

NATURAL REPRODUCTION OF GRASS CARP IN
THE TONE RIVER AND THEIR POND SPAWNING

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INTRODUCTION

Natural reproduction of grass carp (Ctenopharyngodon idella) in the Tone River was considered a rare case, because it was thought that this fish only reproduces within its own original habitat, Mainland China. The original spawning occurred 30 years ago. Since then natural reproduction has continued. During this period, however, the catch of grass carp has been remarkably decreased by environmental changes in the Tone River, especially the rapid change in the quantity and quality of the water, due to its increased use, and the development of swampy areas around the river. In this paper the recent condition of natural reproduction of the fish and the method of pond spawning being operated to supplement natural resources of the fish are reported.

NATURAL REPRODUCTION IN THE TONE RIVER

Transplantation and Natural Reproduction in the Tone River

Record of transplantation

Twice between the years of 1943 and 1945, a total of 23,000 fry, mainly grass carp, were introduced into Lake Kasumi, Lake Kita and the Tone River. The fry, from the Yang-tze River in Mainland China, were between 6 - 10 cm in length and 3 - 12 g in weight (Anon. 1958).

Catch in fingerlings

In September, 1948, 18 fingerling grass carp (8.8 - 25.2 cm) and 9 silver carp were caught in Lake Kasumi and Lake Kita (Tange 1949). Also, 14 fingerling grass carp and 3 silver carp were captured in the Watarase River which connects with the Tone River (Nakamura 1949). From the results of age-examination of these fishes, they were presumed to have naturally reproduced in the Tone River system. Moreover, during investigations between 1950 and 1952, additional grass carp fingerlings were seen along with bighead carp and black carp. It was confirmed that all these species were reproducing in the Tone River (Akiba 1955).

Collection of eggs and fingerlings and confirmation of the spawning ground

For the first time, in 1954, floating eggs and hatched fries were collected at Rokkaku, Inashiki county, in Ibaragi prefecture (Akiba 1955). In

1955, floating eggs were captured upstream at Otonemachi, Kitasaitama county, Saitama prefecture. Furthermore, in 1956, it was observed that adult grass carp and silver carp caught during spawning were spawning between Manume-machi, Osato county and Sukamura, Kitasaitama county, in Saitama prefecture (about 10 km) (Tsuchiya and Takahashi 1956) (Figure 1). Therefore, grass carp, silver carp, bighead carp and black carp transplanted from Mainland China, naturally spawned five years after their transplantation and have continued spawning constantly.

Spawning Habits and Conditions of Breeding

Spawning ground location

In the investigations during 1956-1965, the upper limit of the spawning ground was at Manume-machi, Osato county (165 km up-stream from the river mouth) and the downstream limit at Sakai-machi, Saruchima county in Ibaragi prefecture. The distance is approximately 25 km. Until 1960 the spawning ground was near the upstream part of the river between Manume-machi and Haneoi-city. The spawning site began shifting downstream due to the increase of gravel in that area. Moreover, the construction of the Otone Zeki Weir (154 km upstream from the river mouth), started in 1964, making it impossible for adult carps to migrate upstream from the Weir. The spawning site was confined to the area between Otone-machi and Sakai-machi after the completion of the Otone Zeki Weir in 1968, even though there are fishpaths in the Weir (Suzuki and Tsuchiya 1957 - 1966).

Environment at the spawning site

The river at the spawning area has a silt bottom, a width of 800 - 1000 m and a 400 - 600 m water flow width during normal flow. The depth is 1.5 - 3.0 m deep in the channel and 0.5 - 1.0 m deep for three-fourths of the water flow width. At the time of spawning, however, the water level rises 0.5 - 2.0 m from the usual level and water flow width increases. At Kirikashi, located in the spawning site, the discharge rate becomes 400 - 2300 m³/sec during the spawning period, whereas the annual average is 200 - 250 m³/sec. The flow velocity is 80 - 100 cm/sec in the channel during normal flow, but during increasing discharge, it becomes faster.

