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THE BIOLOGY AND ARTIFICIAL PROPAGATION OF FARM FISHES

Chung Ling
with
Lee You Kwang, Chang Shung Tao,
Liu Chia Chao, and Chen Fun Cheong

AND

GRASS CARP AND SILVER CARP: PRODUCTION OF FRY

Minoru Tsuchiya

November 1980

CANADA

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IDRC published this volume, for use by aquaculturists involved in breeding Chinese carps, in response to numerous requests for suitable instructional manuals. Although more recent material, including FAO's "*Artificial Propagation of Chinese Carps*" by F.A. Pagan-Font and J. Zimet, has been produced since this translation was undertaken, it remains of interest because it describes the simplest early methods of artificial propagation.

THE BIOLOGY AND ARTIFICIAL PROPAGATION OF FARM FISHES[1]

Chung Ling

with

Lee You Kwang, Chang Shung Tao,

Liu Chia Chao, and Chen Fun Cheong

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FOREWORD

This book is a summary of the author's research on the artificial propagation of farm fish during the past ten years, especially the last five. The contents are divided into two major parts: the biology of farm fish and the techniques of artificial propagation. The first part provides a preliminary summary of the research done so far in China on the biology of farm fish, particularly on gonadal development. The second part describes in detail the five important aspects of artificial propagation of farm fish, namely, the rearing of brood fish, "estrualization", insemination, hatching, and the rearing of fish fry. To satisfy the requirements of fresh-water fish culture, special emphasis is given to practical experience in fish fry production.

As a reference book, this publication is suitable for fisheries workers, students and hydrobiologists.

TRANSLATOR'S ACKNOWLEDGMENTS

Since 1953, when fish culturists in China began intensive, systematic research on the artificial propagation of Chinese carp, a great deal of practical knowledge on farm fish has been accumulated. Great success has been achieved in the artificial breeding of Grass, Bighead, Silver and Mud Carp, in the improvement of egg hatching, and in the rearing of fry and fingerlings. In addition to these advances, selective breeding and hybridization of farm fish have been carried out.

Those interested in this field are indebted to Professor Chung Ling and his fellow researchers for their outstanding work and for writing a most valuable summary of efforts and progress in fish culture in China. It has been my good fortune to have had the opportunity to translate their Chinese text into English.

I am indeed grateful to Dr. W.H.L. Allsop and Dr. F.B. Davy of the International Development Research Centre (I.D.R.C.) in Canada for their kind encouragement and endeavours which resulted in sponsorship and financial support by the I.D.R.C. of this translation. I would also like to express deep appreciation to the I.D.R.C. for the confidence it has shown in me by entrusting me with the task of translating this important work. Throughout the translation I have tried my best to follow the original style of writing as well as the ways in which events and things are described.

To my friend Robert Bruce Sheeks, I extend my sincere thanks for his critical reading of my draft manuscript and for correcting linguistic errors.

I would like to extend in advance my sincere apologies to the authors for any misinterpretations and mistranslations of the Chinese text. All errors are entirely my fault, and suggested corrections will be received with appreciation.

The abbreviation "TN" indicates Translator's Note. I should emphasize that I am solely responsible for any errors in these notes.

NOTE ON UNITS OF MEASUREMENT

For the convenience of readers, the Chinese units of measurement used in this book are listed below together with their approximate metric equivalents:

1 mu	=	0.06134 ha or 1/16.3 ha
1 chin or catty	=	0.5 kg
1 tan or picul	=	50 kg
1 chih	=	35.81 cm
1 ts'un	=	1/10 chih = 3.581 cm

PREFACE

Pond fish culture originated in China. Records of pond fish culture in our country date back more than 3,000 years to the era of the Yin Dynasty (1400-1137 BC). By about 460 BC, in the era of the Warring Kingdoms, pond fish culture had developed to a high degree. Fan Li, a high ranking official of the Yueh Kingdom, summarized the practices then used in fish production in his "Treatise on Pisciculture", the earliest monograph on freshwater fish culture. He emphasized fish culture as one of the most economically profitable enterprises and wrote that "There are five methods of livelihood, aquaculture being the first".

The point made by Fan Li holds good even now. Long practical experience has proven that fish culture is the most profitable of all animal culture. Fish have a higher meat conversion rate; that is, given an equal amount of feeding material, fish yield more meat than livestock or poultry. For example, to increase one kg, Grass Carp need 20 kg of good quality green fodder while cattle need more than 40 kg. Fish also have a much higher rate of reproduction. Seed stocks are easily obtainable, and through artificial propagation each kg of body weight of Silver Carp can generally produce from 20,000 to 30,000 fingerlings. Further, fish have a higher growth rate. After one year of rearing, Bighead fingerlings 120 g in body weight can reach more than 3,000 g in body weight - a yearly growth rate of more than 20 times. There are also other advantages with fish culture, such as easy management, high ability to utilize biological foods and fertilizers in water, high production per unit, non-occupancy of agriculture land etc. Given these advantages, pond fish culture should be used in areas where conditions are suitable for its development as one effective means of solving the protein food supply for human consumption. It can be foreseen that, with the ever increasing development of fisheries and irrigation, our future generations will live in many "fish and rice lands", where drought and flood are unknown.

Besides being one of the first countries to develop fish culture, China has the highest absolute yield, or production per unit, from fish culture in the world. The reason for our high production is that apart from the accumulation over a long time of practical and rich experience by the working people, China has several species of farm fish of superior quality such as Lien Yü or Silver Carp (*Hypophthalmichthys molitrix*), Yung Yü or Bighead (*H. nobilis*), T'sao Yü or Grass Carp (*Ctenopharyngodon idellus*) and Ch'ing Yü or Snail Carp (*Mylopharyndodon aethips*). Because these farm fish each have different feeding habits and occupy different living strata, they can be fully utilized for polyculture, and thus used to achieve the aim of high production.

In the interior of our country there are many water areas suitable for fish culture, including wet paddy fields. In order to fulfill the needs of the people, the Party and the People's Government have vigorously used these water areas for freshwater fish culture. However, the amount of fish fry collected from the rivers is far from enough to satisfy the increasing yearly demands, so the crux of the problem of freshwater fish culture is how to ensure a mass supply of fish fry.

On the artificial control of fish propagation, which goes back as far as 2,400 years, our country's pioneer fish culturist, Fan Li, gave this description of controlling the spawning of carp (Common Carp) in ponds: "use a six-mu (TN: about 3/8 ha) pond constructed with nine islets, on which are planted plenty of water chestnuts and aquatic plants, and allow them to fold together several times. Stock with twenty egg-bearing carp of three chih (equivalent to today's 1.8 chih. TN: one chih = 35.81 cm) in length and four male carp three chin in length. Fill the pond with water in the early days of the Second Moon. Keep the pond water silent; the fish will spawn". This might be the earliest artificial method for controlling the spawning of fish on the basis of the habitual behaviour of the fish.

While our country was the first to practise the artificial propagation of fish, because of the prolonged rule and suppression of feudalism, imperialism and reactionaries, fish culture, like many other enterprises, was not as it deserved to be. Not until after 1921 did our ichthyologists who under difficult conditions carried out experiments on artificial insemination and hatching of captured mature Grass Carp, Silver Carp, Snail Carp, Bream (*Parabramis bramula*) and *Elopichthys bambusa* from the Chum River in Kwangsi Province, obtain good results.

After our country gained complete national independence and people's democracy and quickly advanced into socialist reconstruction, every enterprise achieved rapid development beyond all precedents. Research on the artificial propagation of fish was no exception. In 1951 the Central Fisheries Experimental Station at Hsiang River carried out artificial insemination and low-temperature treatment of eggs on Grass Carp and Silver Carp. Between 1951 and 1954 the Institute of Hydrobiology of Academia Sinica surveyed natural spawning grounds in the Yangtse drainage system and did artificial insemination, hatching and estrualization experiments on wild Bighead and Snail Carp. In 1958 the Amur River Institute of Fisheries Research conducted industrial-scale artificial insemination and hatching of Grass Carp and Silver Carp. All these programs achieved good results.

In 1953, owing to the rapid development of aquaculture in our country, the shortage of fish fry became more serious every day. Under such conditions, it would have been very difficult to solve the supply problem if we depended only on the collection of natural fish fry from rivers. We recognized that if we were to solve the problem of fish fry supply once and for all, we had to make farm fish mature in fish ponds and, through certain treatment, propagate in ponds. This was also the long-term goal of many fisheries workers and fish culturists both in this country and abroad. For example, between 1940-1949 the Japanese scientist Kawamoto Nobuyuki did research on the propagation of Grass Carp, but reached no definite conclusion. In 1953, under the encouragement and strong support of the Party, we decided to investigate the problem. We selected a small pond 3 mu in size. The pond water was subject to the tidal influence of the Pearl River, so the natural conditions of a river were imitated. The pond was used for rearing Silver Carp, Bighead and Grass Carp and for observing their gonadal development.

In 1955, after three years, all the Silver Carp and Bighead males were sexually mature; their spermatozoa were morphologically normal and active. The ovaries of females were well developed, reaching Stage IV of maturity. (Because of a shortage of feeding material for the Grass Carp, the observation of this species had to be stopped half-way through the experiment.)

In 1956 all the fish under experimentation had developed more satisfactorily (the testes reached Stage V, and the ovaries reached late Stage IV), proving that Silver Carp and Bighead could reach sexual maturity when kept in a pond. At that time we conducted simple ecological estrualization experiments and physiological estrualization using injections of Silver Carp and Common Carp pituitaries and human chorionic gonadotropin, but our results were negative. The negative results might have been due to the use of an insufficient dosage and to a lack of matching ecological conditions during that time.

In 1957 we changed our method of work. We investigated all natural spawning grounds in the Pearl River system. During the study, we were positive that the process of natural propagation of the farm fish was a reflex action initiated by comprehensive external stimulation. On the basis of this biological theory of reflex activities, we decided that if we could imitate the environment of a river spawning ground on a larger scale and use ecological conditions as a stimulant, spawning might be possible. This was difficult to achieve both conceptually and in practice, and at the same time it had little meaning in economic terms.

In 1958, under the good leadership of the Party, the encouragement of socialist reconstruction and the guidance of dialectic materialism, and with the benefit of the data gathered during our 1957 investigation and of the discoveries and work of our predecessors, we created a "combined physio-ecological method of estrualization". After many tests we eventually succeeded in achieving the breeding of Silver Carp and Bighead in a pond. The long-unsolved and most important problem of freshwater fish production was thus overcome.

In 1960, using the same principle and method as described above, we also solved the problem of pond propagation of Grass Carp. In the same year, Mud Carp (Cirrhina molitorella) were induced to spawn in a pond by the same method at the Nam Tao Commune (Kwangtung Province, Chungshan District). In 1961 at the Fushan Fisheries Research Institute in Kwangtung Province, Snail Carp were also induced to spawn by the same method. Since then, the fish fry production of the four most important farm fish of our country (Grass Carp, Silver Carp, Bighead and Snail Carp) and one of the important pond fish in Kwangtung (Mud Carp) has entered into a brand new phase, namely on-the-spot and planned production.

Not only has the success of breeding farm fish in ponds provided a fundamental and effective method of producing fish fry and a great saving in man-power and materials, it has also opened the way for rapidly domesticating farm fish and producing good quality breeding stock.

After the success of breeding farm fish in ponds the Central and Kwangtung Fisheries Authorities rapidly introduced the masses of fish farmers to experimental production of fish fry. In 1961, after several years of tireless trials, Kwangtung Province alone yielded more than 600 million Silver Carp, Bighead, Grass Carp and Mud Carp fry. This success made Kwangtung self-sufficient (and also gave it a surplus) in Silver Carp and Bighead fry production for the first time in its history. By 1963 more than 20 provinces in the country were each producing greater than 1,000 million fry. Meanwhile, through large-scale production and experimentation, the technique of artificial fish propagation was continually improved, and recognition among the masses of the potential benefits of the scientific method was furthered. These results have demonstrated the wisdom of the Party's leadership, the superiority of the socialist system, the advantages in applying the scientific method to productive enterprises, and the benefit of combining theory and practice to achieve endless vitality.

The contents of this book are divided into two main parts. The first part covers the biology of Silver Carp, Bighead and Grass Carp; the second part discusses artificial propagation techniques. The former part deals mainly with analytical summaries on the growth and development of Silver Carp, Bighead and Grass Carp; the latter part deals mainly with discussions on the rearing of brood fish. Because these aspects are currently at the centre of the problems of production which require quick solutions, they are the important theoretical foundation for freshwater fish culture at present and in the future.

Because all of the major species of farm fish in our country (Silver Carp, Bighead and Grass Carp) belong to the Carp family, they have in many biological aspects, especially in artificial propagation, great similarities and only minor differences. For this reason, we put these species together in our description and general recapitulation. Because Mud Carp is one of the four major farm fish in Kwangtung Province, we provide a preliminary summary of this species and include it in this book in order to satisfy the needs of producers. Although a trial with Snail Carp was carried out successfully in 1961, sufficient data are lacking, and so a summary is not yet prepared.

To provide the most assistance to readers, especially to comrades directly engaged in fish production, who wish to understand the problems of artificial propagation of farm fish from all angles and to use the data in this book for comparison in analyzing certain problems they would encounter, we have used data and references from other research institutions and production units as well as our own data accumulated over many years. The author wishes to extend his sincere thanks to those organizations.

Our work, from beginning to end, has progressed smoothly due to the strong support and encouragement of Shu Kwong Choi, Director of the Fisheries Bureau, Kwangtung Province, Lei Vui Min and Wu Pak Wen, Deputy Directors of the Southsea Fisheries Research Institute.

Mr. Fui Fung Nian read the draft and gave many valuable comments, for which the author wishes to extend his heartfelt thanks. During the writing and compilation of this book, Comrade Zhao Zhi Chu prepared the section on the "rearing of fry"; Comrade She Liu Chong prepared the section on the "feeding habits of Silver Carp and Bighead"; and Comrades Auyong Hai, Liau Kok Chong, Wong Nin Fook, Wong Mau Fong, Lee Huan Lin and Chong Chee Chew helped in arranging the data. The author wishes to express his gratitude to all of them.

CHAPTER I

BIOLOGY OF SILVER CARP, BIGHEAD AND GRASS CARP

Morphology, Classification and Geographical Distribution

Morphology

Silver Carp (Lien Yü): Dorsal: 3, 7. Anal: 3, 12-13. Pectoral: 1, 17. Ventral: 1, 8. Lateral line scales: 110-123, 26/17.

Based on two mature specimens. Body length: 620 and 675 mm. Average body length/height ratio: 3.53. Head: 4.34. Caudal peduncle length: 6.15. Head length/eye ratio: 7.64. Snout: 3.92. Pectoral fin length: 2.13.

Body: compressed, slightly high. Abdomen: keeled from isthmus to anus. Head: medium large. Eyes: comparatively small, situated below the horizontal axis of body. Interorbital space: wide and humped. Mouth: large and oblique, lower jaw slightly pointing upward. Gill membrane: unconnected to isthmus. Gill rakers: fused into a sponge-like membraneous sieve. No spine on dorsal fin, origin of dorsal posterior at base of ventrals. Pectoral fin: near or just reaching ventrals. Scales: small. Anterior of lateral line: slightly high with steeper gradient. Air-bladder: large and divided into two sections, with the almost spherical anterior section bigger than the long pear-shaped posterior section. Pharyngeal teeth: 4/4, upper surface flat, with fine lines and small grooves.

Colour of body: dorsal, greyish green; sides, yellowish white; ventral, silver white.

