On the Complete Rearing of "Ayu," *Plecoglossus altivelis* TEMMINCK & SCHLEGEL. (Plate I)

Naomasa KATAOKA

(Nakayama Farm near Osaka, Japan.)

"Ayu," *Plecoglossus altivelis* T. et S. is one of the most delicious food-fish living in the clear rivers of Japan. Therefore, from olden times, the fish has indeed been a cherished dish of the Japanese people. But, as fry naturally hatched in the river always move to the deep sea to pass the winter, their state of living has been entirely unexplained because of the difficulties in the observation of their habits.

Since 1929, the author has continued the experiments for the artificial rearing of the fish in the pond, and finally in 1936, he obtained excellent results that almost equalled the natural breeding of the fish. In view of the remarkable degree of the growth of the fish in the artificial breeding, this report presents and discusses the results obtained during the period of 1936 to 1939.

I. DEVELOPMENT OF EGG.

Fertilization Process The outer membrane of the egg of this fish is very sticky. Soon as it is fertilized, the outer membrane of the egg is broken, thus enabling it to adhere very easily to any matter near by. There-

Fig. 1. Fertilization frame.

Fig. 2. Eggs stuck to the fibre of hemp-palm's bark.

fore, the eggs are stuck to a bark of the hemp palm set in the wooden frame (Figs. 1 and 2).

The method of artificial fertilization, adopted in this farm is the dry method. The ovulum, pressed out from the female, is placed on a leaf of the taro. Then the sperm, extracted from the male is poured on the ovulum, and mixed up thoroughly with feathers. After this process the mixture is carefully stuck on to the bark of the hemp palm, spread on a frame, which is immersed in water. The direct rays of the sun should be avoided when collecting the eggs. Thus, early morning or evening is considered to be more suitable for this work.

Wooden frames mentioned above are vertically inserted into the Atkin's incubator through which water is constantly running. When left in this condition at a temperature of 17° or 18°C., the eggs on the bark are hatched after a fortnight or so.

There were two collections of eggs, one collection having been eggs which were gathered from eight females and five males on September 23, 1936, and the other having been eggs, collected from seven females and fifteen males on October 3, 1937.

The length and weight of the parent fish are shown in Table 1.

As soon as these eggs were placed on the bark in the frame (36 cm. long by 27 cm. wide) they were put into the incubator.

Hatching The progress of the development of the egg in the water at 15°~20°C., is as follows:

- (1) First day (egg is fertilized)—Only the sign of the blastoderm can be discerned.
- (2) Second day—The blastoderm covers a part of the deutoplasma (yolk).
- (3) Third day—The form of the fish can be noticed.
- (4) Fourth day—Complete form of the body appears.

Table 1.

Parent fish	1936		1937	
	Length	Weight	Length	Weight
	cm.	g.	cm.	g.
Female	18.4	57.0	18.0	58.0
	16.9	39.0	16.0	29.5
	16.4	36.0	17.0	32.0
	18.2	53.0	15.4	25.0
	17.5	45.5	16.5	29.8
	17.6	75.5	17.0	31.5
	15.5	25.5	16.8	31.0
	16.2	28.0		
Male	14.5	27.5	15.2	24.0
	14.2	25.0	15.8	30.0
	16.7	35.1	15.6	37.0
	16.9	37.0	14.8	29.0
	17.1	34.5	15.9	25.0
			16.0	25.0
			16.5	27.0
			17.0	38.0
			16.4	35.0
			15.5	24.0
			17.1	35.0
			16.5	38.0
			16.8	37.0
			16.5	29.0
			14.8	28.0

(5) Fifth day—The body encircles the deutoplasma once. Finally the egg develops into an eyed egg.

(6) Sixth day—The pigments of the eye-ball become dark and the shape, distinct.

(7) Seventh day—The deutoplasma is contracted and the vertebrae and muscles are seen.

(8) Eighth day—The body elongates and the caudal fin begins to move.

(9) Ninth day—The body encircles the deutoplasma one and a half times and it begins to move around in the ovular (egg) membrane.