Migration for spawning

Adult carps start migrating from Lake Kasumi and Lake Kita, their original habitat, and the downstream area of the Tone and Edo River toward the spawning ground prior to the spawning season. Migration usually starts at the beginning of April. By the middle of May the first adult carp arrives at the spawning ground. Since 1963, a sluice gate, which is for the prevention of backflow and salt pollution was established on the Tokiwa River (the entrance of Lake Kasumi and Lake Kita). In 1970, the Kakozeki Weir was built on the main stream of the Tone River (18.5 km upstream of the river mouth), and it has been difficult for the adult carps to migrate. Thus, most of the adult fishes arrive at the spawning site immediately before the spawning starts. Immediately after spawning, the fishes start moving downstream and return to the downstream area after several days.

Period of spawning

According to investigations, from 1956 to 1965, the spawning period lasts three months from June to August, with the most active spawning taking place between the end of June and the middle of July. The spawning periods for the last five years (1973-1977) have been during nearly the same dates as shown in Figure 2. The annual average has been 3.3 times and large numbers of eggs were spawned each time. This does not include data for the times of little spawning activity.

Primary factors for spawning

The main factor initiating spawning is a rapid increase in water level caused by heavy rain in the upstream river. Spawning will begin under circumstances where the water level rises 0.5-2.0 m with muddiness and a water temperature reaching from 19-23 C. Even though the rising water with turbidity occurs due to rain and melted snow, the spawning activity does not take place without an increase in water temperature. The relationship between fluctuation of water level and spawning days from 1973 to 1977 is shown in Figure 2. Transparency of the water ranges between 0.2-0.4 m and pH between 6.9-7.1 during the spawning period.

Spawning activity

Four different kinds of carps, (grass carp, silver carp, bighead carp, and black carp) spawn simultaneously at the same spawning ground. Silver carp are observed more easily than the others since they spawn near the surface. It is difficult to observe the other three carps spawning, because their numbers are few and they tend to spawn in a somewhat deeper strata. All four species of adult carps are captured at the spawning ground and since all produce floating eggs, it is obvious that the four carps spawn simultaneously at the same spawning site. The duration of spawning lasts almost all day. After spawning the adult female fish drift downstream in a cyncopic state from exhaustion.

Drift of the eggs and hatched fries

The spawned and fertilized eggs soon start absorbing water and expand. After 1-1.5 hours they become semi-floating eggs 5.0-5.5 mm in diameter and drift downstream. As distribution of the eggs in the flow is almost uniform, they can be captured at all depths throughout the river. According to the 1964 investigation, the hatching location for the floating eggs was in the main stream of the Tone River near Sahara City, Chiba prefecture. The average drifting velocity of the eggs was 2.7 km/hr (Kasebayashi, Kafuku and Nakano 1966). The fry which hatched near this area slowly drifted downstream and were influenced by tide. They entered a swamp, rice fields and a channel where they grew to young fishes.

Large numbers of eggs also drifted into the Edo River which is connected with the Tone River at Sakai-machi, the downstream limit of the spawning ground. Near Noda City, Chiba prefecture, 22 km downstream from the junction of the Tone and Edo Rivers, large numbers of eggs are collected at present time and they are used for artificial reproduction. Because most of the

floating eggs in the Edo River are useless for natural reproduction, because the Edo River is shorter in length than the Tone River, the collection of the eggs is permitted in this river.

Also the number of drifting fry per one spawning is estimated to be 17×10^8 , but the number of spawning eggs deduced from density of the floating eggs is assumed to be 60×10^6 .

A Tendency and Prediction of the Carp Resources in the Tone River System

Decreasing grass carp numbers

Grass carp and silver carp catches by years in Lake Kasumi and Lake Kita are shown in Table 1. Since 1960, the catches of grass carp have decreased and they are rarely captured now.