Bighead (Yung Yü): Dorsal: 3, 7. Anal: 3, 11-14. Pectoral: 1, 17. Ventral: 1, 8. Lateral line scales: 95-105, 25/15.

Based on two mature specimens. Body length: 650 and 750 mm. Average body length/height ratio: 4.12. Head: 3.37. Caudal peduncle length: 4.96. Head length/eye ratio: 9.43. Snout: 3.07. Pectoral fin length: 1.37. Ventral fin length: 1.89. Dorsal fin length: 2.03. Anal fin length: 2.4.

Body: compressed, slightly high. Abdomen: keeled only between bases of ventral fins and anus. Head: very large. Eyes: small, situated below the horizontal axis of body. Interorbital space: wide and humped. Mouth: large and oblique, lower jaw slightly pointing upward. Gill membrane: unconnected to isthmus. Gill rakers: small, dense and separated. No spine on dorsal fin, origin of dorsal posterior at base of ventrals. Pectoral fin: large, reaching 1/3-2/5 of ventral fins. Scales: small. Anterior of lateral line curved, posterior part comparatively straight. Air-bladder: large and divided in two sections, anterior section spherical, posterior section long and pear-shaped. Pharyngeal teeth: 4/4, upper surface flat and smooth, no fine lines or grooves.

Colour of body: upper surface of head and body, dark green; sides, scattered with black dots; ventral surface, greyish yellow.

Figure 1 shows the variations in the morphological characteristics of Silver Carp and Bighead in relation to age.

From Figure 1 we can see that, with the exception of snout length, the ratio of many characteristics decreases as body length increases. The development of the intestine shows that when the body length is below 400 mm the relative length of the intestine increases with the body length, but after that it decreases relatively slowly.

Grass Carp (Wan Yü) or T'sao Yü): Dorsal: 3, 7. Anal: 3, 8. Pectoral: 2, 14. Ventral: 1, 8. Lateral line scales: 39-45, 6-7/9-11.

Based on data from 4 specimens. Body length: 580-690 mm. Average body length/height ratio: 4.3. Head: 4.29. Caudal peduncle length: 6.2. Head length/eye ratio: 7.17. Dorsal: 1.57. Anal: 2.0.

Body shape: almost round. Head: depressed. Interorbital space: wide and humped. Snout: slightly blunted. Eyes: relatively small. Mouth: positioned low, lower jaw shorter. Gill membrane: connected to isthmus. Dorsal: short, no spine, origin of dorsal opposite to ventral. Lateral line: rather straight. Scales: slightly large. Pharyngeal teeth: comb-like with gaps on two sides, 2 rows, 5, 2-3 or 2-4. Air-bladder: large, divided into two sections.

Colour of body: light green; back, darker; abdomen, greyish white. Dorsal and pectoral fins, dark green; other fins, a lighter colour.

The variations in the morphological characteristics of Grass Carp in relation to age are shown in Table 1 (relation to body length expressed in terms of %).

Table 1 shows that with Grass Carp the ratio of head length, eye diameter, dorsal fin and anal fin generally decrease as the body length increases, but that of caudal peduncle length and length of intestine increase.

Classification

Silver Carp, Bighead and Grass Carp belong in taxonomy to Class Osteichthyes, Order Cypriniformes, Family Cyprinidae. Silver Carp and Bighead both belong to the sub-family Hypophthalmichthyinae, Genus *Hypophthalmichthys*, while Grass Carp belong to sub-family Leuciscinae, Genus *Ctenopharyngodon*.

Silver Carp, Bighead and Grass Carp are typical groups of fish found in the plains. They are the most common high quality farm fish in our country, especially Grass Carp and Silver Carp, which are vegetable eaters and thus feed on the first link in the food chain. They have a high meat/food conversion ratio and therefore give high economic returns.

Through a long period of evolution in different climatic zones, Silver Carp in the Nandu River of the tropical island of Hainan have evolved into a new species. This species ought to be named *Hypophthalmichthys hermandi*, which is the name given to the same species found in the Red River in Vietnam by the French ichthyologist Sauvage in 1884. The Silver Carp in the Nandu River differ in many ways from the Silver Carp found in the Pearl River and Yangtse drainage systems in terms of morphology, structure and other characteristics, as shown in Table 2 and Figure 2.

As can be seen from Table 2 and Figure 2, the Silver Carp of the Nandu River (popularly named Nan Yü or Southern Fish) and the Silver Carp of the Pearl River have marked differences in their characteristics. The former has larger scales, fewer lateral line scales and a relatively robust body that has a higher fat content and is fleshy. These characteristics should make the Silver Carp of the Nandu River a superior fish for purposes of cultivation, because all of them meet the economic requirements of fish cultivation.

Geographical Distribution

Silver Carp and Grass Carp are widely distributed in our country, from the Amur River in the north to the Pearl River system in the south. Bighead are not commonly found in areas north of the Yellow River.

Because Bighead and especially Silver Carp and Grass Carp are highly adaptable, in the last several decades small groups of them have started, through transplantation and domestication, to propagate naturally in rivers in Japan, Southeast Asia and Eastern Europe.

Owing to the special propagation characteristics of Silver Carp, Bighead and Grass Carp, their natural distribution has certain relationships with a river's geographical position, length, hydrological features and aquatic food supply. Initially, the rivers where they live are generally more than 200 km long, or have many lakes along their courses. This is easily understandable, for only in such an environment are the pelagic fertilized eggs and fry of these fish guaranteed of not being washed into the sea and thus of maintaining the survival of their species. (Generally, from the moment an egg is fertilized to the time it develops into a fry with power to swim freely takes about 70 hours, while the average current speed during spawning is about 3 km per hour.) However, the tributaries of large rivers and dams are not affected by the above limits. For example, only Mud Carp schools have been found up to now to be able to propagate themselves naturally in the Mokyong River in Kwangtung Province due to its short length (see Table 3). This might be due to the relatively short time needed for Mud Carp embryo to develop (14-15 hours) and to the fish's ability to swim upstream to shallow waters for spawning.

The distribution and population density of Silver Carp, Bighead and Grass Carp are similar to those of other animals in that they are largely limited by the natural food supply. For example, in the North River in Kwangtung Province the fry of Silver Carp and Bighead have not been discovered. Their absence might be due to an insufficient amount of plankton in the river, which would make it impossible for the fish to propagate.

Furthermore, farm fish live in those rivers where summer flooding that fits in with their spawning habits occurs. We can expand the distribution of fish and increase the fish stocks in water bodies by transplantation and domestication in selected rivers, lakes, dams or reservoirs that satisfy the conditions required by the fish.

Feeding Habits

The Feeding Habits of Silver Carp and Bighead

The most important food for Silver Carp and Bighead in nature is plankton. Silver Carp feed mainly on phytoplankton; in its juvenile stage its feeding pattern varies slightly more than that of the Bighead. Bighead feed mainly on zooplankton throughout their life. The difference in the feeding habits of Silver Carp and Bighead is due to their filtering organ, i.e., the structural differences in their gill rakers.

Silver Carp Fry: Newly hatched fry depend on the yolk-sac nutrition. After 3 days their body length is 7-8 mm. Their intestine is straight and its length comes to 50-60% of the body length. By this time the yolk-sac has been absorbed, and the fry begin to feed on zooplankton such as Rotifera, Cladocera, Copepoda and their unsegmented larvae.

After another 4-5 days rearing in a pond, the body length of the fry reaches 11-13 mm, both sides of the gill rakers begin forming serrations, and the anterior part of the intestine becomes coiled. At this stage its major food remains zooplankton, but the fry have started to feed on some phytoplankton (an amount very small in proportion to their total diet). The phytoplankton eaten consist of *Navicula*, *Synedra*, *Fragilaria*, *Cryptomonas* and *Peridinium*.

After 8-12 days, the body length is 18-23 mm, lateral serratures on the gill rakers have developed, and a thin, ear-shaped membrane has started to grow between the gill rakers. On places where the thin membrane grows, the spaces between gill rakers are covered. At this stage the gill rakers are rapidly developing into a "sieve-like" food-filtering organ. The intestine is also rapidly lengthening to 90-110% of body length, and has more coils. At this time, the amount of phytoplankton in the fry's diet increases conspicuously and greatly exceeds the zooplankton.

The external appearance and structure of gill rakers of a juvenile fish 30 mm body length are basically similar to those of an adult fish. Juvenile fish feed mainly on phytoplankton and eat very little zooplankton.

Although Silver Carp feed mainly on plankton, under artificial cultivation conditions, artificial feeds, such as rice bran, wheat meal, finely crushed and water-softened ground-nut cake and soy-bean milk, should be added, especially when the fish are densely stocked and when natural foods are in short supply.

Bighead Fry: The fry of Bighead feed mainly on zooplankton supplemented by phytoplankton. This is the basic difference between Bighead and Silver Carp fry. The reason is that although the gill rakers of Bighead fry have grown serrations, they are still separated and have fairly wide interspaces. Therefore, phytoplankton of smaller sizes are not easily trapped.

Apart from eating natural foods, Bighead fry also feed on artificial foods such as rice bran, wheat meal and fine ground-nut cake. They feed on the same groups of planktons as Silver Carp, which were listed above.

Adult Silver Carp and Bighead: The natural foods for adult Silver Carp and Bighead are plankton. However, Silver Carp feed mainly on phytoplankton supplemented by some zooplankton, while Bighead feed mainly on zooplankton supplemented by some phytoplankton. According to the results of research by Ni Da Shu and Chiang Shee Tse, the ratio of zooplankton to phytoplankton in the food composition of Bighead is as follows: maximum, 5,75:1; minimum, 1:15.55; average, 1:4.5. On average, then, when a Bighead eats one zooplankton, it will also eat about 4½ phytoplanktons simultaneously. In the food composition of Silver Carp, the ratio of phytoplankton to zooplankton is as follows: maximum, 10,214:1; minimum, 11.7:1; average, 248:1. On average, Silver Carp eat 248 phytoplanktons to every one zooplankton. (Zooplankton are much bigger than phytoplankton; on average, they are 10 times bigger than phytoplankton.) Therefore, the major food for Bighead is zooplankton, and for Silver Carp it is phytoplankton.

The most common groups of zooplankton that Silver Carp and Bighead eat are Rotifera, Cladocera and Copepoda. They are all easily digestible. The shells of protozoa, apart from some shelled species such as Difflugia, Arcella, Tintinnidium and Tintinnopsis are commonly found in the gut-contents of the fish. However, other species of protozoa commonly found in water in considerable quantities, such as Amoeba, Heliozoa and various species of Ciliata, are very difficult to find in the gut contents. Probably they have been quickly digested. The eggs of Rotifers and Copepods are indigestible.

A list of the phytoplanktons which are "easily digestible" and "difficult-to-digest" follows:

Easily digestible phytoplanktons:

Chrysophyta (golden brown algae): Mallomonas and Dinobryon.

Xanthophyta (yellow-green algae): Tribonema, Chlorobotrys, Ophiocytium and Botryococcus.

Pyrrophyta (dinoflagelloids): Cryptomonas, Ceratium and Peridinium.

Bacillariophyta (diatoms): Melosira, Cyclotella, Synedra, Fragilaria, Navicula, Cacconeis, Cymbella, Gomphonema, Surirella, Gyrosigma, Tabellaria, Asterionella, Pinnularia, Frustulia and Caloneis (In view of their great variety and quantity, the Diatoms are the most important among the easily digestible group).

The major difficult-to-digest phytoplanktons:

Cyanophyta (blue-green algae): Microcystis, Anabaena, Merismopedia, Coelosphaerium and Aphanocapsa.

Euglenophyta (euglenoids): Euglena, Phacus, Trachelomonas and Lepocinclis.

Chlorophyta (grass-green algae): Chlamydomonas, Eudorina, Pandorina, Pleodorina, Volvox, Asterococcus, Gloeocystis, Sphaerocystis, Pediastrum, Crucigenia, Coelastrum, Oocystis, Scenedesmus, Tetraedron, Closterium, Costmariu and Staurastrum.

Silver Carp and Bighead lack the enzyme needed to digest plant fibre, chitin, pectin and gelatin. Therefore, they have difficulty in digesting, or are unable to digest, many phytoplanktons belonging to Phyla Cyanophyta, Chlorophyta and Euglenophyta, the eggs of zooplankton, and chitinous shells.

The Feeding Habits of Grass Carp

Grass Carp feed mainly on mixtures of plant material. They are voracious eaters.

Fry 2-3 days old depend on their yolk-sac for nutrition. Newly hatched fry 3 days old with a body about 7 mm and a very short intestine

55-60% as long as their body begin to feed on Rotifers, unsegmented larvae and some lower algae.

Fry with a body 20-30 mm long and an intestine 110-130% as long as their body begin to feed on young and tender higher plants. The proportion of Rotifers in their diet gradually decreases, but planktonic crustaceans continue to hold an important position in their diet.

Juvenile fish with a body 30-100 mm long, an intestine 180-220% as long as their body, and pharyngeal teeth which are suitable for crushing higher plants are fairly well developed. Their feeding habit begins to change to young, tender aquatic plants, especially the Wolffia arrhiza (TN: a species of floating weed) and young leaves and tender shoots of various other plants.

Grass Carp over 100 mm in body length have a fully developed intestine 230-260% as long as their body, and their pharyngeal teeth have also developed a step further into the serrature formation stage. At this stage, Grass Carp feed on all kinds of land and aquatic plants.

Although wild Grass Carp feed mainly on grass in nature, they can digest only the cells of soft grass or of crushed plant matter. The reason is their digestive system. Grass Carp lack cellulase (enzyme) in their intestine, liver and pancreas, and the length of their intestine is comparatively much shorter than that of other herbivorous fish such as Silver Carp (Grass Carp have an intestine 2.3-3 times as long as their body, while Silver Carp have an intestine 6 times as long as their body).

Under culture conditions, Grass Carp feed on a wide variety of foods. When they are 30-60 mm in body length, the most suitable foods are Wolffia, rice bran and wheat meal. When their body length is 70-150 mm, Grass Carp can be given, apart from the aforementioned feeds, Lemna (duck weed), Azolla (water fern) and various kinds of soft grasses. After they exceed 150 mm in body length, they can be fed aquatic and land plants, various kinds of oil seed cakes, soy-sauce residue, winery residue, sweet potato, potato, rice seedlings, leaves and stems of vegetables and melons, animal feeds such as silk-worm pupae, snails, clams, worms, earth-worms and animal entrails, and dung and night-soil.

Growth

In order to relate production practice to textual description, the following notes on the development of farm fish are divided, in accordance with the fish culture traditions of Kwangtung, into three stages: the fry stage, the fingerling stage and the adult stage.

The fry stage commences when the fish are hatched and lasts until their body length reaches about 20 mm, at which time they are 10-15 days old. The fingerling stage lasts from the end of the fry stage until the fish grow to 200-300 mm in body length. The adult stage covers the period from the end of the fingerling stage until the fish reach, or nearly reach, sexual maturity.

The special growth characteristics of farm fish are greatly influenced by environmental factors, such as nutritition, water temperature and water quality. Rates of growth will vary greatly under different nutritional conditions. The following data are based on the results of observations of general fish culture practice in Kwangtung.

Special Characteristics of Growth of Fry

Growth Rate: As shown in Table 4, the relative growth rate of Silver Carp and Bighead is the highest in the fry stage; it is the highest peak of growth in their life cycle. Within 10 days of being reared in a pond, their body weight increases several times, 6 times for Silver Carp and 5 times for Bighead. On average, it increases more than 100% every 2 days. But the rate of increase in their absolute weight is just the opposite. The average daily increase in weight is only between 0.01-0.02 g. As for the rate of growth of body length, the Bighead's average daily increase in length is 0.71 mm; the Silver Carp's is 1.2 mm.