(10) Tenth day—The heart begins to beat.

(11) Eleventh day—A remarkable number of oil globules decreases.

(12) Twelfth day—The eye-ball glitters and the otocyst can be seen.

(13) Thirteenth day—The pigments appear from the head along the vertebrae, and muscle increases. The eye-lens become transparent with a golden blue glitter.

(14) Fourteenth day—The egg begins to hatch from the end of the caudal fin.

The body of the fry, just hatched, is transparent and is about 5 mm. in the length. It has a yolk-sac and several oil globules. The eye-ball retains several star shaped figures of pigment and the pigment grow along the alimentary canal. But since the fish is as yet weak, it is carried about by water currents.

Two days after the hatching of the egg, the fry has rapidly grown, and the pigment of the eye-ball has become blue black. Three days after the hatching, the yolk-sac practically has disappeared, and six days after the hatching, the yolk-sac has been slightly left, but when ten days have elapsed after the egg was hatched, the yolk-sac had been entirely consumed. However, the various steps in the development of the egg and of the fish are certainly dependent upon the temperature of the water.

The order of the development of the egg is shown in Figures 1~16 and Plate I in full detail.

II. EXPERIMENTAL INSTALLATIONS.

Rearing Pond

1. Rearing Pond for Fry.

This pond, made of concrete 10 cm. thick, has a dimension of 3.69 m. long, 1.86 m. wide, and 0.48 m. deep. Water is poured into it from two rubber hoses, 2 cm. in diameter; and water is drained by a cock, 4 cm. in diameter. Near the drainage is an elliptically shaped deeper part (75 cm. by 57 cm. by 10 cm. deep as shown in Figures 3 and 4). Fry are

Fig. 3. Rearing pond for fry.

apt to swim near this deeper part while fish one month after fertilization generally live two inches below the surface. But as they gradually grow, they seem to move to the deeper part, which appears to have considerably important duties. This pond is of a shape of an octagon which has a length 3.69 m. and a width 1.86 m. Two long opposite sides are 2.32 m. long and remaining six sides are of equal length 0.84 m. Six sides among the eight are fitted with electric water heaters as shown in Figure 6. The pond is so contrived as to use water from other ponds, rivers and wells after the water has been mixed up, thus helping the mechanical control of the temperature of the water, preventing the water from the contamination by the rain, and also guarding against the troubles in the lift pump.

Fig. 4. Sketch of rearing pond for fry.

2. Breeding Pond for Adult Fish. When taken care in the pond mentioned before until the later part of March, the fish are carried into the second pond also made of concrete. There are two hexagonal ponds with the dimension 20.2 m. long by 3.6 m. wide and with the area equal to 56 square metres. The depth of the pond where the water is poured in is 1.2 m. and where it is drained is 1.44 m., making a slow incline at the bottom of the pond. The two ponds lie side by side and are so designed that water may flow from one to the other (Figure 5).

Fig. 5. Sketch of rearing pond for adult fish.

Construction and Capacity of Electric Water Heater. The outline of the electric immersion heater which is used for controlling the water temperature of the pond is as follows:

(1) This apparatus is 66 cm. in length, and consists of the spirally shaped copper pipe (outside diameter 0.95 cm.) with the "Sheath wire heat element." It has its both ends soldered to a brass pipe to prevent the entry of water. The details of the construction are presented in Figure 6.

(2) A terminal box is fitted to one side of the pipe. Two wires, connected with the heat element are attached through the porcelain bushing to the outlet terminal. To this outlet terminal is joined one end of the cab-tire

Fig. 6. Sketch of electric water heater.

cord, thus connecting the electric source. The connection of the terminal and the cab-tire cord is covered with a rubber tube.

(3) Near the upper end of the pipe, there is an earth terminal and a ring which is used to hang the apparatus.

(4) The heat element and the pipe are carefully nickel-plated to prevent corrosion.