Ratio change of grass carp fry to total numbers of all carp fry

The ratio of numbers of grass carp fry to total numbers of all carp fry obtained from the collection of the floating eggs and the number of the fry hatched from the floating eggs (1958-1964) is shown in Table 2. Since 1964, the ratio has been assumed to be 3% although an accurate investigation has not been made.

Factors assumed to diminish catch

The fry hatched in the main stream of the Tone River around Sahara City enter swamps, rice paddy fields and channels in the downstream area where they grow to adulthood. The environment of these rearing grounds have been changed rapidly by river improvement and land development since 1960. In other words, due to improvement of water banks, channels, sluice gates and reclamation of swampy areas, soft water weeds needed for growth of the fingerlings have decreased.

Decrease of water weeds due to use of chemical weed killers

Water weeds, needed for growth of grass carp, in the downstream areas and lakes decreased because of increased use of the weed killer, PCP, between 1960 and 1970. Water weeds in the main stream of the Tone River have increased since the use of PCP has been restricted.

Influence of the construction of dams and weirs

Since 1976, the dams constructed for the purpose of increasing water supply and flood control have been completed at seven different locations in the upstream area of the Tone River system and five more dams are under construction or planning. Moreover, the Otone Weir and Kako Weir were constructed in 1968 and 1970, respectively. Owing to the construction of these dams and weirs, the following influences have been observed:

- (1) The habitat for fingerlings and adult fishes in the river was decreased by less water discharge.
- (2) Since the Otone Weir was built, at the center of the original spawning ground, the spawning site moved downstream and was narrowed.
- (3) The Kakozeiki Weir made it difficult for the adult carps to migrate upstream to the spawning ground.

Influence of increased eutrophication in Lake Kasumi and Lake Kita

Around Lakes Kasumi and Kita, located near Tokyo, many houses and factories have been built recently. Their drainage discharge into the lakes increased eutrophication. An abnormal increase in phytoplankton caused by increased eutrophication has been constantly observed for the last several years. It followed that, in 1973 and 1974, many cultivated carps perished. The vast increase of phytoplankton in lakes lowers water transparency and decreases the growth of submerged plants. This is advantageous to silver carp which feed on phytoplankton, but it is thought to be one of the main reasons why herbivorous grass carp have remarkably decreased (Figure 3).

Future prediction

As mentioned above, absolute numbers of grass carp have been decreasing since 1960, and in the present situation it is doubtful their numbers will increase. The causes, as pointed out previously, are due to environmental changes. Therefore, if the irrigation plan for the Tone River, causing more and more water demand, is carried out, natural reproduction will not take place.

PRESENT SITUATION OF ARTIFICIAL REPRODUCTION SUCCESS BY POND SPAWNING

Background for the Necessity of Collecting Eggs by Artificial Spawning

For several years, since the spawning site in Saitama prefecture was discovered in 1956, the Saitama Prefecture Fisheries Experimental Station has carried out the production of eggs based on artificial mating of the adult carps caught at the spawning ground during spawning. By this means, however, it was difficult to capture adult fishes with mature eggs. Thus, since 1958, egg production has depended on the collection of floating eggs. Yet, as mentioned before, the proportion of grass carp floating eggs was low. It was therefore, recognized that collection of eggs from adult fishes directly is the only way to obtain sufficient grass carp eggs.

Progress of the Research on Artificial Spawning

Between the years 1960 and 1967, adult fishes migrating for spawning were captured near the spawning ground and were induced to spawn by injecting the pituitary of the grass carp, silver carp and so on. For the first several years adult fishes were held for spawning in the river after injections, but this did not produce good results due to injury during catch and cultivation.

Since 1964, adult fishes were anesthetized with MS-222 immediately after capture and were carried to an experimental pond where they were given a hormone injection. This method worked well and for the first time fry were obtained from artificial spawning. The method of collecting eggs from wild adult fishes under anesthesia continued until 1967.

Artificial spawning of mature fishes reared in a pond

The method of anesthetizing wild adult fishes, until 1967, was applied to cultivated mature fishes being reared since 1960, and succeeded in artificial spawning. Moreover, in the same year, albino grass carp were found among the fry which were artificially hatched from the eggs of the wild mature fish. In 1976, we were successful in developing albinos from these fry.