Comparison of Growth: For fry less than 6 days old, Grass Carp grow the fastest, Bighead are second, and Silver Carp are the slowest. When they are over 6 days old, the growth rates are reversed (see Figure 3).

Relationship between Growth and Stocking Density: As shown in Table 5, under the same conditions of cultural management, at stocking rates of 100,000 fish per mu and 200,000 fish per mu, the difference in weight increase is 2-3 times, and in body length it is about 30%. There is, however, very little difference in growth between stocking rates of 100,000 fish per mu and 135,000 fish per mu. These results suggest that if the Kwangtung "Big Grass" fry rearing method is used, the suitable stocking density should be 100,000-150,000 fish per mu.

Special Characteristics of Growth of Fingerlings

Growth Rate: Compared with the above stage, the relative growth rate of the fish in the fingerling stage have conspicuously decreased, as shown in Table 6. Within a rearing period of 100 days, the body weight increases 9-10 times; it increases about 100% every 10 days, a rate 5-6 times slower than that in the fry stage. However, there is remarkable progress in the rate of increase in absolute weight. The average increase in weight in Silver Carp is 4.19 g; in Bighead, 6.3 g; and in Grass Carp, 6.2 g - rates 200-600 times greater than that in the fry stage. On the growth of body length in this stage, average day-night (24 hours) increase rates are as follows: Silver Carp, 0.27 mm; Bighead, 0.32 mm; and Grass Carp, 0.29 mm. The body length of Silver Carp increases 22.5% over its length in the previous stage; that of Bighead increases 45%.

Comparison of Growth: As shown in Table 6, at the age of 20-30 days, Bighead and Grass Carp grow the fastest; Silver Carp, the slowest. At the age of 60 days and above, Bighead grow the fastest; Grass Carp, second; and Silver Carp, slowest.

The Relationship Between Growth and Stocking Density: If the gradual thinning culture method is adopted (at a body weight within 20 g the stocking density would be 10,000 per mu, and at a body weight of 20-100 g the stocking density would be 5,000 per mu), it generally takes only 50-60 days to complete the rearing stage of the fingerlings. If the fingerlings are cultured to the adult fish stage, they will reach commercial size (1-1.5 kg) in the same year. If the traditional dense culture method of Kwangtung is used (i.e., a constant stocking density of 10,000 per mu is maintained), it will take about 150 days to reach the required standard of fingerlings.

Special Characteristics of Growth Before and After Sexual Maturity

Between the years 1953-1958, we used a pond 3 mu in size which had a constant inflow of fresh water, and had the fertility of the pond water suitably adjusted in order to provide a stable ecological environment. Under such stable conditions, we observed the growth of Silver Carp and Bighead. The results of these observations are listed briefly in Table 7.

As can be seen in Table 7 and Figures 4 and 5, under suitable culture conditions, the increase in body length of Silver Carp and Bighead in their adult stage is fastest during the second year, when it reaches a peak. Silver Carp increase 35 cm, which is 55.5% of their body length at 5 years old. Bighead increase 46 cm, an increase of 59.1%. The rate of increase in body length becomes slower in the third year and still slower in the fourth.

The increase in body weight is greatest in the third year when the fish reach sexual maturity. Silver Carp gain 2,780 g and Bighead gain 7,450 g, which are 43.4% and 63.1%, respectively, of their body weight at 5 years old. Thereafter, the rate of increase in body weight drops rapidly, coming almost to a standstill.

However, the relative changes in plumpness of the fish follow the rules of growth development. For instance, in a 2-year old fish, the plumpness is very low, generally between 1.3-1.7, due to superior growth in body length. In a 3-year old fish, which is beginning to mature sexually, the plumpness rises rapidly to between 2.34-2.57, owing to its rapid gain in body weight. The plumpness of Silver Carp and Bighead in relation to their body length is shown in Figure 6.

At present, the pond fish culture system in our country has generally adopted a 2-year rearing cycle (one year for culture of fingerlings and one year for adult fish). In light of the aforesaid growth rates of farm fish, it seems that the present 2-year culture system does not make the maximum use of the special characteristics of fish development. As mentioned above, the reason is that 2-year old fish are generally low in plumpness. If a 3-year cycle were adopted (or if the rapid rearing method is adopted in the fry stage, the 2-year cycle can be used), a higher quality fish product could be achieved, because the greatest increase in body weight for farm fish occurs at the age of 3 years (see Figure 7). In the same period, the nutritive value of the fish also increases proportionately with age, until it reaches a peak before sexual maturity, as shown in Table 8.

Comparison of Growth of Male and Female Fish

Comparisons of growth of 4-year old males and females of Silver Carp and Bighead under the same pond rearing conditions are shown in Table 9.

As can be seen from Table 9, with 4-year old Silver Carp, the body length of males is slightly longer than that of the females. The body weight of the females is slightly heavier than that of the males, probably because the females were bearing eggs. (This experiment was conducted during Silver Carp's reproductive season.)

Bighead develop in a way opposite to that of Silver Carp. The females always grow faster in terms of both body length and body weight.

Under the same rearing conditions, the body weight of a 4-year old Bighead is about twice that of a Silver Carp, and its body length is also about 20% longer.

Gonadal Development

Maturing Age and Minimum Size at Maturity

The speed of growth of farm fish is similar to that of other cold-blooded animals, and to a very large extent is controlled by the temperature and thermal energy of the environment. For this reason, the farm fish of our country mature earlier in the south than in the north. Apart from that, in regions of the same latitude, unevenness in their age of sexual maturity would also occur due to differences in rearing conditions or in types of water.

In the sub-tropical and tropical zones of southern China, owing to the abundance of thermal energy, farm fish mature early. For instance, in Kwangsi Silver Carp generally reach maturity at the age of 2 full years. In Kwangtung it generally takes 3 full years, although a few fish can reach maturity in 2 full years. Bighead in Kwangtung generally attain maturity in 4 full years, but we have found in our experiments that if the fish are cultured in favourable conditions, they can attain sexual maturity in 3 full years. Grass Carp of Kwangtung take, on average, 5 full years to attain maturity. If the rearing conditions are favourable, some fish can mature in 4 years.

In central China, according to determinations made by Chekiang Freshwater Fisheries Research Institute, Silver Carp generally mature at the age of 3 full years and Bighead at 5 full years. In Hunan, the Hunan Normal Institute determined that Grass Carp mature at the age of 6 full years, though some fish mature at 5 full years.

In northern China, according to a report of the Hopei Animal Husbandry and Fisheries Bureau, 4-year old Silver Carp (2-4 kg) have reached maturity and can be used effectively for artificial propagation.

In north-eastern China, according to preliminary determinations made by the Fisheries Research Institute of Heilungchiang Province, the maturing age for Silver Carp is 5 to 6 years; for Bighead, 6 to 7 years; and for Grass Carp, 6 to 7 years.

With farm fish, sexual maturity is related more to age and less to body length and weight; however, a well grown fish generally attains sexual maturity earlier (see Table 10).

The males generally mature one year earlier than the females; some mature even two years earlier. We have discovered a one-year old male Silver Carp with a body weighing only 240 g which has distinguishable secondary characters and which produces normal sperm.

Up until now, the smallest mature Silver Carp in Kwangtung was found in Sinfui District at the Tongha Commune, Shaktao Brigade. The fish had a body length of 200 mm, weighed 325 g, and after artificial estrualization laid about 30,000 eggs, several thousand of which were successfully hatched into fry. The smallest mature Bighead in Kwangtung came from our Research Institute. It weighed 2,700 g and could reproduce normally.

The brood fish of Silver Carp and Bighead used for artificial propagation in Kwangsi are smaller. Generally, the Silver Carp weigh 1-2 kg; the Bighead, 2.5-4 kg.

Sexual Cycle

The sexual cycles of Silver Carp, Bighead and Grass Carp in Kwangtung are basically the same. In the case of Silver Carp, the stages of sexual maturity are to a large extent within Stage II or III in winter, and the maturity coefficient* is generally 1-4%. In some large individuals or in those reared under favourable conditions, the gonads may reach Stage III-IV, the maturity coefficient being 5-7%. We have never found any individuals with their ovaries at complete or nearly complete Stage IV maturity during winter. During spring of the next year, in February and March, when the water temperature has risen to 15-20°C, the gonads begin to develop into the late stage of the rapid growing stage in 35-50 days. Generally, when the ovaries complete Stage IV, the maturity coefficient may reach 14-22%. The gonads of Grass Carp generally develop slightly earlier, in late March to early April, when the water temperature reaches about 20°C. Some individuals can be used for artificial propagation, but the results will not be entirely satisfactory. Estrualization of Silver Carp and Bighead in early spring has proved less effective. The reason, apart from the influence of water temperature, is that the majority of the ova in the gonads have not reached late Stage IV of maturity. The proper time for artificial propagation in southern China is after the second half of April, especially in May and June, when the water temperature has settled at above 24°C. After September the majority of those ovaries that have not ovulated show distinctive

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*Maturity coefficient (%) = $\frac{\text{weight of gonads}}{\text{body weight (whole)}} \times 100$

degeneration. The maturity coefficient generally drops rapidly to 3-10%, but some late maturing individuals are still capable of being effectively artificially estrualized. It looks as if the degeneration of ova is gradual and proceeds by lots; to complete the whole process of absorption, it would take until November to December. Thereafter, they will once again return to Stages II and III in the succeeding new sexual cycle. Variations in the maturity coefficient of the ovaries of pond-reared Silver Carp in Kwangtung and Chekiang regions, are presented in Figure 8.

As mentioned above, the annual variation of gonadal development in several species of farm fish is basically similar. The annual variation of gonadal development in Grass Carp in the Hunan Region is shown in Figure 9.

The testes of male fish develop earlier than the ovaries of female fish. Generally, they have developed to Stage IV in winter, but will not reach Stage V until about March of the following year. At that time, the secondary sexual characteristics of male fish will also be present. The maturity coefficient of the matured testes in pond-reared farm fish in Kwangtung is generally low, from 0.3-0.8%; that of the Bighead is lowest, followed by Silver Carp's. In pond-reared Silver Carp with a body weight of 2-4 kg, matured testes generally weigh only 6-25 g. It should be noted that the testes of pond-reared farm fish in Kwangtung are less developed than those of wild individuals. For example, the maturity coefficient of the testes of mature Silver Carp in the Pearl River System is generally from 0.7-1.4%.

The situation is just the opposite to that mentioned above in the case of the maturity of ovaries. That is, the maturity coefficient of the ovaries of pond-reared female fish is higher than that of wild individuals. These phenomena are worthy of deeper investigation.

The sexual cycle of farm fish in the northern region is basically the same as that of fish in Kwangtung Region; however, it is slightly prolonged because of climatic differences (Figure 10). In the central region of China it is generally about one month later compared with that in southern China. In the north-eastern region, farm fish generally attain full sexual maturity after June.

The Structure of the Gonads and the Growth and Maturity of Sex Cells

The Structure of the Ovary and the Growth and Maturity of Egg Cells:

The Structure of the Ovary and Its Stages of Development: The ovaries are in pairs and sac-like. Their walls are formed by connective tissue and smooth muscle. The egg cells are produced from the inner surface of the ovary and the internal foldings of the wall, which are also called egg-bearing plates. There are blood vessels and branches of nerves on the ovary tissue; the posterior tips are fused into an oviduct with its opening outside the body.

The development stages of the ovary: Stage I ovary: Lineal in shape. Grayish-white in colour. Firmly attached to the membrane at the lower part of air-bladder. Its appearance does not indicate whether it is a male or female organ.

Stage II ovary: The distribution of blood vessels on the surface is vaguely visible. White in colour and semi-transparent. Small eggs are visible when examined under a magnifier. The maturity coefficient is about 1-2%.

Stage III ovary: Its capacity has become conspicuously enlarged. Greenish-gray or brownish-gray in colour. Eggs are visible with the naked eye but not easily separable. The maturity coefficient is generally 3-6%.

Stage IV ovary: Long and sac-like, filling up the whole body cavity. Greenish-gray or light yellow in colour. Membrane of ovary is transparent. Eggs are filled with yolk and easy to separate. Ovary is fully distributed with blood vessels. The maturity coefficient is 14-22%.

Stage V ovary: A large quantity of oocytes has just been released from the follicles and are now suspended in the ovary. The ovaries and the abdomen are very soft. If a fish is lifted up, the eggs will run out from its cloacal opening.

Stage VI ovary: The major portion of eggs has already been laid. Generally, there are still some phase-4 oocytes which have remained in the ovary. The ovary membrane is slack and its size has been reduced conspicuously. Flat, transparent blood vessels have become enlarged.

Growth and Maturity of Egg Cells: The development of the egg cells, or the oogenesis, of Silver Carp is similar to that of many other teleost fish, which pass through three stages: (1) the propagative stage of oogonia, (2) the growing stage (which is divided into the minor growing stage and the major growing stage), and (3) the maturity stage.

The oogonia are grown from the germ cells, which in turn are developed from the reproductive foldings at the dorsal region of the body cavity. At this stage, the oogonia multiply through mitosis and increase greatly in number. Thereafter, they enter the next stage of development.

The growing stage, according to Meüen, can be divided into three stages: the "linin-matching" stage, the minor growing stage, and the major growing stage.

The results of research on Silver Carp by the Biological Department at Wuhan University and the Institute of Hydrobiology, Academia Sinica, indicated that the linin-matching stage can be divided further into the "fine-linin", "linin-matching", "shrinking", "thick-linin" and "double-linin" stages. These are the earliest stages of egg development.

At this stage, the chromosomes undergo a series of orderly changes. In the fine-linin stage the chromosomes are fine; in the linin-matching stage the chromosomes are slightly thicker; in the shrinking stage the chromosomes shrink into lumps; in the thick-linin stage the chromosomes are again stretched; and in the double-linin stage the chromosomes split into pairs. Thereafter, the egg cells enter the minor growing stage.

The minor growing stage can be divided into the juvenile stage and the "one-layer-follicle" stage.

In the juvenile stage, the diameter of the oocytes is about 24-68 μm. The cells contain more cytoplasm compared with the previous stage. The chromosomes in the nucleus gradually disperse and there are 2-8 nucleoli of different sizes. The ovary, which has phase-1 oocytes as its major component, belongs to the first maturing stage, or Stage I maturity.

In the one-layer-follicle stage, the diameter of the oocytes attains 189-240 μm. The major characteristic is that the oocytes are covered with one layer of membrane. Chromosomes in the nucleus have completely dispersed. There are 6-13 nucleoli. The cytoplasm has changed from a granular structure to a net-work form. The ovary, which has phase-2 oocytes as its major component, belongs to the second maturing stage (Plate I, 1). Farm fish that are kept under unfavourable environmental conditions normally stay within this maturing stage.

The major growing stage is divided into the yolk-beginning-sedimentation and yolk-filled stages.

The characteristics of the yolk-beginning-sedimentation stage are the appearance of vesicles, yolk granules and adipose rings around the oocytes; the thickening of the cell membrane with the appearance of radial striata, also known as radiant rings; and the transformation of follicles into two layers. The sedimentation process of the yolk proceeds from the peripheral region towards the centre. The fluid in the vesicles contains polysaccharides, which are one of the essential materials for the future formation of the cavity surrounding the egg. The centre of the nucleus appears to be irregular or oval-shaped; the number of nucleoli increase to more than 20. The cell diameter has generally expanded to over 500 µm. The ovary, which has phase-3 oocytes as its major component, belongs to the third maturing stage (Plate I, 2).