(5) The heating capacity is 500 W. (100 V.). In the operation of this apparatus, the important fact that must be kept in mind is to prevent electric leakage. Some years ago, for instance, through the accident of the leakage, fry were totally destroyed. In order to eliminate these unpleasant failures, there are the following requirements in the apparatus now used in this farm.

(a) Specially made apparatus is used instead of the articles on the market.

(b) Each apparatus is tested in the presence of the responsible person of the farm and only the articles that come up to the following standard are passed:

(i) Electric pressure test... 1,000 V. 5 min.

(ii) Insulation resistance test... over 100 megohms (measured in the water 50°C.).

(c) To safeguard from leakage, each apparatus is grounded.

(d) Insulation resistance test is occasionally carried out.

Quality of Water. As *plecoglossus altivelis* lives naturally in a clear river, careful attention must be paid to the pond water. The following data of the analysis of the natural river water which was sampled on March 7, 1933 from the Ina River near this farm were obtained (Table 2, Figures are expressed in milligram per litre of water):

As it is impossible in this farm to obtain a large quantity of the water similar to that of the Ina River, underground water is now substituted. But when the underground water is used, the substances injurious to the fish contained in the water have to be removed.

In this farm, there are two artesian wells, one of which is 43 m. deep which pours out per day 540~900 kl. of 16°C. water; and the other is 50 m. deep which produces per day 630 kl. of 17°C. water.

Table 2.

Sample water	Upper stream	Down stream
Water temp., °C.	4.7	5.0
Reaction	A little alkaline	A little alkaline
Odor and taste	Slight change	Normal
Turbidity	9.0	7.0
Color	10.0	7.0
Chlorine	12.0	11.0
Sulphuric acid	Very little	Very little
Nitrous acid	Hardly noticeable	Hardly noticeable
Nitric acid	Very little	Very little
Ammonia	Little	" "
Consumption of potassium permanganate	16.21	13.27
Solid matter	100.00	88.00
Iron	0.10	0.07
Hardness	1.28	1.28

The iron of the underground water is removed through aeration by a mechanical process and through the self purifying action by microorganisms. An iron removal concrete tower (5.5 m. high) is now fulfilling this purpose. The water pumped to the upper part of the plant, is aerated, making a jet in an aero-mix ball made of lead plate, and run through the spray tube and then emitted from the spray holes. Then the water is drawn through layers of smashed stones. In this process, the water is exposed thoroughly to air, causing the soluble iron to be oxidized to the insoluble ferrous oxide. Most of the ferrous oxide, therefore, is stuck to the surface of the smashed stones and a part of it is precipitated in the setting tank. The water in the setting tank is next led to the underground tank and passed through a sand filter which consists of sand bed and gravel bed (the thickness of the sand bed is 76 cm. and that of the gravel bed, 30 cm.). The purified water is kept for a while in a clear water reservoir and from there supplied to various places.

Because the entire operation takes about four hours, a double wooden roof is built on each tank to prevent the rise of the water temperature affected by the outdoor temperature.

The results of the analysis of the underground water after passing the plant are given in Table 3 (milligram per litre).

As Table 3 shows, the water is purified to such a degree that it may be safely used as drinking water. When this underground water is compared with the water of the Ina River, the iron content of the former is a little higher, but the consumption of potassium permanganate is much less.

The raw well-water of this farm has a constant temperature of 16.2°C. throughout the year, but when passing through the plant it rises to 17°C. in the summer and falls to 15°C. in the winter because of the effect of the outdoor temperature.

Table 3.

Sample water	Raw Well-water	Filtered water
Reaction	Slight alkaline	A little alkaline
Odor and taste	Unusual	Usual
Turbidity	36.0	Clear
Co'or	44.0	Colorless
Chlorine	32.0	30.0
Sulphuric acid	Very little	Very little
Nitrous acid	Trace	Hardly noticeable
Nitric acid	Very little	Very little
Ammonia	Trace	Hardly noticeable
Consumption of potassium permanganate	3.79	3.37
Solid matter	246.0	183.0
Hardness	2.50	1.60
Iron	5.40	0.21
Percentage of the iron removed	96.1	

III. STEPS IN BREEDING.

Atmospheric Temperature and Water Temperature. From September to December in 1936, the highest atmospheric temperature which was late in September was 27°C., and the lowest which was early and late in December was zero. During the same term the highest temperature of the water which was late in September, was 23.5°C., and the lowest which was towards the end of October, was 13.5°C., the average having been 19.3°C.