Conversion from the method of artificial fertilization to pond spawning

From 1964 to 1969, artificial fertilization techniques were applied. In this method the adult fishes kept in a pond after injection were ovulated after a certain time interval. Eggs were collected and fertilized utilizing the dry-leading method. As a result, however, this method injured the adult fishes very badly and caused stress. It was also difficult to calculate the proper spawning time. Because of these reasons, the method of pond spawning has been used since 1970.

Pond Spawning

Adult fish

Cultured adult fish, over five years old, 5-20 kg in weight are used. Adult fishes are given fresh weeds and feed with low protein, and their genital organs are allowed to develop. In looking from the rear, externally, fish with expanded bellies and swollen excretory openings are chosen. The ideal ratio of sexes is 1.0 to 1.5-2.0 in the spawning pond. After spawning the adult fish are given a mixture of feed added to fresh weeds, and they are allowed to recover for the next spawning.

Hormone injection

The pituitary of wild silver carp is most effective. Pituitary taken from mature fish obtained in spawning condition is dried with acetone and ground. Pituitaries taken from silver carp during the winter (January through March) are also effective. On usage, the ground pituitary is dissolved with 0.6% salt water and used as an injection liquid.

Quantity of injection and number of injections

Females were injected with 5-10 mg/kg of pituitary extract; males were given one half this amount. Injections are given inside the abdomen through the muscles at the base of the pectoral fin. The mature fish are kept in shallow water, therefore, they should be injected carefully and quickly without injury. Although injections can be given twice, once every six hours, a single injection is usually sufficient.

Spawning pond

A pond 100 - 250 m² in area and 1 - 1.5 m deep is sufficient though it varies with the size of the adult fish and number of fishes. After the injection, water is discharged into the pond to stimulate the mature fish. The discharge should be 50 - 100 m³/h for a pond 250 m² in area. Ten to twenty females and 15 to 30 males can be treated in a pond of this size.

After the first injection, spawning begins after 20 hr in 20 C water, 15 hr for 22 C water and 12 hr for 24 C water. Spawning usually lasts from 6 - 12 hr. Spawning activity can be observed many times from dawn until sunrise. Active spawning tends to take place during the night.

Egg collection

Floating eggs are collected in an egg collecting net (a fine meshed net) installed at the outlet manhole. Since the eggs immediately after spawning are small in size, they will be discharged after a certain time period. Because of this, during spawning, only surface water is discharged; during egg collection, bottom water is discharged.

Hatching

The hatching tank shown in Figure 4 is used to hatch the eggs. The egg membrane has a tendency to be easily broken as compared to the naturally spawned eggs. The results of grass carp spawning in ponds by hormone injection for the last several years is shown in Table 3.

Raising of the Fingerlings

For the period between egg yolk absorption and the beginning of normal swimming, fry should be allowed to drift in a rearing tank within the hatching tank. Because the fry tend to lie over one another in stationary water during this period, attention should be given on avoiding death from suffocation.

The fingerlings are transferred to either cagenets or rearing ponds where feeding begins. A rearing pond made of concrete with 30 - 100 m² area and 30 - 50 cm deep is used. Cagenets are effective in larger ponds. This net is 4 m² (2 x 2 m) and 1 m deep and is hung on bamboo poles. The number of net meshes at the beginning is more than 30 meshes. The mesh should be changed into a larger size as the fry grow. A solution of boiled egg-yolk and compound feed (powder) dissolved in water is sprayed over them. The fingerlings are raised with this feed for 2 - 3 weeks until they become 2.0 - 2.5 cm in length.

Raising of breeding fishes

Breeding fishes are raised in a large rearing pond of 10 - 20 acres and are fed on a compound powder feed and crumbling feed. During the rearing period, between July and October, they are sent as breeding fish at 5 - 20 cm in length on request.