The most important characteristic of the yolk-filled stage is that the yolk has almost filled the whole cavity of the oocyte. Only a thin layer of cytoplasm remains on the peripheral region of the cell surrounding the nucleus. The shape of the nucleus is either irregularly oval or elliptical; the nucleoli are inlaid in the nuclear membrane. The oocytes have reached their maximum size generally 1100-1300 µm in diameter. The ovary, which has these phase-4 oocytes as its major component, belongs to the fourth maturing stage (Plate I, 3, 4). Under unfavourable ecological conditions for spawning, or when artificial propagation is not being conducted, Silver Carp, Bighead and Grass Carp may stay at this stage of maturity for 1-2 months. Some individuals may stay there for as long as 3 months.

The oocytes proceed very fast from Stage IV to maturity (Stage V). In nature, the process may be completed in 20-40 hours after the rising of water in the rivers. Under artificial estrualization, it can generally be completed within 8-20 hours. The essential characteristics of the process are as follows. Initially, the yolk granules begin to fuse, becoming plate-shaped; the ooplasm and nucleus move towards the animal pole, the appearance of the so-called polarized phenomenon; the nucleoli in the nucleus move from the edge of the nucleus towards its centre and begin to melt; and the egg body turns transparent. Thereafter, the chromosomes proceed to the first maturity division, or first meiotic division, and release the first polar body. This is then followed by the second maturity division or second meiotic division. In the middle of the second maturity division, the egg suddenly slows down its speed of development and waits to be fertilized. Meanwhile, eggs are released from the follicles (this is known as ovulation or internal spawning), and the brood fish appear highly erotic, chasing each other in the process of spawning. It has been proven through experiments that the mature eggs of farm fish, i.e., the eggs that are in the middle stage of their second maturity division, can stay only briefly in such a stage, for about 1-2 hours only. If they are not fertilized at this time, they will become over-ripe and lose the ability to become fertilized; even though part of these eggs might become fertilized, the embryos will not develop normally. The ovary, which has these phase-5 oocytes as its major component, belongs to the fifth maturing stage.

The Structure of the Testes and the Formation of Sperm, or Spermatogenesis:

The Structure of the Testes: The testes are paired and tubular. They are formed by a numerous series of irregularly placed receptacles. The spaces between the receptacles are filled with connective tissue. The receptacle is constructed of numerous seminal vesicles, which are filled with germ cells at a similar stage of development. The seminal vesicles are separated by a thin layer of follicular cells. The centre of the receptacle forms a hollow cavity. When the sperms are formed, the seminal vesicles dissolve and the sperms enter the hollow cavity.

Spermatogenesis: The formation of sperms in farm fish is basically similar to that in many teleost fish. Initially, every spermatogonium continues to multiply by mitosis in the seminal vesicle, resulting in mass production of spermatogonia, which, with a diameter reaching 9-12 μm, are the largest cells in the testis. When the spermatogonia cease to multiply, the next development stage takes over. The spermatogonia go through a not-so-conspicuous growing stage, are slightly enlarged in size, and are transformed into primary spermatocytes. The primary spermatocytes are then transformed into secondary spermatocytes (now smaller in size, 4-5 μm) through the first maturity division. Every secondary spermatocyte proceeds to the second maturity division and is transformed into two, even smaller (about 3 um) spermatocytes, which again pass through a series of morphological changes and become sperm or spermatozoa.

The spermatozoa of the farm fish are composed of head, mid-piece or neck and tail portions. The spermatozoon of Silver Carp has a spherical-shaped head 2.2-2.5 μm in diameter, a neck length about 1.1 um, and a tail length about 35 μm (Plate I, 6).

The ripe sperms are concentrated in the receptacles, where they are mixed with the fluid secreted from interstitial cells in the testis. The mixture is called semen or milt. The milt can be exuded at any time when the fish is in a highly erotic mood, or it can be squeezed out.

Gonadal Development of Farm Fish in Different Latitudes

On the basis of an analysis of available data, we are positive that all pond-reared Silver Carp, Bighead, Grass Carp and Snail Carp in the country, from the Amur River in the North to Kwangtung in the South, can attain maturity when they have reached a certain age under normal rearing conditions. But in different latitudes, there are certain differences in the development of their gonads. The present data show that in the regions south of the Yangtse River, especially in the sub-tropical area, gonadal development in farm fish is slightly better than that in the regions north of the Yangtse. For example, the maturity percentage of Silver Carp in the Kwangtung and Chekiang areas when they have reached the maturing age under normal pond culture conditions generally reaches 70-100% but the maturity percentage of the Silver Carp in the regions north of Yangtse River will generally not be that high.

Although pond-reared Bighead can grow to maturity in all parts of the country, those that are reared in the sub-tropical region have generally a maturity percentage of 80-100%, which is higher than those in northern and north-eastern China. Experienced fish farmers in Kwangtung consider that the best growing period for Bighead is the summer when the temperature is high; for Silver Carp it is autumn; and for Grass Carp it is almost year-round. These observations seem to suggest that the development and growth of Bighead require more thermal energy.

Throughout the country pond-reared Grass Carp have shown special differences in gonadal development compared with Bighead. The gonadal development of Grass Carp seems to have less connection with climatic zones than that of Silver Carp and Bighead, especially Bighead. For instance, the maturing age of Grass Carp in southern China is 5 years (4 years for some individuals); in the central region, 5 to 6 years; and in the northeastern region, 6 to 7 years (see Table 10). Their differences are not as great as those of Silver Carp and Bighead. In addition, in Kwangtung the maturity percentage of Grass Carp is normally lower than that of Silver Carp and Bighead, and there are no marked differences compared with that in central China and northern China. In view of the above situations, Grass Carp do not seem to have regional differences in gonadal development similar to those of Bighead.

Gonadal Development of Farm Fish in Different Water Areas in the Same Region

Under the same water temperature conditions, different water areas and different methods of cultivation can variously affect the gonadal development of farm fish. Even in the same water area, differences in gonadal development can occur in different groups of fish of the same species.

In Kwangtung, the gonadal development of Silver Carp is less affected by the types of water area as compared with that of Bighead. Many years of experience have proven that once Silver Carp in Kwangtung have reached the maturing age, regardless of whether they are living in still-water ponds, slow-flowing water ponds, natural ponds, streams with dams, or rivers, they will normally become sexually mature, although there may be slight differences in the maturity percentage and maturity coefficient among the fish. In general, the maturity percentage, maturity coefficient, fecundity and maturing age of pond-reared Silver Carp are better than those of Silver Carp living in large and medium-sized water bodies. Similar phenomena are observed in the Chekiang region, where the Silver Carp in a fish pond mature earlier and with a higher percentage of maturity than those kept loose in impounded water, which in turn are slightly better than those found in the rivers. In Liaoning Province both male and female pond-reared Silver Carp of 4 to 5 full years of age and 2-5 kg in body weight are generally able to develop to maturity. But in Heilungchiang Province at Tungdapao the majority of Silver Carp of 4 full years of age and 5 or 6 kg in body weight do not mature; their gonads remain in Stages II-III only. These phenomena are basically the same in every water area in the country.

The conditions of the water area have greater effects on the gonadal development of Bighead. In Kwangtung region, the maturity percentage of Bighead was very high when the fish were cultured in a "fat" water pond such as No. 4 pond in the Southsea Fisheries Research Institute, where the maturity percentage of Bighead reached 100%. A great majority of the pond-reared Bighead in Kwangtung region attained a high maturity percentage

(80-100%). However, no sexually mature Bighead have been found so far among those reared in impounded waters, such as those in the Liuchee River Reservoir and the Hupsui Reservoir in Kwangtung; although the Bighead grow well, they apparently mature late. Judging from these situations, the gonadal development of Bighead, compared with that of Silver Carp, has a more intimate relationship with the environmental conditions of the water area, especially the chemical properties of the water and the planktons. This point will be discussed further in relevant parts of this book.

The gonadal development of Grass Carp is generally similar to that of Silver Carp. As proven in the Southsea Fisheries Research Institute during 1958-1960, all Grass Carp, no matter where they were reared, in still-water pond, slow-flowing-water pond, "fat" water pond or "lean" water pond, were able to grow to maturity, provided the nutrititional conditions were normal. Grass Carp which live in natural impounded waters, reservoirs and rivers are generally able to attain maturity, though there are differences in the maturity percentage and maturity coefficient.

Relationship Between Internal and External Factors of Growth and Development

The growth and development of a living organism is controlled by its internal hereditary make-up and the external ecological conditions. The internal hereditary foundation is the premise of growth and development. In addition to this premise, it is also necessary for the organism to pass through relevant external ecological conditions in order to achieve its goal. Therefore, both internal and external factors are of essential importance. In this section, before proceeding with an in-depth discussion of the growth and development of farm fish, we would like to present some basic knowledge on the internal (physiological) factors relating to the growth and development of fish.

Relationship Between Growth and Development and Endocrine System

Animals, in the process of their systematic development and adaptation to frequent changes in the external environment, have evolved distinctive endocrine systems and gradually formulated a complete neuro-glandular regulatory system. In the endocrine system of fish, the pituitary gland, or hypophysis, irrespective of morphology and function, has evolved more completely than any of the other glands. Other glands such as the thyroid and suprarenal are still in their early stage of evolution. Nevertheless, their physiological functions are basically similar to those of higher vertebrates.

The endocrine glands, under the direction of the nervous system and with coordination between each other, secrete a kind of stimulant (hormone) which is carried through the circulatory system to stimulate or control the functions of certain of the animal's organs, so that all physiological functions inside the organic body will be suitably regulated, and so that the animal will be more adaptable to the outside environment.

The pituitary gland of fish is similar to that of other higher vertebrates and is the centre of the endocrine system. Not only does it directly control many physiological functions, but to a very great extent it also controls the activities of other glands.

The Pituitary Gland of Fish: The pituitary gland of fish is situated on the ventral side of the thalamencephalon, or 'tweenbrain, and attached to the infundibulum. It is divided into two parts: the neurohypophysis and the adenohypophysis. The neurohypophysis is connected to the thalamencephalon; its nerve fibres penetrate deeply into the adenohypophysis. The adenohypophysis is divided into the anterior lobe (pro-adenohypophysis), the transitional lobe (meso-adenohypophysis) and the posterior lobe (meta-adenohypophysis). Their locations are different from that of higher vertebrates. For example, in the Common Carp (Figure 11), the anterior lobe (which corresponds to the gangliated part in higher vertebrates) is located near the thalamencephalon. The transitional lobe (which corresponds to the anterior lobe in higher vertebrates) is situated at the lower front of the anterior lobe. And the posterior lobe (which corresponds to the transitional lobe in higher vertebrates) is situated at the lower front of the transitional lobe.

Experiments have proved that in the pituitary gland of fish it is the basophil cells in the meso-adenohypophysis which secrete the sexual hormone. This hormone can promote and accelerate the growth and development of gonads, maturity and ovulation. The pituitary gland of fish can also secrete another hormone - the growth hormone. For example, when the pituitary gland is removed from a juvenile fish, not only will its gonads stop developing, but the fish will stop growing. If the pituitary gland is transplanted back into the body, or if the fish is continually given pituitary injections, it will immediately resume its growth and development. If an adult fish is given the same treatment, it will show similar physiological reactions. Furthermore, the pituitary gland also secretes thyrotropic and corticotropic hormones which reciprocally control the activities of relevant glands in the body.

Other Endocrine Glands Affecting Growth and Development:

Thyroid Gland: The thyroid gland of fish is similar to that of the higher vertebrates. It has certain effects on growth. A researcher put fish into a 0.03% solution of propylthiouracil (an anti-thyroxine compound) and after 30 days found that their growth was retarded, their subsidiary sexual organs were not developed, and their thyroid glands were swollen. When thyroxine was added to the solution, the symptoms did not appear. This experiment proves that the thyroid gland has certain effects on the growth of fish. The thyroid gland also has some indirect effects on the development of the gonads. For example, thyroxin can be used to cause variations in the secondary sexual characteristics in guppies (*Lebistes reticulatus*).

Adrenal Cortical Tissue (or Inter-Renal Tissue): If the inter-renal tissue of a fish is surgically removed, the fish will not live. This phenomenon also applies to the higher vertebrates. But a mouse will continue to live when its inter-renal tissue has been removed if it was given injections of inter-renal tissue extracted from fish. This proves that the functions of inter-renal tissue in fish are, to a certain extent, similar to the functions of cortical tissue in the higher vertebrates. It can regulate the metabolism of carbohydrates and the equilibrium between organic salt and water.

Gonads: The gonads of fish, apart from producing germ cells, secrete a kind of sex-stimulant hormone which causes the development of subsidiary sexual organs and the appearance of sexual behavior. The male sex hormone secreted by the testes is called antrogen. The female sex hormone secreted by the ovaries is called estrogen. In fish with their gonads removed, secondary sexual characters as well as sexual behavior will degenerate and disappear, but they will reappear after injections of the sex hormone. Juvenile fish injected with the sex hormone will show the early appearance of secondary sexual characteristics. The body of males injected with estrogen will appear feminine. So far it is still undetermined whether the sex hormone has certain effects on the growth and development of germ cells.

Many scholars believe that antrogen is manufactured by the interstitial cells or the lobule boundary cells in the testis. Estrone is produced from the yellow bodies or the cortical cells of the follicular membrane.

In fish the production of the sex hormone is directed by the central nervous system and regulated by the hypophysis.

Among the other endocrine glands in fish is the Islets of Langerhans, which has the functions of regulating the metabolism of carbohydrates, fats and protein, and of maintaining normal sugar levels in the blood. Besides the Islets of Langerhans, there are the thymus, the ultimobranchial gland and the urohypophysis. The functions of these glands, owing to a lack of research materials, are yet to be determined.

The Relationship Between Growth and Development and Ecological Conditions

Owing to their continuous adaptation to external environments over their long period of evolution, animals have formulated every kind and variety of heredity. Because of the conservative nature of heredity, every animal demands different ecological conditions in its different stages of growth. In the case of Grass Carp in the embryonic stage, the principal ecological requirements are temperature (optimum temperature: 22-28^{o}C; upper and lower limits: 18-31^{o}C) and dissolved oxygen (above 3 g per 1), followed by the chemical properties of water and light intensity. In the fry stage, the main ecological requirement, in addition to the aforementioned two factors, is the supply of relevant feeds - zooplankton. From the fingerling stage onwards, the principal ecological requirement besides a wider range of water temperature and dissolved oxygen, is vegetable feeds. Hence, irrespective of the stage of development, if the relevant ecological conditions or requirements are lacking, the growth of an animal will, to a certain degree, be restricted; or if the conditions are excessively unfavourable, the animal will die. The importance of ecological conditions and physiological characteristics for every stage of development of an individual animal should be fully recognized. The control and improvement such ecological factors for the service of mankind have great implications, both in theory and in practice.

Very little research has been done on the relationship between the growth and development of farm fish and the external conditions. The principal ecological factors identified in our preliminary investigation, which was based on some materials accumulated over the past few years, are as follows:

Nutrition:

The Relationship Between Nutrition and Growth: Growth, in this context, refers to an organic body which digests and absorbs foreign materials, and through complicated biochemical processes converts them into its own body materials, thus enlarging its body. In this section, development means gonadal development.

To maintain life activities, animals must continually absorb energy-producing materials. If the nutrition level is just enough to supply the life activities of the organic body, the animal will be able only to remain alive, but it will not grow normally, not to mention develop normally. Therefore, animals can grow and develop normally only under proper nutritional conditions.

Because fish are cold-blooded animals, their metabolic rate, i.e., their energy requirement, is lower than that of warm-blooded animals. In general, they can endure hunger better. Moreover, there is always a certain amount of natural food available in the water in which they live. However, because of that people engaged in fish culture tend to neglect the problem of nutrition. Yet the growth and development of farm fish are very closely related to nutrition.

