria by treating them with formalin.

Fry were fed about 10 times each day while they were on mash. Once they were on pellets, the number of feedings was reduced to 5 times each day. Generally rearing took place from January until the fish were released.

In order to assess growth, 40 fry were drawn at random, anesthetized with MS 222 (0.1 g per liter of water) and measured to determine fork length (nearest 0.1 cm) and weighed (nearest 0.1g).

*Transport and release*

The juveniles were released between mid-February and March as they reached about 1 g in weight. We released some juveniles into the Namdae River through the fishway linking the institute to the river, while others were transported to other rivers for release. All juveniles were judged in good condition before they were released.

*Determining survival from juveniles at release to returning adult*

The annual survival rate for returning adult salmon was determined by dividing the number of returning adults in any year by the number of juveniles released three years before.

## *RESULTS*

Juveniles were from 4.7 to 5.6 cm long and weighed from 0.6 to 1.2 g at release from mid-February through March. Various patterns of fin clipping were used to mark and later identify the fish (Table 1). The number of juveniles released has increased annually and a total of 147,270,000 fish have been released in the program through 1995. Survival from juvenile to returning adult has ranged from 0.3% to 1.5% (Fig. 2).

The return of adult chum salmon (Fig. 3) occurred from mid-September through mid-December with 0.1% returning in September, 36.2% in October, 62.5% in November and 1.2% in December. November was the peak period of upstream migration; 34.9% of the upstream movement took place in the first several days of the month. The sex ratio of the returning adults captured in the river was 42.7% female.

The length of adult salmon varied by age and sex. The fork length of males ranged from 42 to 88 cm and that of females from 46.5 to 83.8 cm. Most males measured from 55 to 60 cm; females from 65 to 70 cm. The weight of males ranged from 0.5 to 6.8 kg; female weight ranged from 0.7 to 5.2 kg.

Most of the returning adult fish were 3 and 4 years old; 64.5% of the males were 3 years old and 56.9% of the females were 4 years old. The 2 and 5-year-old salmon respectively represented only 1.25% and 0.4% of the adults. Average fork length and weight of male adults according to age (Fig. 4) was: 49.4 cm and 1.235 kg at 2 years; 58.1 cm and 1.952 kg at 3 years; 64.7 cm and 2.739 kg at 4 years; and, 73.1 and 3.981 kg at 5 years of age. The average fork length and weight of females at age was: 53.9 cm and 1.465 kg at 2 years; 60.1 cm and 2.240 kg at 3 years; 65.1 cm and 2.786 kg at 4 years; and, 68.8 cm and 3.381 kg at 5 years of age.

## *SUMMARY*

1. The length of juveniles at release (mid February through March) was from 4.7 to 5.6 cm and the

**Table 1. Release of marked chum salmon by year.**

| Year | Cutting of left ventral fin | Cutting of right ventral fin | Cutting of left ventral fin and adipose fin | Cutting of right ventral fin and adipose fin |
|---|---|---|---|---|
| Total | 210,000 | 210,000 | 150,000 | 200,000 |
| 1985 | 100,000 | 100,000 | | |
| 1986 | 50,000 | 50,000 | | |
| 1987 | 20,000 | 20,000 | | |
| 1988 | 20,000 | 20,000 | | |
| 1989 | 20,000 | 20,000 | | |
| 1990 | | | | 50,000 |
| 1991 | | | 50,000 | |
| 1992 | | | | 50,000 |
| 1993 | | | 50,000 | |
| 1994 | | | | 50,000 |
| 1995 | | | 50,000 | |
| 1996 | | | | 50,000 |