Complications

The following problems are encountered during artificial spawning and fry culture:

- (1) Determination of the most effective age of mature fish for spawning.
- (2) The rearing environment and management of feeds to develop genital organs of mature fish.
- (3) The appropriate time for injection of brood fish.
- (4) Development of effective methods for collecting eggs in pond spawning.
- (5) Defining the price of pituitary glands and securing them.
- (6) Improvement of hatching methods.

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Table 1. Grass carp and silver carp catches in Lake Kasumi and Lake Kita.

Year	Silver Carp		Grass Carp	
	Catch	Ratio	Catch	Ratio
1956	4	21.1	15	78.9
1957	6	42.9	9	57.1
1958	2	22.2	7	77.8
1959	8	14.5	47	85.5
1960	6	50.0	6	50.0
1961	48	94.1	3	5.9
1962	64	100.0	0	0
1963	87	96.7	3	3.3
1964	128	93.4	9	6.6
1965	278	97.5	7	2.5
1966	491	99.2	5	0.8
1967	1,528	99.5	8	0.5
1968	549	99.8	1	0.2
1969	295	99.0	3	1.0
1970	304	100.0	0	0
1971	241	100.0	0	0
1972	66	98.5	1	1.5
1973	94	95.9	4	4.1
1974	119	95.2	6	4.8
1975	415	98.3	7	1.7

Table 2. Percent of grass carp fries collected from hatching.

	Year						
	1958	1959	1960	1961	1962	1963	1964
Percent	39.5	26.2	9.4	12.9	25.0*	4.9	34.3
						15.0*	19.0*

* indicates fries collected from natural river.

Table 3. Results of grass carp spawning in ponds by hormone injection.

Date	Female Parents		Pituitary Kind	Hormone Dose	Injection time	Starting time of spawning	Time required for spawning	Water temp. in pond	Number of eggs (volume)	Survival rate after 24 hrs.
	Heads	Avg. Body Weight								
6-24-49	18	12 kg	acetone dried	5 mg/kg	4 - 5:00 pm	7:00 am	15 h	19.8-21.5° C	4.98 million (311 l)	64.5%
	4	12 kg	fresh	5 glands/head						
6-23-50	15	13 kg	acetone dried	5 mg/kg	2:45 - 4:00 pm	5:00 am	14 h	20.0-21.5° C	2.85 million (155 l)	60.9%
	6	15 kg	fresh	36 - 226 mg/head						
6-21-51	10	15 kg	acetone dried	5 mg/kg	4:30 - 5:00 pm	10:00 am	17 h	18.2-19.8° C	3.70 million (200 l)	48.0%
	21	12 kg	acetone dried	6 mg/kg	3:30 - 4:00 pm	3:30 am	12 h	24.5-24.8° C	3.79 million (209 l)	63.1%