The speed of growth of farm fish in their fry stage is in inverse ratio to the stocking density. That is, given the same area, time and feeding conditions, the body weight of the fry will be reduced to half of what it was if the the stocking density increases 100% (say, from 100,000 to 200,000).

In the fingerling stage, the growth rate is also in inverse ratio to the stocking density. This proves that under certain feeding conditions, when the stocking density has increased, the amount of feed per fish is relatively reduced, and so the growth of the fry or fingerlings will be markedly influenced.

In the adult stage, the growth rate of farm fish is similarly related to nutrition. For example, in the No. 4 brood fish pond of our Institute, 3-year old Silver Carp attained an average body weight of 4.65 kg due to the pond's comparative richness in planktons, while in the adult fish pond at Wanglek Station, which used the rough release method, 3-year old Silver Carp attained an average body weight of only 1.69 kg. According to reports from the Fisheries Institute of Heilungchiang Province, the Silver Carp and Bighead of similar age groups which were reared separately at Tungdapao (lake) and Pohaipao (lake), two bodies of water with great differences in the quantity of planktons available showed differences in growth of more than 100%, as indicated in Table 11.

The Relationship Between Nutrition and Gonadal Development: Gonadal development is also related very closely to nutrition. In order to explain this relation, we should begin with a discussion of the characteristics of gonadal development of farm fish, especially during the major growing stage. For example, before February the ovary maturity coefficient of sexually mature female fish in Kwangtung is generally 3-6%. In late April or early

May, the gonadal coefficient rapidly rises to 14-22%. In other words, in a period of about two months, the fish have absorbed nutrition from outside and, through the internal systems of the body, converted it into materials, to the extent of 10-16% of body weight, for the rapid development of the gonads. Experiments have proved that if brood fish have good rearing conditions in autumn and are able to accumulate sufficient nutritious materials in the body, and are again able to maintain a certain nutritional level in the following spring, then a great majority of the fish will have well developed gonads. In contrast, if the nutritional conditions are bad in the autumn, the brood fish will have low plumpness, and even if feeding was intensified in the following spring, the maturity of the fish would still be delayed. If there were no intensified feedings after spring, then the gonads of the brood fish would certainly not develop well.

Among the farm fish, the Grass Carp's gonadal development is most closely related to feeds (nutrition). For example, in 1959 the Southsea Fisheries Research Institute conducted intensive culture studies on a school of brood Grass Carp. Every day a sufficient amount of terrestrial grasses and other fine feeding materials (wheat sprout and rice bran) were given. Until the summer of 1960, all the male brood fish, whether reared in a still-water pond, a fat-water pond or a slow-flowing water pond, were able to reach maturity. The maturity rate reached 30-50% (failure to mature might have been due to age). With estrualization, good results were obtained. All male fish matured. In the second half of 1960, an experiment was done to study the gonadal development of Grass Carp under bad cultural management conditions (only a small amount of green grass was given). The experiment ended on June 8, 1961, when the fish were dissected for examination. All the brood fish were found not matured, their ovaries had only a few phase-4 oocytes, most of the oocytes were phase 2 or 3. The maturity coefficient was only 1.1-6.4%, as shown in Table 12.

From the above discussion, one can appreciate that the brood fish, though having the internal physiological conditions for maturation, will not develop mature gonads if the relevant ecological conditions, especially nutritional are not provided on a timely basis.

The nutritional condition has not only a profound influence on the maturity rate of Grass Carp, but also a very great effect on the reproductive power, or fecundity, of the fish (measured in terms of the number of eggs produced per kg of body weight), as shown in Table 13.

Table 13 shows that the fine feeding materials which have high protein content, such as dried silkworm pupae, soy bean, ground-nut cake, etc., have a great effect on promoting the reproductive power of the brood fish.

In the case of Bighead, the nutritional condition plays a distinctive role in gonadal development. In 1958 the Fisheries Department of Kwangtung Province released 110 Bighead (average body length: 96 mm; average body weight: 9.135 kg) in the Pearl River for the purpose of improving its fish fry resources. These Bighead had been living for a long time in the lean-water of a natural pond. Although they had reached maturity age, their gonads were still within the Stage II. We transplanted 10 of these fish into our fat-water pond, and all 10 Bighead attained maturity the following year.

The gonadal development of Silver Carp shows a less distinctive relationship with feeding and water fertilization than that of Grass Carp and Bighead. This may have something to do with their filter feeding on phytoplanktons, which are always available in fair number in water. In general, Silver Carp can attain maturity in a great majority of water areas, though there are some differences in the maturity coefficient among the areas.

Water Temperature: Animal metabolism is a complicated biochemical process. The metabolic rate of cold-blooded animals is generally related directly to temperature within a suitable range.

The metabolism of fish is clearly influenced by the environmental temperature. Farm fish of our country are warm-water species. Their suitable range of temperature is generally between 13-30^{o}C, with their optimum temperature between 22-28^{o}C. In the past, we believed that the growth and development of farm fish required the same water temperature. That is, within a suitable temperature range, the higher the temperature, the faster the fish would grow and develop; and on the other hand, the lower the temperature, the slower their growth and development. However, an analysis of data now available indicates that the temperature demands for growth and development differ to a certain extent. For instance, development and the requirement for thermal energy are generally in direct proportion, but growth does not entirely have the same relationship with thermal energy. Table 14 illustrates, to a certain degree, the above points.

Table 14 shows that there are no big differences in the rate of growth in Silver Carp and Bighead (with the exception of 3-year old Bighead) in Heilungchiang and Kwangtung Provinces, although the growth conditions in the No. 4 pond of the Southsea Fisheries Research Institute were much better than those in Tungdapao in Heilungchiang Province. No. 4 pond had, for instance, more phytoplanktons, more fertile water quality, a longer growing period, and more total thermal energy. This phenomenon demonstrates that the growth and the requirement of thermal energy in farm fish are not in direct proportion exactly.

What causes this puzzling phenomenon? We considered some of the possible causes. During the summer the temperature of pond water in Kwangtung is excessively high (above 30^{o}C in July and August and close to 30^{o}C in June and September), and it might be that the optimum temperature for the maximum growth of farm fish is about 25^{o}C (in general, the summer water temperature in Heilungchiang is 21-25^{o}C). Fish farmers in Kwangtung recognized that autumn (when water temperature is about 25^{o}C) is the best season for the rapid growth of farm fish, especially Silver Carp. They also recognized that big ponds (the characteristics of big ponds are, among others, more stable water temperature and relatively low water temperature in the summer; they are so-called "cool in the summer and warm in the winter") can cause pond fish to grow faster. This suggests that in southern China we should prevent pond water from becoming too hot, and in the northern region we should take advantage of the optimum temperature season to intensify culture management so as to obtain the best possible growth in a relatively short time.

Furthermore, the cause of the above phenomenon may also relate to the spaciousness, high oxygen content and relatively weak lighting (deep water) that characterize Tungdapao lake.

The development of fish has a more distinct relationship with water temperature, and fish development and water temperature are, to a very large extent, in direct proportion. For example, the whole process of embryonic development of Silver Carp takes 50 hours at 20^{o}C, 24 hours at 25^{o}C, and 16 hours at 30^{o}C. The speed of development of some organs in Silver Carp fry is also, to a certain extent, in direct ratio with water temperature.

Similarly, the maturing age of farm fish is very closely related to water temperature (total quantity of heat). Table 15 clearly describes this relationship.

Table 15 shows that the maturing age of the Silver Carp which live in different regions differs because of different water temperatures and growth periods, but the total quantities of heat for their maturing period are basically the same, requiring about 18,000-20,000 degree-days (average water temperature multiplied by number of days). This explains the direct relationship between speed of development and water temperature. This relationship should be considered seriously when dealing with the problem of maturation of farm fish in the northern region of our country.

Hydro-Chemistry:

Dissolved Oxygen: Energy for an animal's life activities is derived from the oxidation of materials in the body. A fish is an aquatic animal, so it must carry out normal gas exchange in water in order to maintain its normal life activities. Because of the differences in their living environments, fish have developed during their evolution different adaptations to the oxygen factor. For example, the demand of the cold-water Salmonids for dissolved oxygen content in water is about twice as high as that of the warm-water Cyprinids. Practical experience has shown that farm fish begin to appear on the surface gasping for air when the dissolved oxygen in water falls below 2 mg per l. The fish will gasp heavily for air when the dissolved oxygen level drops to 0.5-0.6 mg per l. When the oxygen level drops further, to below 0.4 mg per l, it will normally cause suffocation and death.

Dissolved oxygen has a fairly large influence on the food consumption of farm fish. Experiments conducted at the Hainan Fisheries Research Institute indicated that generally within a certain water temperature range, the higher the amount of dissolved oxygen, the greater the feeding intensity. When the dissolved oxygen level drops to 2 mg per l, farm fish lose their appetite greatly. When it continues to drop to below 1 mg per l, the fish stop feeding (Figure 12).

In different types of water bodies, the content of dissolved oxygen is also different. In still-water ponds, because the water is relatively still and has a higher biomass, the dissolved oxygen content is generally relatively lower, and it also shows greater daily fluctuations. According to our measurements, the average annual dissolved oxygen content in the lower reaches of the Pearl River was 5.513 mg per l; in the tidal ponds with slight flows of water it was 4.54 mg per l; and in the No. 1 and No. 2 experimental still-water ponds it was 2.52 and 2.15 mg per l, respectively. In other words, the difference in dissolved oxygen content between still-water and running-water bodies is more than twice. The daily fluctuation of dissolved oxygen content was very obvious in still-water ponds, such as the fry rearing pond and sewage water fish culture experiment pond at the Southsea Fisheries Research Institute. The daily fluctuation amplitude reaches 400-500% (Figures 13 and 14).

In view of the above situations, when rearing brood fish, especially in a small fat-water (or fertile water) pond, one should pay particular attention to the use of fertilizers and to the stocking density and at the same time to the letting in of fresh water in a timely way in order to adjust the quality of the water.

Questions on the Functions of "Fat-Water" (Fertile Water): Pond-reared Silver Carp and Bighead generally mature earlier and have a higher maturity rate than wandering or wild fish in small rivers (some pond-reared Silver Carp attained maturity when they were about 1 kg in body weight), while wild farm fish in small rivers generally mature earlier than those living in big rivers. This fairly normal phenomenon has been mentioned in preceding paragraphs.

What causes this phenomenon? At present the majority consider that it is related to nutrition. Pond water is more fertile, and its planktonic biomass is richer than that of small rivers (impounded waters). The planktonic biomass in reservoirs is generally slightly higher than that in big rivers.

We will discuss in the following paragraphs various aspects of the question, including whether fat (or fertile) water has the function of promoting maturation and higher maturity rates in Silver Carp and Bighead, and whether, apart from the nutrition factor, there are other factors.

In pond-reared Silver Carp and Bighead the growth speed is not always faster than that of individuals in the wild (or in reservoirs), but the fish are better developed. We think that this phenomenon is caused by, apart from nutrition the following factors:

First: According to the general rules of development, when domestic animals have reached a certain age, the chemical elements in the body, such as nitrogen, phosphorus, ash, etc., have gradually become sufficient and stable and have reached the so-called "chemical maturity stage". On the basis of this chemical foundation, the animals are transformed physiologically into mature adults. Therefore, domestic animals which are better kept generally mature earlier.

Fat-water is very rich in inorganic salts, which, under certain conditions can be absorbed into the fish's body through the gill filaments, intestines and skin. In view of the above related phenomena, the rich inorganic salts in fat-water may be absorbed through those passages and, under certain conditions, accelerate the farm fish's reaching of the so-called "chemcial maturity stage" and thus cause early maturation.

Among the elements in fat water, sodium and chlorine are the two chemicals which may have greater influence on the development of farm fish. They are important components in the formation of blood, body fluids and cells in a fish's body, and are also present in the form of inorganic salts in order to maintain osmotic pressure and the proper pH in the body. They are also required to be maintained at a certain level of concentration in order to sustain normal life activities. These two elements are available only in very small quantities in the food of farm fish, especially that of Grass Carp, which have limited sources of supply. Following this reasoning, in 1959-1960 we conducted comparative feeding experiments on Grass Carp by adding table salt (1% of feed weight) to the food. The results showed that the group of Grass Carp fed with additional table salt matured earlier and had a higher maturity rate. On April 21, 1960, our country achieved its first success in the artificial propagation of pond-reared Grass Carp, and the brood fish used were selected from the above experimental group.

Several years of practical experience have proved that animal feeds such as Silkworm pupae have a very good effect on the growth and development of brood Grass Carp. The effect may be brought about by the chemical elements in the animal feeds, which are better suited for gonadal development in brood fish.

Second: Fat water can promote early maturation and a higher maturity rate because it contains hormones which may have some effect on development. Of all the fertilizers used in Kwangtung for brood fish culture, human night-soil and urine, which are well known to contain a fair amount of sex hormones, constitute the bulk. In practice, these fertilizers have been used to promote sexual maturity of Silver Carp and Bighead with good effects. Apart from this, the Southsea Fisheries Research Station frequently applied, from 1959-1960, stable fertilizer from a neighbouring dairy farm to its No. 2 experimental pond. The results showed that the Silver Carp and especially the Bighead in the pond attained better gonadal development compared with fish in other ponds. It is also well known that the urine of pregnant cows or dairy cows contains sex hormones. Further investigations on the real effect of human and animal urine on the maturation of farm fish will have a certain significance for fish production.

And third: There may also be an indirect effect from the fat water which can generally promote early maturation of farm fish. The reason is that fat-water ponds generally have a relatively small volume of water and a low content of dissolved oxygen. These conditions have a certain controlling effect on the growth of farm fish. On the other hand, they may have some promotion effect for early maturation, because growth and development under different ecological conditions have, to a certain degree, shown a reciprocal relationship. For example, in a fat-water pond, the early maturing brood fish are generally smaller individuals.

Light: Recent scientific experiments have proved that after the light has stimulated the visual organ of an animal, through its central nervous system, it can activate the secretion of the pituitary gland and thus affect the growth and development of the animal.

On the relationship between light intensity and growth and development of fish, some foreign scholars, namely, Haxard and Eddy, have done research. By controlling the period of lighting, they succeeded in causing the early spawning of fish. They also concluded that excessive light could cause the slow growth of the fish.

The relationship between light intensity and growth and development of farm fish has so far not been critically studied. However, from the practical experience of the masses and the observation of many phenomena, we recognized that light intensity has similar effects on the growth and development of farm fish.

We can preliminarily ascertain that prolonged lighting and excessive light intensity are not beneficial to the growth of farm fish, but they are good for gonadal development. For example, in the paddy fields in the Kwilin area in Kwangsi Province, owing to high temperature and strong light, Common Carp are generally very small (150-250 g), but their gonads mature very early (after one full year). Again in Kwangsi Province, Silver Carp and Bighead that are reared in shallow water ponds also showed the phenomena of slow growth and early sexual maturity, probably because of the influence of strong light and particularly high temperature. Fish farmers in Kwangtung customarily lower their pond water in early spring in order to increase light intensity and raise water temperature, so as to hasten maturation and spawning of Common Carp. In contrast, farm fish in large and medium-sized deep water bodies generally grow well, but their gonadal development is relatively slow.

Excessively strong and prolonged lighting has an adverse effect on growth. The reason is that the thyroid gland is indirectly affected by light (through the pituitary gland) and secretes hormones eccessively, thereby causing too much metabolism. Because growth in general belongs to the assimilation type, the metabolic level should not be too high; while development belongs to the dissimilation type, the metabolic rate should be slightly higher. Many experiments on animals have proved that light can promote the development of the pituitary gland and the secretion of sex hormones, and therefore is beneficial to gonadal development.