During the months of January to April in 1937, the highest atmospheric temperature which was about the middle of April, was 24.0°C., the lowest, which was at the beginning of January, was 5° below zero. The highest temperature of the water, which was late in April, was 19.5°C., and the lowest which was late in January, was 14.0°C., the average having been 16.0°C.

During the months of May to October, the highest atmospheric temperature, which was in the middle of August, was 34.0°C., and the lowest, which was early in May, was 5.0°C. The highest temperature of the water, which was early in August, was 27.0°C., and the lowest which was about the middle of May, was 16.5°C., the average having been 20.9°C.

During the months of October to December, the highest atmospheric temperature which was early in October, was 24.0°C., and the lowest which was late in December, was 4° below zero. The highest temperature of the water, which was early and late in October and about the middle of December was 21°C., and the lowest which was late in November, was 12°C., the average having been 17.9°C.

During the months of November, 1937 to April, 1938, the highest atmospheric temperature, which was late in April, was 22°C., and the lowest,

which was early and about the middle of February, was 0.5°C . below zero.

Table 4.

Period	Range of atm. temp. $^{\circ}\text{C}$.	Range of water temp.	Average water temp.	Period	Range of atm. temp. $^{\circ}\text{C}$.	Range of water temp.	Average water temp.
1936 :				1938 :			
Sept. 25~30	27.0~15.0	23.5~22.0	22.5	Apr. 1~10	15.0~-0.5	14.0~13.0	13.5
Oct. 1~10	25.0~10.0	23.0~19.0	21.0	11~20	16.0~2.0	13.5~11.0	12.1
11~20	24.5~7.0	21.5~17.0	18.7	21~30	22.0~4.5	16.5~11.5	13.4
21~31	21.0~3.0	20.0~13.5	16.9	May 1~10	18.9~13.6	15.0~14.2	14.6
Nov. 1~10	17.0~2.0	21.5~17.0	18.8	11~20	21.6~14.0	17.0~14.2	15.6
11~20	17.0~5.0	21.5~17.0	18.7	21~31	22.6~12.9	18.3~15.1	16.7
21~30	14.0~3.0	22.0~16.5	19.1	June 1~10	25.3~17.6	19.3~17.0	18.2
Dec. 1~10	12.5~0.0	22.0~17.0	18.7	11~20	23.5~17.6	18.2~16.9	17.6
11~20	14.5~1.0	23.5~16.0	20.0	21~30	24.5~17.8	19.2~17.2	18.2
21~31	11.0~0.0	22.2~16.0	18.8	July 1~10	24.8~20.7	19.4~18.0	18.7
1937 :				11~20	29.3~22.9	21.2~19.4	20.3
Jan. 1~10	13.7~-5.0	18.0~14.5	16.2	21~31	28.4~22.5	21.5~20.4	21.0
11~20	8.0~-0.2	18.5~14.5	16.5	Aug. 1~10	27.4~21.8	22.1~20.8	21.5
21~31	9.0~-0.1	18.5~14.0	16.2	11~20	29.1~23.1	20.2~21.3	20.7
Feb. 1~10	14.0~-0.1	19.0~15.0	17.3	21~31	27.4~21.8	22.1~20.8	21.5
11~20	12.0~-0.2	18.0~15.0	16.8	Sept. 1~10	29.0~20.0	21.5~20.0	20.7