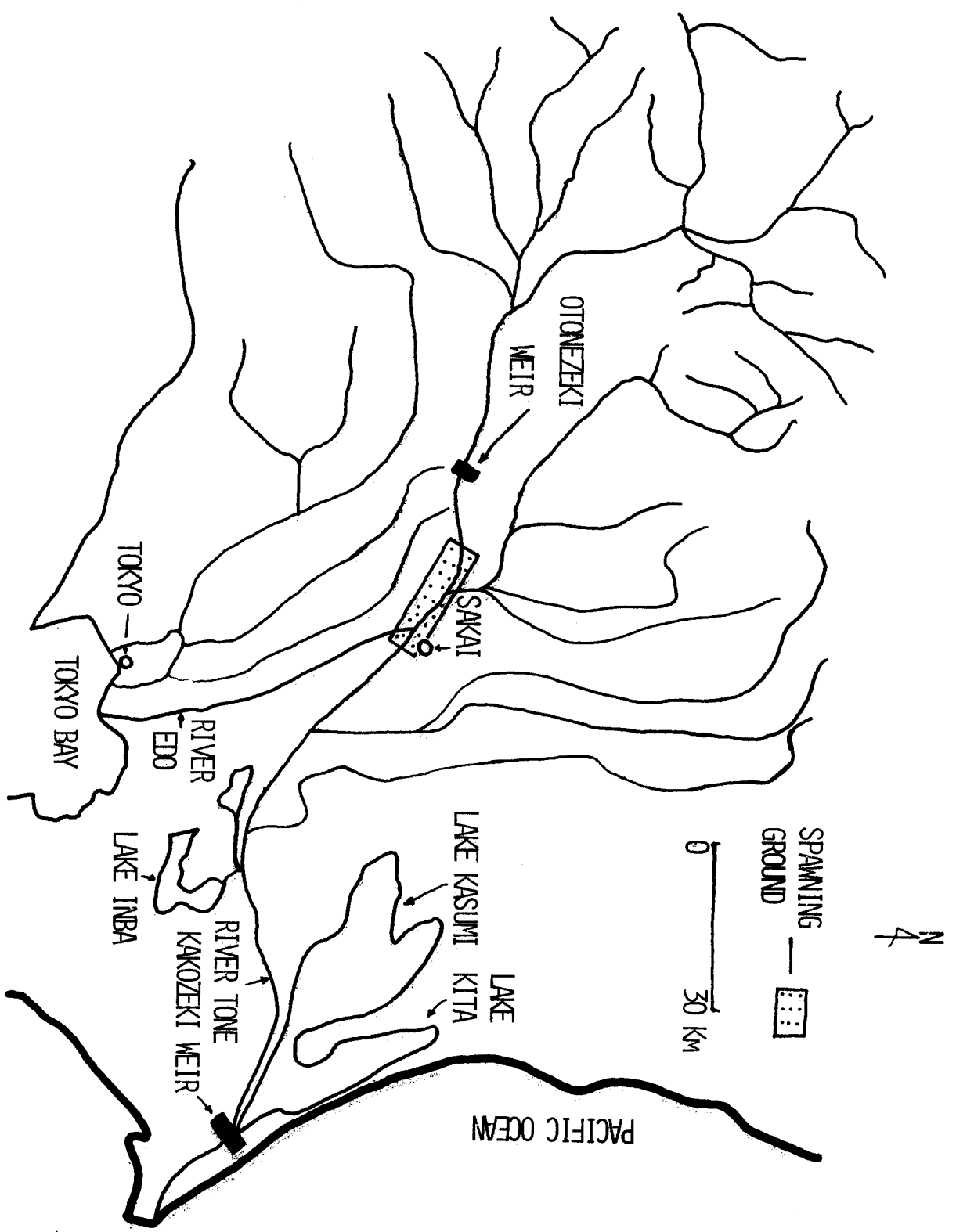


Figure 1. Natural spawning ground of grass carp in the Tone River.