Questions on Changing Water and Flowing Water: When rearing brood fish in fertile still water ponds, one should at various periods adopt the changing water and flowing water techniques, respectively. These two arrangements have about the same function in the culture of brood fish, but they also have certain differences.

Changing Water: The primary objective of changing the water is to maintain good water quality in the pond, so that the fish can live comfortably in an environment conducive to growth and development. Secondly, the timely admission of fresh water will result in a more rational composition of phytoplankton and an increase in those groups of phytoplankton which can be digested by Silver Carp and Bighead, thus raising the nutritional level of the brood fish. Furthermore, it can also supplement some unknown elements in the pond water, such as calcium, silicon and other trace elements, which have certain effects on the propagation of the food organisms and on the growth and development of the brood fish. The admission of fresh water must be done at the right time and in the right amount to avoid causing undesirable side-effects (eg., water turning too lean, or the fish using up a large quantity of energy), especially in the farm fish's fattening stage. The right timing and right amount here means that when the water is too fertile, or when difficult-to-digest groups of phytoplankton become too numerous (more than one half), or when the dissolved oxygen is not high, we should admit some fresh water slowly into the pond. If the above situations do not appear, one should admit only a small amount of fresh water or none at all. The amount of fresh water and the frequency of admission (generally 1-3 times per month) should be based on the overall conditions. Each time the amount of water let in should be 1/4-1/5 of the volume of water in the pond. In order to prevent the fertilizers from flowing away, the best way is to let in fresh water without letting out any water from the pond and thus to increase the depth of the water. After the actions of seepage and evaporation have again lowered the water level, slowly let in some more fresh water. The right timing and right amount of fresh water admission will have good effects on the growth and development of the farm fish.

The Southsea Fisheries Research Institute and the Hydrobiological Institute of Academia Sinica conducted trials on the effects of changing water partially every day by means of tidal action. The results showed that it had a good effect on the growth and development of Silver Carp and Bighead, especially Silver Carp. Another trial was conducted by the Chekiang Freshwater Fisheries Research Institute on the effects of periodically (once a month) replenishing fresh water and still water culture on the growth and development of Silver Carp (other conditions were basically the same).

The results showed that in the former case all Silver Carp developed to maturity, but in the latter case the ovaries were not well developed. This is a distinctive difference.

Flowing Water: The function of flowing water is somewhat different from that of changing water. At a certain speed (0.1-0.4 m per second) and slightly longer duration, flowing water directly stimulates brood fish at their late development stage (Stage IV) to further maturation and uplifts the effects of estrualization. The latter's function, as mentioned above, is to a large degree only to improve the environmental conditions of the water body, so as to benefit the growth and development of the brood fish. It must be pointed out that, in order to obtain the best effect, flowing water should be used when the gonads of brood fish have reached late Stage IV, especially before estrualization.

We once placed a batch of Bighead in flowing water (0.2-0.5 m per second) for seven days before estrualization. The result was that all the fish laid eggs and the hatching rate reached 45-70%, which was 15-20% higher than that of the untreated fish.

In 1960-1961 we tried to use ecological conditions (chiefly flowing water and adjusting water level) to stimulate the farm fish to spawn. During the experiment, one could see clearly that flowing water had an excellent effect on promoting the further development of the Stage IV gonads of the brood fish, especially in the first 10 days of the experiment. The abdomen of the brood fish distinctively increased in softness, commencing from lower abdominal position and extending rapidly to the whole abdomen. The degree of reaction was similar to that of brood fish about to spawn after estrualization. After 2-4 days of the flowing water treatment, the milt capacity of male fish also increased markedly. In the past, some people have suspected that flowing water might cause the degeneration of the gonads, but during our experiment, which lasted 40 days, there was no sign of degeneration in the gonads of part of the brood fish, as shown in Table 16.

It seems that the flowing water treatment applied for a certain period of time (2-3 days; 1-3 hours per day; speed of flows: 0.1-0.3 m per second) is an important treatment for brood fish before estrualization.

Because flowing water can increase the metabolic intensity of farm fish, it has highly adverse effects on the growth of farm fish. This should be clearly noted.

The Environment of Ponds: As mentioned above, the growth and development of farm fish demand not entirely similar conditions. Therefore, the best way of selecting brood fish ponds, if conditions allow, is to separate the ponds into brood fish ponds and reserved brood fish ponds (for use in fattening the fish). The former should be 3-6 mu in area; the latter, 6-15 mu.

Experiments and practices have proved that the best way of rearing farm fish in their growing stage is in a relatively large body of water. When they have reached sexual maturity, the brood fish should be reared in a smaller water area. For example, our Institute has used two ponds with areas of 3 mu (No. 1 pond) and 14 mu (No. 2 pond) for rearing brood fish. Even though these two ponds received similar treatments of fertilization and feeding, and even though the brood fish were of the same age, the brood fish in No. 2 pond grew relatively bigger than those in No. 1 pond. The relatively larger body of water probably had a good effect on the growth conditions of the farm fish -- relatively more stable water temperature, dissolved oxygen, natural food and water quality. To facilitate the catching of the fish and the controlling of the water quality, the brood fish ponds should not be too big. Because Grass Carp and Silver Carp do not demand that the fatness (fertility) of the water be high, the pond area can be bigger. Bighead prefer fat (fertile) water, so the pond area should not be too big.

The depth of the water in the reserved brood fish pond should be 2-3 m. This will provide more stable living conditions for the pond fish. The brood fish demand higher water temperature and light intensity, and therefore the depth of the water in the brood fish pond should be 1-2 m.

Inter-Relationship Between Growth and Development

It has been pointed out in the above paragraphs that growth and development involve, to a certain degree, different characteristics. Thus some of their ecological requirements are similar and some are different. Therefore, under different ecological environments, the growth and development of the farm fish frequently show many reciprocal or inter-accelerating phenomena. Such phenomena are commonly seen in the biological world.

Rapid Growth, Excellent Development: The appearance of this phenomenon is caused by good ecological environments which provide optimum conditions for growth and development. For example, Silver Carp and Bighead reared in No. 4 experimental pond in the Southsea Fisheries Research Institute attained excellent growth and development due to the pond's good ecological conditions. Silver Carp 3 full years of age attained 4.65 kg in body weight; Bighead, 10.7 kg. All the male fish reached Stage V; female fish completed Stage IV. The maturity coefficient was 20-22%; the maturity rate, 100%. Because of the admission of some river water during high tides every day, the water in the pond had special physical chemistry characteristics. It had a higher level of dissolved oxygen than the still-water pond (annual average: 4.89 mg per l; nitrate: 0.0999 mg per l) and it was richer in planktons (annual average of zooplankton: 21,729 individuals per l; phytoplankton: 3,997,500 individuals per l).

Slow Growth, Bad Development: The causes of this phenomenon are just the opposite to those of the previous case. They arise from a lack of the needed conditions in the water area for the growth and development of farm fish. This phenomenon appears mostly in the lean water of deserted ponds, in ponds with an excessive stocking density, in small shallow-water ponds where the fish cannot obtain reasonable amounts of food, or in ponds with unfavourable water quality. The general defects of these water bodies are very lean water quality, scarcity of natural feeds, and low level of dissolved oxygen (due, for instance, to over-stocking). This phenomenon appears more frequently with Grass Carp and Bighead. Their characteristics are lean and weak body, low growth rate, gonads remain permanently at Stage II.

Normal Growth, Slow Development: This phenomenon occurs in large and medium-sized water bodies throughout our country. Farm fish that live in these water bodies, especially Bighead have a very low maturity rate and ovary coefficient, as shown in Table 17; although their growth is good, their gonadal development is slow. At Shangwen Reservoir in Kwangtung (which is over 2,000 mu in area), Silver Carp and Bighead attain the normal speed of growth, but their gonads are not well developed. The largest ovary coefficients are 2.5% (Bighead) and 6% (Silver Carp). At many large dams in the southern China region, Bighead are found quite frequently in such a stage. This phenomenon may also appear in pond-reared Grass Carp when there is a lack of suitable feeds.

The special characteristics of these water bodies are generally medium-range nutrition conditions and fatness of water slightly lower inorganic salts content, more stable water temperature, high level of dissolved oxygen, deep water, slightly weak lighting, etc. In other words, they possess better conditions for growth, but are lacking in the conditions needed for gonadal development.

Slow Growth, Normal Development: This phenomenon appears south of the Yangtse River in our country, in small ponds at low altitude, and in densely stocked fat-water ponds. As previously mentioned, at the Shaktao Brigade, Sinfui District of Kwangtung, a Silver Carp only 20 cm in body length was found to have attained sexual maturity and to be able to reproduce. In Kwangsi, most of the Silver Carp used for artificial propagation are generally only 1-2 kg in body weight, and the Bighead are 2.5-4 kg. Furthermore, in the high-yield ponds at Lingfu, Chekiang, Silver Carp weighing 0.75 kg have reached sexual maturity (♂) or near sexual maturity (♀). Again in Hunan Province, Chitung District, sexually mature Silver Carp are generally only 1-2 kg in body weight.

These are slow growing, but normally developed, little mother fish. Their reproductive power and the quality of their eggs are generally inferior compared with those of normal-growth brood fish.

The special characteristics of these water bodies are as follows: comparatively small in area, shallow water, exceedingly high water temperature with high fluctuation, abnormally low dissolved oxygen content with high daily fluctuation, strong light intensity, excessively fertile water, slightly high inorganic salts content and higher stocking density.

This phenomenon appears mostly in Silver Carp, next in Bighead, and slightly less in the Grass Carp.

Reproduction

Reproductive Season and Spawning Migration

Reproductive Season: Because of climatic differences among various regions, the reproductive season of farm fish in our country has some slight variations in timing, but it is concentrated in summer. In the Yangtse River drainage basin, the reproductive period of Silver Carp generally starts in late April or early May, and for Bighead it begins in mid or late May. In the Pearl River drainage area, the reproductive period of Silver Carp and

Grass Carp generally starts in mid or late April, and the period begins slightly later for Bighead. The reproductive period of farm fish in Heilungchiang starts quite late, generally in late June. The overall situation is that the reproductive period in the southern region starts 1-2 months earlier than that in the northern region.

Although it starts in April, the reproductive period of farm fish in the Pearl River system is fairly concentrated. In the early production period, there are very few Silver Carp and Bighead fry, especially Bighead fry. The peak of production is in May-June; after July, fry production decreases greatly. The situations are largely similar to those in the Yangtse River system. In Kwangtung the most efficient period for artificial propagation of farm fish falls also in May and June; this is consistent with the rules of gonadal development of farm fish.

Spawning Migration: In ordinary times farm fish live mainly in slow flowing and slightly fertile waters, fattening themselves in the lower courses (deltas) of rivers and in lakes or tributaries where there are more planktons and higher aquatic plants. In the Pearl River system, spawning schools of farm fish begin to gather in its middle and lower courses from late February to early March each year and to migrate along both sides of the river toward the middle and upper course spawning grounds. In the lake and marshy areas of the Yangtse River drainage system, during the spawning season the fish enter the river from lakes or from the lower course to migrate upstream to the spawning grounds. At this time, the gonads of the brood fish (in the case of Pearl River drainage system) have, in a great majority of cases, reached Stage IV; male fish have reached Stage V. After they arrive at the spawning grounds, and when the ecological conditions for reproduction are suitable, they will proceed to spawn.

Spawning Grounds

Yangtse River Drainage: Along the main flow of the Yangtse River, the spawning grounds of Silver Carp and Grass Carp are located in Hupeh Province, from Sintan (4 km below Siangchi) to Kulaupei (27 km below Ichang city). Within this stretch of river, the section between Loktianchi and Ichang city, a total distance of some 100 km, is an important spawning ground.

Along the Hsiang River, the major spawning grounds are distributed between Hangyang and Lingling in Hunan Province, and within this section of the river, spawnings are more concentrated at Paimenshik, Dayuwan and Siangsitam.

Along the Han River, the major spawning grounds are distributed between Hsiaohochi and Laohokao (27 km below Tanchiangkao), and are more concentrated at places below Anyangkao to a distance of 11 km to Shikfuiyau.

In the Kan River, the spawning grounds are distributed along that section of the river between Kanchow and Chongshu, and the most important part is between Kanchow and Chian. This is an important spawning ground for Snail Carp.

Pearl River Drainage: The most important spawning grounds for Silver Carp and Grass Carp in the Pearl River drainage system are located in the West River, where spawnings are more concentrated in the Chum, Yu and Chien rivers (tributaries of the West River). The most important spawning grounds in the Chum River are located between Tungtap and Shikjui in Kweiping District. In the Yu River, they are located at Hwatang and Chikwan, in Kweishian District, and at Chiangtung, Enshian and Chungchuan in Yiklin District. In the Chien River, the spawning grounds are more concentrated at Sanchiangkao and Shiklungtan in Shiklung District, at Dabuchio and Pantan in Laipin District, and at Huangtan in Chianchiang District.

Details on the distribution of spawning grounds in the West River are given below:

Tso River: Shangszu District Pingfook Division Shiungchahsiang at Shiktung village's Datan (Big Bank); Tzaimui Division Lungshinghsiang at Pintai village's Ertan (No. 2 Bank); Wanghang village's Santan (No. 3 Bank); Lungtaiu village's Szetan (No. 4 Bank).

Haungshui River: Tuan District's Dahua wharf at Chu-lok Bank about 1 km; upper course of Haungdu at Lalu village's three shoals; from Shikpu village to Lungcha about 10 km at Yuwongshik (Fish-flourishing rock).

Chien River: Lungsing District, Hopin Division, Lungtoughsiang's Lungchik creek; Sanchiotsui and Shiklung Bank and Yunchiang.

Haungshui River Chien River: Laipin District's Li-lanma Bank bottom, Dalung No. 15 Bank, head of Chumhsiang Bank, Dayia, Wang Bank bottom, Tongchi wharf, Chiaukung, Tingtze Bank, Laipin wharf, Chengshiang wharf and Dapu.

Yu River: Within the Yiklin District; the bank at the border lines between Yiklin and Lungaun Districts; Nalung Division, Aunchihsiang at Lieu village's Lungshi Bank, Nanyenhsiang at Hwaliang village's Hwaliang Bank; about 2 km upriver from Kimlin township at Tulin Bank, near Tungnam township's big and small banks; Nakan Division near Tungnan township's Na-mai Bank, one km below the junction of Tso (left) and Yu (right) Rivers at Haungshik Point; below Haungshik Point at Paisha Point; below Paisha Point at Chungeh Bank; Laukao Division Datung township's Datung Bank; riverside of Tingtam at Kim-kai Railway station; Tungchow's Funtantao and Potantao; Shikfau township's ferry crossing Halungmu Bank; Pu-mau Division, Yinfookhsiang's Ping Bank, Lailung Bank and Chingsan pagoda bottom; and Lingli Division, Chongtong township 3 km upriver at Kaitsui Bank, Hayin Bank, Tungkua Bank and Liyuchi Bank.

Within the Wangshien District: Mancheng Division at Liucheong township from Yusian Rock upstream to Paisha Point at its lower course; from Mipu downstream to Ehchowwai at a place about 15 km from Wangchow to its upper course; from Chowwui downstream to Silutshang, at 5 km upstream from Wangchow.

Within Kweihsien District: from Datan bottom at Fupo to Chiangbiankang; Watang upstream from Tiandochi to Fuwupei; from Kweihsien upstream to Lomi Bank (about 500 m from the old sugar factory); Suwang downstream at Shakongwan; and from Tungpok to Shiklungkao.