21~28	17.0~2.0	17.0~15.5	16.3	11~20	28.0~18.0	21.5~17.5	19.0
Mar. 1~10	17.0~1.0	17.0~15.5	16.1	21~30	27.0~14.0	26.5~15.5	18.4
11~20	14.0~-0.2	17.5~15.5	16.6	Oct. 1~10	29.0~14.0	26.5~22.5	24.2
21~31	18.0~-0.1	18.5~16.0	17.2	11~20	21.0~7.0	23.0~18.0	20.5
Apr. 1~10	15.0~-0.1	18.7~16.5	17.6	21~31	20.0~5.0	20.0~16.0	17.5
11~20	24.0~3.0	19.0~17.0	18.3	Nov. 1~10	18.5~5.0	20.0~17.5	18.5
21~30	22.0~5.0	19.5~17.5	18.5	11~20	16.0~2.5	18.0~15.5	27.3
May 1~10	26.0~5.0	20.5~17.5	20.0	21~30	16.0~1.0	20.0~8.0	14.5
11~20	26.5~5.5	20.5~16.5	19.4	Dec. 1~10	12.0~4.0	18.0~5.0	11.0
21~31	23.0~10.0	22.5~17.0	19.6	11~20	12.0~-1.5	17.5~6.0	11.7
June 1~10	28.5~10.0	22.5~17.5	20.0	21~31	9.0~-2.0	18.5~14.5	16.3
11~20	27.0~10.0	22.5~18.0	20.2	1939 :			
21~30	27.0~15.0	22.5~18.0	19.9	Jan. 1~10	7.0~-3.0	18.0~15.0	16.2
July 1~10	32.0~16.0	24.5~18.5	21.6	11~20	6.0~-4.0	19.0~17.0	18.0
11~20	31.0~19.0	23.0~20.5	21.5	21~31	9.5~-2.5	18.5~16.5	17.8
21~31	32.5~21.5	22.0~26.0	23.4	Feb. 1~10	11.0~-1.0	17.5~15.5	16.5
Aug. 1~10	32.0~21.0	27.0~23.0	24.3	11~20	11.0~-1.0	17.0~16.5	16.8
11~20	34.0~21.0	24.0~21.0	21.3	21~28	12.0~-2.5	16.5~15.0	15.8
21~31	33.0~21.0	24.0~20.5	22.4	Mar. 1~10	12.0~-2.5	16.0~14.0	15.8
Sept. 1~10	31.0~19.0	23.0~20.0	22.0	11~20	14.0~-1.0	16.0~14.0	15.9
11~20	27.0~16.0	23.0~20.5	21.0	21~31	16.0~-1.5	15.0~14.0	14.5
21~30	27.0~14.0	21.0~19.5	20.3	Apr. 1~10	17.0~2.0	16.5~12.0	14.3
Oct. 1~10	24.0~10.0	21.0~18.5	20.0	11~20	20.0~8.0	16.0~14.5	16.0
11~20	21.0~13.5	19.5~18.8	19.2	21~30	22.0~11.0	17.5~13.5	15.6
21~31	19.0~7.5	21.0~19.0	19.8	May 1~10	26.0~3.5	17.5~15.0	16.7
Nov. 1~10	17.5~8.5	19.5~16.0	18.1	11~20	26.0~6.0	17.5~14.0	15.9
11~20	14.0~4.0	16.5~14.0	15.4	21~31	25.0~11.0	16.5~14.5	16.0
21~30	10.0~1.0	19.0~12.0	14.7	June 1~10	27.5~11.0	17.5~15.0	16.1
Dec. 1~10	8.0~-3.0	20.0~16.0	18.3	11~20	30.5~14.0	17.5~15.5	16.5
11~20	10.0~0.0	21.0~17.0	18.3	21~30	30.5~17.5	17.5~16.0	16.8
21~31	7.0~-4.0	19.0~16.0	18.0	July 1~10	31.5~18.0	18.5~16.0	17.3
1938 :				11~20	33.5~24.0	19.5~16.5	18.0
Jan. 1~10	4.0~-5.0	16.0~18.0	17.3	21~31	33.5~22.0	20.5~18.0	19.0
11~20	10.0~-4.0	19.0~15.5	16.8	Aug. 1~10	33.0~18.0	20.5~17.5	19.1
21~31	7.0~-4.0	18.0~15.0	16.6	11~20	32.5~18.0	21.5~19.5	20.5
Feb. 1~10	4.0~-5.0	17.0~4.0	16.3	21~31	32.0~22.0	21.0~19.5	20.3
11~20	9.0~-5.0	18.0~14.0	15.8	Sept. 1~10	34.0~19.0	21.0~20.0	20.5
21~28	4.0~-3.0	17.0~14.0	15.8	11~20	32.0~18.5	20.5~18.0	19.3
Mar. 1~10	17.0~-2.0	17.0~13.0	15.2	21~30	26.5~12.0	19.5~18.0	18.6
11~20	10.0~-3.0	16.0~14.5	15.2				
21~31	11.5~4.0	15.0~13.0	13.7				