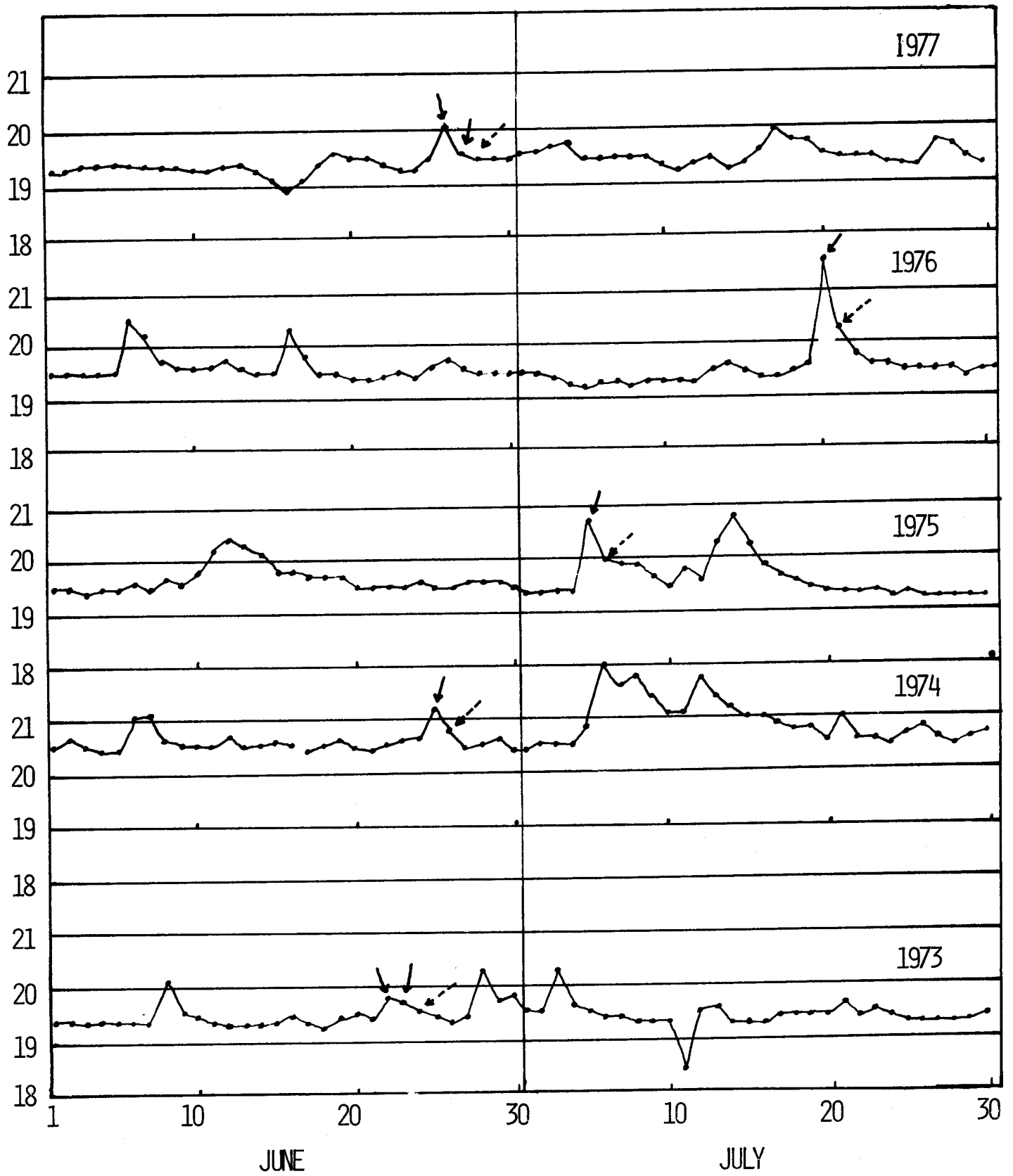


Figure 2. Water level fluctuation (meters) of the Tone River as observed at Suka, near Otonezekii Weir. Solid arrows represent spawning; dashed arrows represent egg collection.