From Tungtak to Shiktsui in Kweipin District.

In Pinnan District at Punlung near Pinnan township, slightly downstream at Kwanyinkok; and Yangchi Bank between Paima and Wulin.

The spawning grounds in the East River are mainly distributed near Lungchuan.

Han River: The spawning grounds in the Han River are mainly distributed from Hsiashik Bank in Dapu District to Fungshih township in Fukien Province.

Nandu River: In the Nandu River of Hainan Island, the spawning grounds are distributed within that section of river near Tingan.

Huai River: In the Huai River the important spawning grounds are located in Chenyangkwan at Mohokao and Lukaotze, in Fungtai District at Chengsankao, and near the Huai River bridge at Paung-pu.

Wuiyuen River: The important spawning grounds for Silver Carp and Grass Carp in the Wuiyuen River are located in Shantung Province, Kwentau District near Chingtewwan.

Songari River: The important spawning grounds in the Songari River are these: Pialung River mouth spawning ground (Chilin Province, Yungchi District, Pialung estuary's Ching village); Lungwangmeo spawning ground (Tekfui District, Chewyanghsiang, from Lungwangmeo to Chuchia ferry crossing); Shihpapun spawning ground (Yeeshu District, Chengchahsiang, from Hungshikloktze village to Laonewkang village); and Yinma River mouth (Tekfui District, Chichiatze-hsiang, from Pauchia village to Yinma River estuary).

Tsientang River: The important spawning grounds in the Tsientang River are located near Kientek District at Shema Bank, Wuihau Bank, Mayit Bank and Mashik Bank.

Spawning Behaviour and Schooling

Generally, in spawning schools of Silver Carp and Grass Carp under the stimulation of suitable ecological conditions for 20-30 hours, spawning behaviour will be seen at the spawning ground at the surface water in the middle of the river. A common sight is to see several females chased by males, which outnumber the females by several times, and which appear very excited, making splashes and sprays. The male fish bump against the abdomen of the female fish with their head, at times even squeezing the female fish out of the water, thus stimulating them to lay eggs. At this moment, both male and female fish are at their peak of oestrum, swimming vigorously against the currents and simultaneously releasing sperms and eggs. At times the brood fish suddenly stop swimming and lie on their backs, their pectoral fins shaking; they look extremely tired and are carried downstream by the currents (according to observations made in a fish pond, the brood fish still continue to lay eggs or to exude sperm). After a few minutes or more than ten minutes, the fish repeat their spawning activities, again swimming against the currents. Generally, the fish lay eggs two or three times.

Bighead have not been discovered to form spawning schools in order to spawn in the middle of a river. According to the fishermen in Shiklung, Kwangsi, Bighead spawn near the spawning ground of Silver Carp and Grass Carp in the bottom layer of the river water where the currents are slower, and where the fishermen usually catch the brood Bighead. It was observed that when Bighead spawn in a pond, they often prefer to chase each other during spawning, but they do not select places where the currents are too swift.

The sizes of a spawning school are not regular; they are generally related to the stimulative strength of hydro-meteorological conditions and to the timing of the spawning season. If the combined hydro-meteorological conditions are right, or if spawning occurs at the peak season, the spawning schools are generally larger (less than 100 fish); otherwise, they are quite small (from less than 10 to not more than 20 fish).

The sex composition of a spawning school is such that male fish usually outnumber female fish in absolute terms as shown in Table 18.

In big rivers, the body weight of the brood fish in the spawning schools is quite varied. For example, the Silver Carp of the spawning school in the Yangtse River are generally heavier than those in the West River by 4-6 times (Figure 16).

An Analysis of the Natural Environment of the Spawning Ground and of Spawning Ecological Conditions

Analyses of the natural environment of spawning grounds and of spawning ecological conditions have a certain meaning for present and future research on the application of ecological methods of controlling farm fish reproduction. When we proceed to design an artificial spawning ground, we must follow the conditions of the natural spawning ground; if we apply pure ecological conditions to stimulate the brood fish to spawn, we must also follow the hydro-meteorological factors of the natural spawning ground.

An Analysis of the Natural Environment of Spawning Grounds: An analysis of available data indicates that it is generally recognized that the elements of the natural spawning ground environment (excluding hydrological conditions) for farm fish are these: locality or position (most important), width, depth and bottom materials (substratum). We shall try to analyze these factors.

Locality: Many survey reports on natural spawning grounds indicate that the spawning grounds of farm fish are mainly located at the junction of two rivers (or the junction of a main river and one of its tributaries). The reason is that the hydrographic conditions at the junction of two rivers are generally more suitable to the spawning demands of farm fish, such as faster flows, deeper water, more complex hydrographic conditions, etc. Because of these conditions, great numbers of brood fish are easily attracted to spawn there. However, according to our analysis, the survey data on the West River show that the junction of two rivers does not constitute the requisite condition for a spawning ground, because we often found that the farm fish spawn at an ordinary river section and not at a river junction; in such cases, though, the fish were not as concentrated as those at the junctions. We observed the spawning of farm fish in an ordinary stretch of a river at Pingnan in Kiangsi Province, at Cheongshauhu Reservoir in Szechwan Province, and at Sheung River Reservoir (2,000 mu) in Hupeh Province. All the spawning was not taking place at the meeting points of two rivers.

Width: According to currently available data, there are vast differences in the width of rivers where farm fish spawn. For example, the spawning ground at Wachang in the West River has a width of 200-300 m; the Sanchiangkao spawning ground, about 300-600 m; and the Puyang River spawning ground, about 40-100 m. In many small rivers in Kwangtung Province, such as the Nanliu River and Nandu River, the spawning grounds are all less than

100 m in width. The width of the Hseung River Dam spawning ground in Hupeh Province is only 8-10 m, owing to the fact that it is situated at a narrow strait.

What is the exact lower limit of width for a natural spawning ground for farm fish? This is one of the questions worthy of attention. Because this matter will be one of the most important bases for designing artificial spawning grounds (if they are necessary in the future), it is also, to a certain degree, one of the points of reference for determining the possibility of natural propagation for farm fish in a reservoir or a small river. According to our analysis of recent two-year experiments on the ecology of natural spawning grounds for farm fish, the reason for failure could be, to a fairly large degree, that the size of the spawning pond was too small (130 m^2).

In the course of the experiment, we did our best to imitate every hydrographic and meteorological condition of the natural spawning ground - speed of flows, 0.5-1.5 m per second; greatest fluctuation of water level, 0.8 m; water temperature, 25-28°C; transparency of water, about 20 cm; pH, 7.4-8.0; dissolved oxygen level, generally over 5 mg per l. On the climatic aspect, we conducted experiments on clear, sunny and rainy days; and on the aspect of time (lighting), we did experiments in the morning, noon, evening and night. The results of the experiments showed that the brood fish reacted very favourably after being stimulated by the above mentioned combination of conditions. The quantity of male fish milt increased markedly; the abdomen of the female fish was very soft, almost reaching the stage of "touch and go" (lay eggs). But the fish in the experiments never spawned, They always swam against the currents near the water inlet, and sometimes they even tried to leap over the water inlet, as if they were looking for better places to spawn. After a preliminary analysis of these phenomena, we recognized that a spawning pond too small (width and length) in area could be one of the controlling factors for natural spawning of farm fish.

Depth: There are great differences in water depth in the natural river spawning grounds of farm fish. For example, the Chum River spawning ground in the West River is 10-12 m deep; the Sanchiangkao is 7-9 m; the Watong spawning ground is about 5 m; the Ichang spawning ground in the Yangtse River is over 30 m; at Puyang River in the dry season it is 1-3 m, and during floods it is 3-5 m; and the Hseung River Dam spawning ground is 2-5 m. According to this data, the minimum depth for a natural spawning ground is about 2-4 m. What is the exact lower limit for the depth of water in a natural spawning ground? This is also a very interesting question. In view of the special habit of Silver Carp and Grass Carp spawning in the upper layer of water, a water depth of 2-3 m might be able to satisfy their needs.

Bottom Materials: The bottom materials of farm fish natural spawning grounds are chiefly formed by gravel, rock and coarse sand. This is due to the faster speed of currents at the spawning ground, where the river bed is constantly being washed and where most of the soil has been carried away. It is only natural for the gravel and coarse sand to remain in the area. Our investigation shows that the bottom of some spawning grounds, such as the lower section of the Chum River, are also formed by loamy soil, or chiefly by loamy soil. Given the fact that Silver Carp and Grass Carp spawn in the upper layer of river water, we recognized that bottom materials may have very little effect on the spawning of farm fish.

Summing up the above, the natural conditions (excluding the hydrographic condition) of farm fish spawning grounds vary widely. There are great variations in the natural environment of spawning grounds in different rivers. In other words, not only is there a great amplitude of variation, but there are also certain inter-relationships; i.e., the environmental conditions of spawning grounds in big rivers are much more complex than those in small rivers.

In general, the above mentioned environmental conditions for spawning grounds, such as locality, width and depth, only provide, to a certain extent, the function of attracting brood fish, but do not have the function of inducing the brood fish to spawn. The conditions for the inducement to spawning from sexual maturity are the combined influence of hydrography and meteorology, which is analyzed below.

Analysis of Spawning Ecological Conditions: Our country is situated in the eastern part of Asia. The main special climatic characteristics of East Asia is that there are distinctive trade winds in summer and winter. In winter the cold and dry north or north-west winds blow; in summer the hot and humid south winds blow. The rainy season is concentrated in the summer. These special climatic characteristics have in turn formed the following special hydrographic features of all the rivers in our country: floods in summer, great variation in water level, rapid increase of flow capacity and flow speed, etc. Having adapted over a long period to these special hydrographic conditions, farm fish of our country have formed their particular propagation habits. In other words, they must be stimulated by the above mentioned combined hydrographic conditions in order to proceed to propagating.

On the basis of available data on various aspects, a preliminary analysis of the ecological factors of farm fish spawning follows.

Speed of Flows: To bridge over to the spawning condition (Stage V), farm fish at Stage IV maturity require the stimulation of a certain speed of water flow. This is recognized by all concerned to be a clear fact. But is the speed of flow an absolutely required condition for the spawning of farm fish? What amplitude is demanded? The questions of relationships with other factors are all worthy of investigation. According to survey data from various regions, the speed of flow at every farm fish spawning ground in the rivers is not at all uniform. For example, in the West River it is 0.67-2.22 m per second; in the Yangtse River at Ichang section, 0.78-2.26 m per second; in the Puyang River, 0.8-1.18 m per second; at the Changshauhu Dam in Szechwan Province, 0.45-1.1 m per second; at the Sheung River Dam in Hupeh Province, 0.6-2.0 m per second. These figures suggest that the minimum speed of flow is 0.45 m per second. Such a speed of flow is generally easy to imitate in an artificial spawning pond. However, in our experiments on ecological estrualization in the past two years, we have found that under artificially controlled conditions, the speed of flow alone could not provide the function of stimulating the brood fish to maturity and spawning (even though it reached the desired demands of the brood fish at their spawning time). As mentioned before, we tried using very high speeds of flow (1.5-1.8 m per second), and also combined them with other factors, such as a sudden rise in the water level, etc., to stimulate the fish to spawn, but our efforts failed. Evidently, the speed of flow is only one of the essential factors in the combination of spawning ecological conditions, but it is not the only factor (at least this is so under artificially controlled conditions). Moreover, in situations when other combined factors are suitably coordinated, such as when torrents run down from the hills after a downpour, the function of speed of flow at this time could only be rated as very unimportant. (This point will be brought up in a following paragraph which discusses mountain torrents.)

Water Level: Water level and speed of flow are interrelated factors; a fast speed of flow raises the water level. From an analysis of the data available at present, the change in water level may be one of the essential factors for stimulating the brood fish to maturity (from Stage IV to Stage V), but it is not an absolutely necessary factor. According to a discovery at a Yangtse River spawning ground by the Institute of Hydrobiology of Academia Sinica, when mountain torrents rush down near the spawning ground, even if the water level does not rise, the farm fish are still stimulated to spawn. When we did our investigation in the West River, many fishermen also confirmed this observation. According to survey data from various regions, during the spawning of brood fish the rise in the water level in many rivers was quite high, such as Ichang (Yangtse River), 0.5-1.41 m; West River, 1.33-2.67 m; Puyang River, 2-3 m; Sheung River Dam in Hupeh Province, 3-4 m. It seems, then, that if there were no mountain torrents occurring at the spawning ground, the sudden rise in the water level could have greater effects on stimulating the brood fish to maturity and spawning. From an analysis of the data, it seems that the rising in the water level in the small rivers has a more prominent effect upon the spawning of farm fish than that in large rivers. This may be due to the fact that small rivers are narrower and shallower than large ones, and so it is easier to effect good stimulation of farm fish.

Mountain Torrents: As mentioned above, if there is heavy rain in the vicinity of the spawning ground, mountain torrents can often induce the spawning of farm fish (fishermen in the West River and Yangtse River call the mountain torrents "life water"). It seems that the mountain torrents have a very distinctive function in stimulating farm fish to spawn. For example, when mountain torrents rush down, even if the water level at the time remains almost unchanged (in some cases it may even fall) and the speed of flow also remains the same as it was the previous day, farm fish are nevertheless stimulated and spawn. Table 19 reflects these phenomena.

In 1957 we conducted ecological estrualization experiments on mature (late Stage IV) Silver Carp and Bighead (Table 20). The experimental pond was situated at the outflow drain in Sin Lake (over 9,000 mu in area), Shaoching District, Kwangtung. A temporary spawning pond was constructed with a split bamboo fence; it was 9 m long and 3 m wide, had an average depth of water 2 m, and the bottom materials were crushed stones. Owing to the leaking sluice gate, the lake water always flowed into the experimental pond. When it rained, a great amount of rain water could also flow into the experimental pond from the nearby fields.

In mid-June the above test fish were released in the experimental pond. Because the water level in the West River was higher than that in Sin Lake, the lake water could not flow through the experimental pond and into the West River. Thus the experiment could not get started until the water level in the West River had dropped.

From early to mid July, there were torrential rains in the Shaoching area. The highest daily rainfall was 82.7 mm (Figure 17).

After every heavy rain, the water level in the experimental pond rose suddenly, and a certain speed of flow also occurred. On July 12 the brood fish were examined. One Silver Carp was discovered to have 5-6 mm of its ovaries protruding outside its body (Figure 18) with some eggs scattered on them. These eggs were very easily detached from the ovaries, and we took out a few hundred of them for artificial insemination. These eggs were able to absorb water and swell, but they were not normal; as a result they were not fertilized. The rest of the fish under experiment also showed good response. The amount of male fish milt increased, and the abdomen of females was softer than before.

A further examination on July 15 showed that the Silver Carp which had the protruded ovaries had basically recovered, and only about 0.5 mm of its ovaries were exposed.

On July 15 there was a heavy rain. On July 21 we examined the fish for the third time and found, to our great surprise, that that particular Silver Carp which had "already laid eggs" had exposed ovaries once again, similar to the first time. The changes in its body condition are shown in Table 21.

Although the above situation was not a normal spawning phenomenon, it clearly demonstrated that the complicated hydro-meteorological factors caused by torrential rains have a distinctive function in stimulating the spawning of Silver Carp.

Why did only one out of the three test Silver Carp respond? The reason may be that the remaining two fish sustained injury of the body and eyes during transportation. They were not so active. The response of the Bighead, though, was not as strong as that of the Silver Carp, but they did show, to a certain degree, good response.