The highest temperature of the water which was about in the middle of December, was 21°C., and the lowest, which was in the middle of April, was 11.0°C., the average having been 15.8°C.

During the months of May to August, the highest temperature which was about in the middle of July, was 29.3°C., and the lowest, which was late in May, was 12.9°C. The highest temperature of the water, which was early in August, was 22.1°C., and the lowest, which was early and about in the middle of April, was 14.2°C., the average having been 18.7°C.

During the months of September to December, the highest atmospheric temperature which was early in September and early in October, was 29.0°C., and the lowest, which was late in December, was 2° below zero. The highest temperature of the water, which was late in September and early in October, was 26.5°C., and the lowest which was early in December, was 5°C., the average having been 18.3°C.

During the months of January to April in 1939, the highest atmospheric temperature which was late in April, was 22°C., and the lowest, which was in the middle of January, was 4° below zero. The highest temperature of the water, which was in the middle of January, was 19°C., and the lowest which was early in April, was 12°C., the average having been 16.1°C.

During the months of May to September, the highest atmospheric temperature, which was early in September, was 34°C., and the lowest, which was early in May, was 3.5°C. The highest temperature of the water, which was about in the middle of August, was 21.5°C., and the lowest, which was about in the middle of May, was 14.0°C., the average having been 18.0°C.

The details are presented in Table 4.

Quantity of Water, pH Value and Oxygen Content of Water. Fresh water was supplied at the following rates of 1,000 c.c. per minute in October and November, 1937; 1,500 c.c. per minute in December; 3,000 c.c. per minute in January, 1938; 8,000 c.c. per minute in February; 15,000 c.c. per minute in March and April; 20,000 c.c. per minute from that time on.

The average of pH value was 7.3, having been 7.4~7.6 in summer and having fallen to 6.8~7.2 in winter. And the oxygen content of the pond water was 3.5~4.5 c.c. per litre.

Natural Food. To rear fry, natural food is an essential requirement, but in the period of fertilization and growth of the fish natural food is generally scanty. Efforts were made in searching for food in the nearby ponds and marshes. However, since it was already late in autumn and since fish had grown considerably, it caused a fast shortage of food. In this respect there is still room for further research on the part of the pisciculturists of Ayu-fish. Furthermore, the supply of natural food is greatly affected by the weather conditions. This fact is to some extent responsible for the

yearly production of the fish because of its dependence upon the supply of food. Fortunately, the author found near his farm two ideal ponds, named "Kamino Ike" and "Komo Ike." From these ponds he constantly gathered natural food in abundance in order to increase its supply. But since the supply of food ran low in the coldest season of the year, living planktons were occasionally brought from Lake Biwa.

Fig. 7. Fry fish (about Jan.)

Pisciculturists of Ayu-fish must previously choose a suitable place from where natural living food may easily be obtained. Kinds of natural foods in the two ponds named above are shown in Table 5.

Table 5.