**Fig. 2 Numbers of juveniles released and annual changes in return rates of chum salmon in Korea, during 1985-1996.**

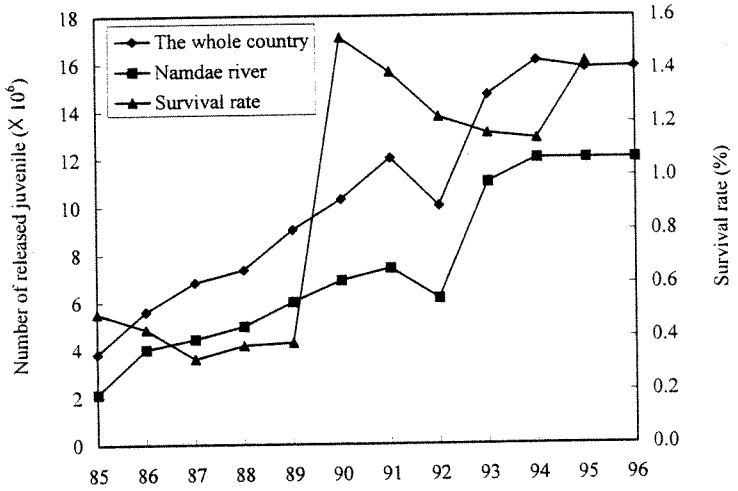



**Fig. 3 Numbers of adult chum salmon returning to Korea, during 1984 to 1995.**

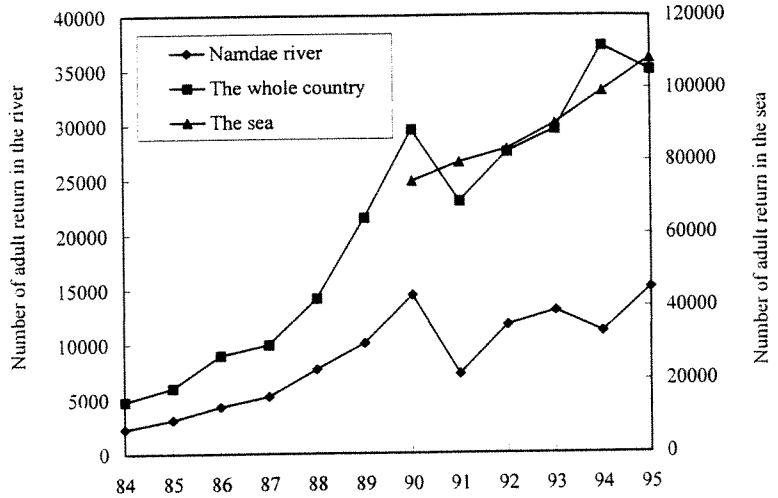
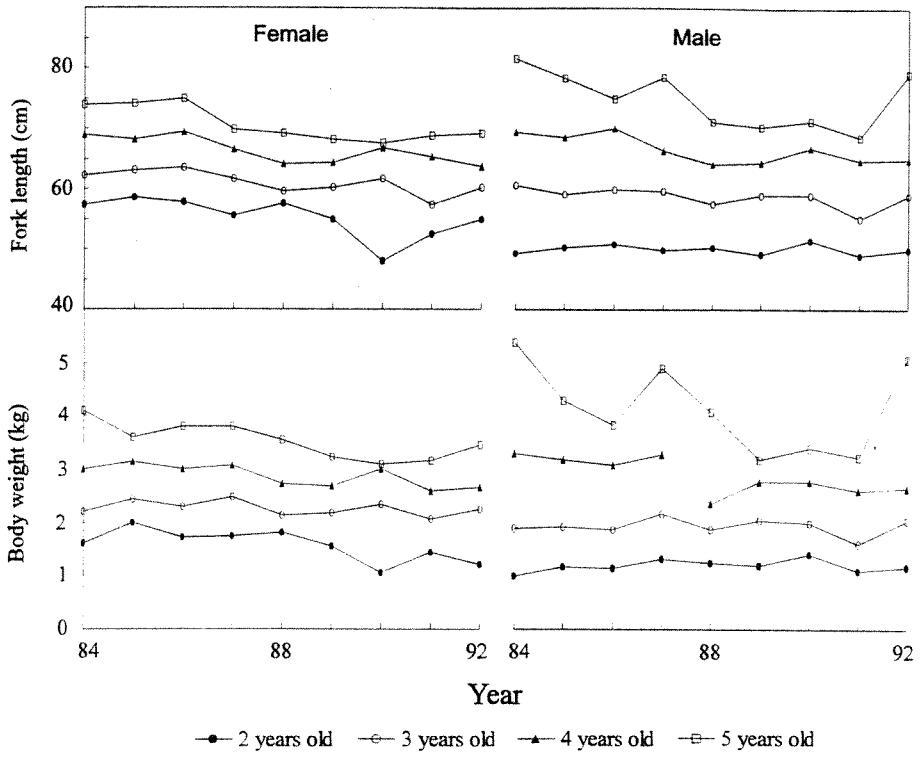


**Fig. 4 Annual changes of fork lengths and body weight of adult chum salmon returning to Namdae river in 1984-1992.**




weight of the same juveniles was from 0.6 to 1.2 g.

2. The survival rate for juvenile fish to adult ranged from 0.3% to 1.5%.
3. Adult upstream migration occurs from mid-September to mid-December with the peak of migration into freshwater in early November.
4. The run in freshwater was composed of 42.7% female fish.
5. Most adult females captured in the river were from 65 to 70 cm long (fork length) while most males were from 55 to 60 cm long (fork length).
6. The age of returning adults was from 2 to 5 years; females were predominantly 4 years old and males 3 years old.

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