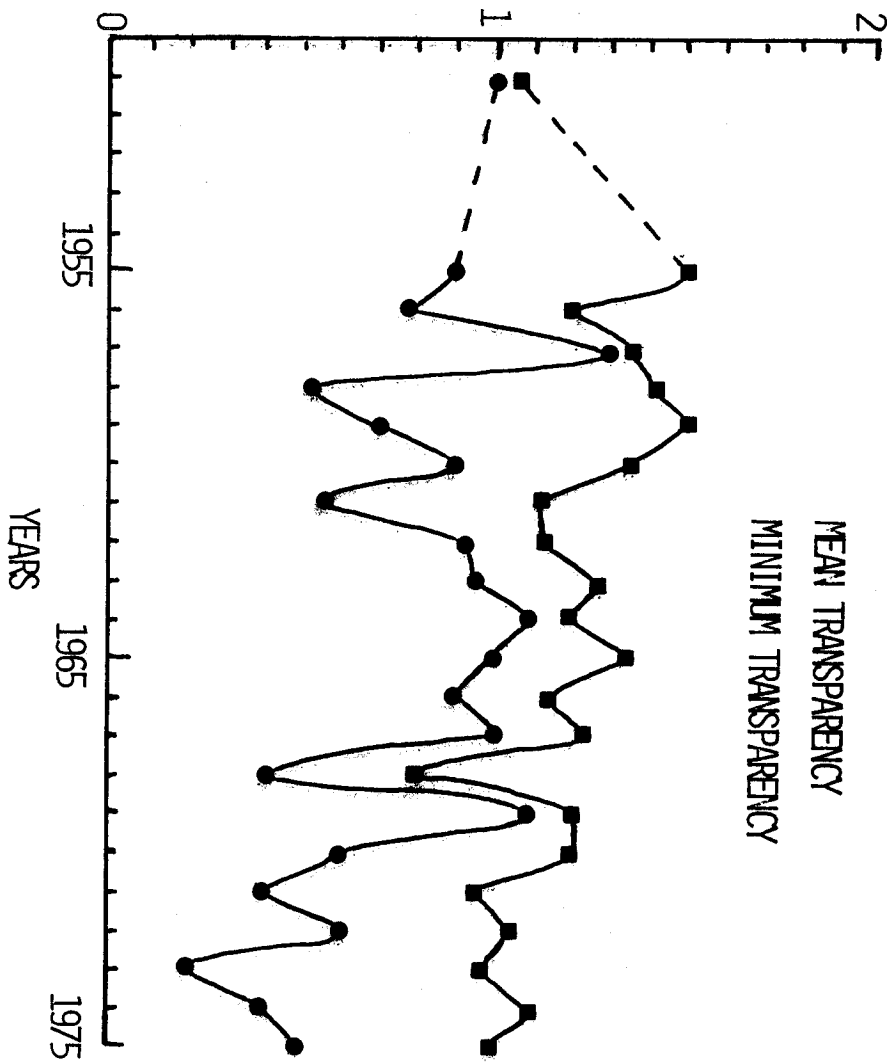


Figure 3. Annual transparency (meters) in Lake Kasumi (Idamada 1976).

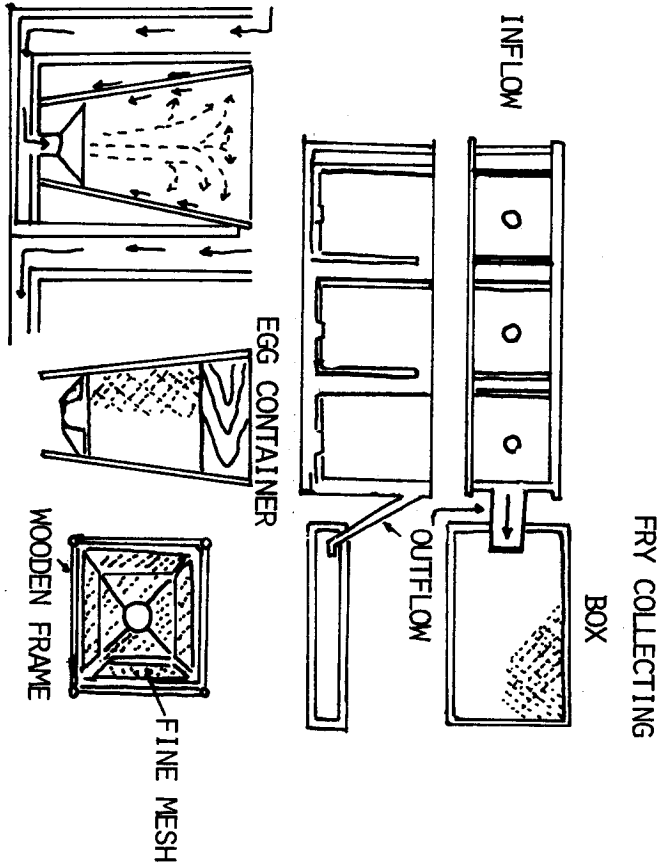


Figure 4. Hatching tank.