Kind	Month							
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
<i>Eudorina elegans</i>	m							
<i>Ceratium</i> sp.	m							
<i>Pediastrum duplex</i>	m							
<i>Melosira varians</i>		m	m					
<i>Amphora ovalis</i>		m	m					
<i>Cymbella</i> sp.		m	m					
<i>Navicula</i> sp.		m	m					
<i>Synchaeta stylata</i>					m	m	m	
<i>Brachionus</i> sp.	m	m						
<i>Polyarthra platyptera</i>					m	m		
<i>Anuraea cochlearis</i>					m	m		
<i>Synechocystis</i> sp.					m	m		
<i>Asplanchna</i> sp.					m	m		
<i>Hydatina</i> sp.		m	m		m	m	m	
<i>Simocephalus vetulus</i>		m	m				m	m
<i>Cyclops paraspinus</i>		m	m				m	m
<i>Diaptomus</i> sp.				m	m			
<i>Bosmina longirostris</i>				m	m			
<i>Conochilus unicornis</i>				m	m			

m: much

Since it was necessary to replenish the natural vegetable food, as fry were growing larger, pebbles to which diatomaceae had stuck were transported from the Ina River, running before Tada Shrine in the vicinity of the fish-farm. These pebbles were gathered from the surface, the middle part and the base of the river, and the following change of the supply of diatomaceae, which had stuck to stones about the size of the first, was observed throughout the year (Table 6).

Table 6.

Kind	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
<i>Navicula baciliformis</i>	m	m	m	n					l	n	m	m
<i>N. rhynchocephala</i>	m			n						n	m	m
<i>N. sp.</i>				n							m	m
<i>Surirella</i> sp.	l	l	l							n	n	n
<i>Gomphonema</i> sp.	l			n						n	m	m
<i>Syndra ulna</i>	l			n	n						n	n
<i>Melosira varians</i>	n	n	n								n	n
<i>M. italica</i>			n	n	l			n	n	n	n	n
<i>Cocconeis lanceolata</i>	n									n	n	m
<i>C. gastroides</i>	n									n	n	n
<i>Asterionella gracillima</i>				n	n						n	n
<i>Denticula inflata</i>					l	l						
<i>Epithemia turgida</i>										n	n	n
<i>Amphora ovalis</i>	m											m

l: little, m: much, n: normal.

Artificial Food. There are two kinds of artificial food used in the rearing of Ayu the animal and vegetable food. Fishmeals, livers of horses and cattle, and powdered pupa of silkworm belong to the former. Potatoes, clovers, lettuce and carrots belong to the latter. The greatest quantity of potatoes is properly mixed with the fish-meals and livers, and then is added a little quantity of silkworm pupa, clovers, carrots and lettuce. To begin with, potatoes are boiled and mixed up thoroughly with other foods and ground together by the chopper connected to a motor power. Then in a dish it is lowered into the water at several places in the pond.

Artificial food is not given until about five months after the hatching. Although, at first, fish do not readily take the food, they will soon become used to it in two days or so when it is served again and

Fig. 8. *Diaptomus* sp. Fig. 9. *Bosmina longirostris*

Fig. 10. Contents of the stomach.

Fig. 11. Contents of the stomach.

again with patience.

A day's ration of this kind of food is one fifteenth or twentieth of the total weight of the fish in the pond. The day's ration is served three to five times according to the rate at which the food is consumed by the fish. Every day the fish are fed between 7.30 A.M. and 5 P.M.

IV. DEGREE OF GROWING.

The degree of the development of Ayu-fish hatched artificially in the pond keeps pace with that of the fish hatched naturally. If artificial hatching is properly carried out, the degree of the growth of the fish will exceed that of natural hatching. For example, the egg, fertilized in September, 1936, grew to a length of 4.7 cm. and to a weight of 0.5 gram about the middle of December; and it became 6.6 cm. long and weighed 2.05 grams early in March of the next year, having had surpassed already the size of the fish

Fig. 12. Artificially hatched Ayu-fish
Female (above)
Male (below, caught on Sept. 10, 1938,
length, 23.4 cm. weight, 122 grm.)

of Lake Biwa. It grew to a length of 11.5 cm., and to a weight of 12.0 grams early in May; and to a length of 16.0 cm., and to a weight of 39 grams in August. In August, when this fish was compared with the fish of the Ina River, it was found that the former fish, which had a perfect adult shape, was not in the least inferior to the latter.

The degree of the growth of the fish hatched in October, 1937, was much higher. It had already grown to a length of 4.8 cm., and to a weight of 0.5 gram in December; and in February of the following year, it had fully developed to a length of 6.0 cm. and to a weight of 1.78 grams; and in April, to a length of 11.6 cm. and to a weight of 15 grams. In April this fish was tremendously larger than the fish taken from Lake Biwa in the same season.

The detailed results appear in Table 7.

Table 7.

Date		Length	Height	Weight
1936 :		cm.	cm.	g.
Sept.	26 (Hatched)	0.60	0.05	—
Oct.	17	1.80	0.12	0.03
Nov.	15	2.90	0.25	0.10
Dec.	19	4.70	0.55	0.50
1937 :				
Jan.	4	5.00	0.60	0.80
Feb.	10	5.80	0.80	1.65
Mar.	12	6.60	0.90	2.05
Apr.	10	9.80	1.40	6.20
May	10	11.50	1.90	12.00
June	13	13.60	2.30	20.05
July	9	15.50	2.80	35.60
Aug.	12	16.00	2.90	39.20
Sept.	15	16.15	2.90	40.30
Oct.	20	16.15	2.90	38.70
1937 :				
Oct.	15 (Hatched)	0.60	0.05	—
Nov.	13	1.90	0.12	0.03
Dec.	21	4.80	0.56	0.52
1938 :				
Jan.	20	5.20	0.63	0.85
Feb.	21	6.00	0.93	1.78
Mar.	5	6.80	1.00	2.50
Apr.	28	11.60	2.10	15.20
May	4	12.00	2.20	16.20
June	11	14.80	2.50	31.50
July	13	17.50	2.90	42.50
Aug.	25	21.20	4.30	82.50
Sept.	10	23.40	4.40	122.00
1938 :				
Oct.	11 (Hatched)	0.60	—	—
Nov.	16	2.00	0.13	0.05
Dec.	18	4.70	0.56	0.50
1939 :				
Jan.	20	5.10	0.62	0.83
Feb.	14	5.90	0.84	1.70
Mar.	15	6.90	1.00	2.30
Apr.	10	11.00	1.50	11.00
May	11	13.80	2.30	21.70
June	12	16.20	3.30	39.00
June	28	17.60	3.70	43.00
July	19	20.30	4.20	79.00
Aug.	9	21.50	4.40	83.40
Sept.	10	23.40	4.40	122.00

following three points:

(1) In the artificial rearing of Ayu-fish the most suitable temperature of the water is 16°C. or so for the first month after the hatching, and 12°C. or so after that time.

(2) The depth of the water and the area of the pond have little importance.

(3) Natural food is of the great necessity for about one hundred days after the hatching of the eggs.

The size of the fish between the period of September and November, 1937, was smaller than that of the same period of the previous year, because the egg was fertilized nineteen days later in 1937. The rapid development, from that period 1937, depended upon the higher temperatures of the water.

V. CONCLUSION.

It has been considered very difficult to rear fry of Ayu-fish in the pond artificially. But the eggs, artificially fertilized in Nakayama Farm were placed in the concrete pond (5.8 sq.m., depth of the water 33 cm.), the temperature of the water was controlled and natural food was supplied for approximately one hundred days after the hatching.

The experiments carried out in this farm has shown worthwhile progressive steps, and the results of the tests can be summarized into the

Explanations of Figures of Plate I.

1. Immediately after fertilization.	9. 9 days after fertilization.	
2. 12 hours after fertilization.	10. 10 days " "	
3. 54 hours " "	11. 11 days " "	
4. 78 hours " "	12. 12 days " "	
5. 100 hours " "	13. 13 days " "	
6. 6 days " "	14. 14 days " "	(just hatched out)
7. 7 days " "	15. 17 days " "	
8. 8 days " "	16. 20 days " "	(7 days after hatching)