Transparency: Transparency of water and speed of flow, or mountain torrents, are interrelated factors. When the speed of flow is strong, or when mountain torrents run down from the hills, the transparency is low. When farm fish spawn the transparency is generally 10-15 mm. For example, at the West River and Puyang River it is 10-15 mm; at the Yangtse River (Ichang), 6-16 mm; and at the Hseung River Reservoir, Hupeh, below 8 mm. Transparency during the entire flood period, that is, the reproductive season of farm fish, is generally very low and varies little. It seems that it has less effect on the spawning of farm fish than do the other aforementioned factors. However, from the nursing and protection aspects of some fish, transparency may have a certain influence on the spawning of farm fish. In the big rivers in our country there are many malignant fish which feed on eggs and fry. Fishermen in the West River commented that during the spawning period of farm fish there were often many carnivorous fish following the spawning school, as if they were waiting for the eggs. This may be one of the reasons that has forced farm fish to select spawning grounds with characteristics such as swift flowing water, sudden rises in water level, turbid water, or mountain torrents as a way of avoiding predators. Naturally, the special spawning characteristics of farm fish are also an adaptation chiefly for the pelagic eggs and fry.

Water Temperature: Water temperature is a very important influencing factor in the spawning of fish generally, and farm fish are no exception.

The temperature demands for farm fish spawning in nature differ slightly with locality. In the West River it is generally 25-30°C; in the Puyang River it is 20-28°C. Although water temperature is one of the essential combined factors for the spawning of fish, it cannot be regarded as the key factor in inducing mature farm fish to spawn. During the reproductive period of farm fish, the water temperature is always within the suitable (or desirable) range.

Weather: It seems that weather has a certain influence upon the promotion of the spawning of farm fish. As described previously, after torrential rains had fallen over the spawning ground, they always caused farm fish to spawn, although the factors which had directly caused the spawning of farm fish were mountain torrents, or speed of flow, and water level. Nevertheless, we cannot deny that the torrential rains may have caused the brood fish to begin their physiological preparation for spawning. The fishermen in the West River observed that, when heavy rain fell in the morning or at noon time and the sky cleared afterwards, then at dusk or early the next morning the farm fish often gathered to spawn. Naturally, if the hydrographic conditions had not changed to a certain degree, this meterological factor alone could not have caused the spawning of farm fish.

Lighting: According to observations by fishermen in the West River, farm fish gather to spawn at late dawn or at dusk. The rate of appearance of spawning at noon or at night is low. This may have some relationship to lighting conditions.

Dissolved Oxygen and pH: These two factors are similar to water temperature in that the spawning of farm fish can occur within a certain suitable range of these two factors. However, during the natural reproductive period of farm fish, these factors are usually within the suitable range: pH, 7.5-8; dissolved oxygen content, 5-8 mg per l. Therefore, it can be said that they too are not the factors that induce farm fish to spawn.

To summarize, the factors that induce the natural spawning of farm fish are of a combined nature. Their ways of acting in combination are also quite variable. Strictly speaking, any one factor alone will not induce farm fish to proceed to the spawning stage. Therefore, there is basically no necessity to differentiate between the individual ecological factors that constitute this combination as to their status or importance. For instance, if any one factor such as water temperature or dissolved oxygen content or pH has exceeded its suitable range, the spawning of brood fish will be restricted, even if the other factors are suitably matched. But, in the farm fish's reproductive period, factors such as water temperature, dissolved oxygen and pH are more stable and are generally considered to be of secondary importance. Other factors, such as the speed of flow, mountain torrents and water level, are more variable and show a more marked stimulating function on the spawning of brood fish; thus they are considered the primary inducement factors. When applied to the natural propagation of farm fish in big rivers, this analysis is quite reasonable. However, when such an analysis is applied in artificially controlled ecological estrualization experiments it seems insufficient to cover the whole situation. In this case, all combined factors should be equally considered in detail. As mentioned before, the reason for the failure of our ecological estrualization experiments in the past was, to a very large degree, that we neglected the important influence of other factors such as water body, space, etc. We had taken into consideration only the speed of flow and the water level.

In conclusion, in the reproductive period the gonads of farm fish have developed to the late Stage IV. Only if the combined external conditions begin to change at a certain time and to produce a certain degree of stimulating function will they in a short time help the fish to bridge over to the spawning stage. The combinations of these conditions are highly variable. If the stimulating intensity of one factor is high, the stimulating intensity of other factors may be reduced. For example, mountain torrents can largely replace water level and speed of flow. In general, the higher the stimulating intensity of the combined factors, the more concentrated the spawning of brood fish.

Judging from the situation discussed above, the use of ecological methods to control the spawning of farm fish should be possible, especially after the recent discoveries of spawning grounds at Changshao Lake Dam in Szechwan and at Hseung River Dam in Hupeh, which have clearly indicated that hydrographic conditions vary greatly in natural spawning grounds.

The reason that present ecological estrualization experiments fail may be because the area of the spawning pond is too small, resulting in a greater restriction of its stimulating function, or because the stimulating intensity of the combined conditions is too low. Since the success of artificial propagation of farm fish, a new stage in the rapid domestication of farm fish has begun. It can be predicted that in the not too distant future the use of ecological methods to control the propagation of farm fish in ponds will, and must, succeeed.

Reproductive Capability

An assessment of the reproductive capability of fish is generally based on their maturing age, sexual cycle, fecundity, effective production of eggs, and the survival rate of fry. In this section the emphasis is on fecundity and the effective production of eggs (under artificial spawning conditions). The other aspects have already been described in previous chapters.

Fecundity: In order to reflect the fecundity situations of each farm fish in various regions and different water bodies, we have selected some representative figures, as shown in Tables 22, 23, and 24.

For ease of comparison, the number of eggs per gram is taken as 700. The absolute number of eggs is the total number of eggs in one fish. The relative number of eggs is the number of eggs per gram of body weight.

Tables 22-24 show that farm fish bear a great number of eggs, and in many ways the eggs have similar characteristics. For example, the ovary coefficient is generally between 17-19%; the relative number of eggs is between 100-120; and the absolute number of eggs and the relative number of eggs generally increase with an increase in body weight. Among the three species of farm fish, Silver Carp bear the greatest number of eggs. The number of eggs borne by a fish does not differ markedly among regions, but relates more closely to culture management, i.e., chiefly feeding materials.

Egg Production Under Artificial Propagation: As noted, farm fish bear a great quantity of eggs, but exactly how many eggs can they lay (the effective egg production)? This question has practical relevance. In natural rivers, it is very difficult for us to get brood fish which are fully ripe and which have not yet spawned, so it is difficult to obtain accurate information on egg production. As a preliminary reference on this question, data on effective egg production under artificial propagation conditions are given in Table 25.

To summarize the relevant data given in Table 22-25 the egg release rate of farm fish (mature eggs leaving the ovaries) are shown in Table 26.

As indicated in Table 26, with farm fish under artificial propagation and using artificial insemination (TN: actually artificial stimulation) the first-time egg release rate was not high, averaging only about 45%. At present, many production units in Kwangtung have adopted the intensive culture method to hasten brood fish, after they have laid eggs (excluding some individuals which laid all their eggs), to lay eggs a second time. It seems that this is a very good method. (This will be discussed in more detail later.)

Embryonic Development

Embryonic Development of Silver Carp, Bighead and Grass Carp

The embryonic development process of Silver Carp, Bighead and Grass Carp is essentially the same. Silver Carp embryonic development will be described briefly as an example (see Plates II, III and IV).

Mature Germ Cells and Their Fertilization: Mature spermatozoa are composed of head, neck and tail portions. The head portion is spherical-shaped and has a diameter of 2.2-2.5 μm. The neck is also spherical-shaped, about 1.1 μm, and is small. The tail is fine and thread-like, with a length of about 3.5 μm (Plate I, 6).

Ripe ova are round and translucent and light green, blue-green or yellowish-brown in colour. Their diameter is 1.3-1.5 mm. They sink in still water, but are in semi-suspension in flowing water. The egg membrane is transparent, non-adhesive, and about 2 μm thick. The yolk is very large and yellowish. When eggs begin to ripen, the yolk material moves towards the animal pole. After the yolk is activated by water, the movement becomes faster, and the egg also begins to absorb water and swell. In 40-60 minutes, the egg membrane swells to its maximum capacity and has a diameter of 4.8-5.5 mm.

Experiments by the Experimental Biological Research Institute of Academia Sinica show that the fertilization of the ripe ova of Silver Carp takes place in the middle of the second maturity division. The spermatozoon enters the egg through the micropyle, and generally the egg is fertilized by one spermatozoon. Under a water temperature condition of 25°C, the star of the spermatozoon begins to form (at the late phase of second maturity division) five minutes after fertilization. The second maturity division ends about 10 minutes after fertilization. Twenty minutes after fertilization, the nuclei of the sperm and egg fuse and consequently form a zygote, thus completing the function of fertilization. The first mitotic division - the beginning of cleavage - appears in the fortieth minute.

The fertilization process of the ripe ova of Grass Carp is basically similar to that of Silver Carp.

Cleavage: Our observations of Silver Carp under water temperature conditions of 28.5-29.5°C show that 25 minutes after fertilization the blastodisc of the fertilized egg heaves upward (Plate II, 6), and that 35 minutes after fertilization it proceeds to the first mitotic division, the cell dividing equally along a longitudinal line into two cells (Plate II, 9). The second mitotic division occurs 46 minutes after fertilization. The cells divide again along the longitudinal line perpendicular to each other, into 4 cells of similar size (Plate II, 10). Fifty-four minutes after fertilization, the third mitotic division takes place. There are two longitudinal clefts which are parallel to the first cleft, and there are now 8 cells of nearly equal size (Plate II, 11). Sixty-one minutes after fertilization, the fourth mitotic division takes place. It also has two longitudinal clefts which are parallel to the second clefts, and it now has 16 cells (Plate II, 12), which are arranged in 4 parallel rows; the 4 central cells are slightly larger than the 12 surrounding cells. One hour and twenty minutes after fertilization, the fifth mitotic division takes place. There are 4 clefts which are parallel to that of the first and third. It now has 32 cells of similar size (Plate II, 13) arranged in 4 rows. The sixth mitotic division also has 4 clefts, resulting in 64 cells of different sizes (Plate II, 14). From then on the speed of cell division is not uniform. The cell sizes become smaller and smaller and are difficult to distinguish. The cells are piled together on top of the yolk, looking like a mulberry. It is called the morula (Plate II, 16).

Unfertilized ripe eggs, after they encounter water, show immediately the so-called "activating phenomenon". They can absorb water and swell and undergo abnormal cell divisions (Figure 19), but they generally collapse before reaching the gastrula stage (Figure 20). The characteristics of these so-called parthenogenetic eggs are as follows: the cells are irregular in size, the cleft faces are rather irregular, and cleavage speed and water absorption are slower than that of fertilized eggs. In view of this, the checking and counting of eggs for fertilization should not be carried out before the blastula stage.

Blastula: Two hours and twenty minutes after fertilization, cells at the placenta continue their divisions, forming layers. The line of demarcation of cells can still be vaguely distinguished, but the blastocoele, semi-circular in shape, is not yet formed. This is the early high blastula (Plate II, 17). Thereafter, the blastoderm layer gradually forms a central cavity - the blastocoele. Three hours and thirty-two minutes after fertilization, the blastoderm cells begin to extend downward to cover the cavity (about 1/3), and the blastoderm layer becomes flat - the flat blastula (Plate II, 18).

Gastrula Stage: Three hours and fifty-five minutes after fertilization, the blastoderm layer develops without interruption and reaches the equator. As a result of its inward coiling, its edge forms a thick ring, i.e., germ ring (Plate II, 21). At this time the embryo has entered the gastrula stage. After about 50 minutes, the cells at a certain spot on the germ ring become more concentrated and thicken, forming the embryonic shield (the dorsal side of the future embryo). This is the middle gastrula stage (Plate II, 24).

Five hours and fifty-two minutes after fertilization, the neural plate begins to form. The embryo has now entered the neurula stage. In a few moments, a rod-like notochord appears at the centre line of the neural plate, the anterior end of the neural plate expands to form the head, and two pairs of somites (or myotomes) also appear in the middle of the embryo (Plate IV, 35). The embryo now has three germ layers and the archenteron. These germ layers provide the origins of various organs.

Embryo and Formation of Organs: Six hours and forty-seven minutes after fertilization, the optic vesicles appear at the anterior and sides of the brain (Plate III, 37). The number of somites has now increased to 5 pairs.

Seven hours and fourteen minutes after fertilization, the olfactory plate appears. The origins of the forebrain, midbrain and hindbrain, in this order, also appear. The number of somites increases to 10 pairs (Plate III, 39).

Eight hours and ten minutes after fertilization, there are 15 pairs of somites. The optic vesicle caves in to form the optic ring (Plate III, 43).

Nine hours and seven minutes after fertilization, the auditory vesicles appear at the sides of the hindbrain. There are 17 pairs of somites (Plate III, 46).

Nine hours and forty-five minutes after fertilization, the tail bud appears. Following the development and extension of the tail bud, the round yolk-sac becomes elongated. There are 20 pairs of somites (Plate III, 48).

Ten hours and thirty-six minutes after fertilization, a crystal body appears in the optic vesicles. An oval-shaped branchial plate also appears beneath the optic vesicles. There are 25 pairs of somites. The embryo begins a slight twisting movement (Plate III, 51).

Fifteen hours and fifteen minutes after fertilization, the otolith appears in the auditory sac. There is more intense twisting movement by the embryo. There are 35-36 pairs of somites (Plate III, 54).

Sixteen hours and fifty-five minutes after fertilization, part of the embryo begins to hatch (Plate IV, 62).

Fry and Juvenile Stages: The development characteristics of the fry (or larvae) and juveniles of Silver Carp and Bighead are basically similar. The development process of Silver Carp fry and juveniles is described below.

Newly hatched Silver Carp Fry: total length, 4.9-5.2 mm; body, transparent; pairs of somites, 36-38; abdomen, filled with pear-shaped yolk; blood, light yellow in colour. The fry possess a preliminary form of brain, notochord, optic organ, auditory organ, olfactory organ, anus, intestine, anal fin and gill slits. They cannot eat; they depend on the yolk for nutrition. Nor can they swim. They can only wave their tails vigorously towards the water surface once every few minutes, and then they sink to the bottom slowly, lying on their back.

The first day after hatching: total length, 5.8-6.5 mm; somites, 40-42 pairs; yellowish brown pigments appear in eyes; pectoral fins appear; gill slits become conspicuous; fin folds are well developed; mouth slit ventrally positioned; yolk-sac is gradually shrinking.

The second day after hatching: total length, 7.5-8.0 mm; air-bladder begins to form, but not yet filled; yolk-sac, narrow and elongated; lower jaw now able to move; mouth moves to anterior position; pectoral fins are slightly larger, but have no bony rays; the fry begins swimming horizontally.

The third day after hatching: total length, 8.2-8.5 mm; air-bladder filled with gas; intestine completed in tube-form, slightly bent at the portion beneath the air-bladder; mouth anterior; gill-rakers conical in shape, 8-10 in number; yolk-sac almost totally absorbed; many colour pigments appear on body; the fry begin to feed on small zooplankton, such as Rotifers and the unsegmented larvae of Cladocera and Copepods.

The fourth day after hatching: total length, 8.7-9.4 mm; dorsal fin membrane upheaved, but with no bony rays; bony rays appear in caudal fin; posterior end of notochord slightly bent upwards; 26-27 gill-rakers in the first gill arch, 100 μm in length; thorn-like pharyngeal teeth also appear in the cortical layer of the mouth cavity; yolk-sac completely absorbed; feeding habit same as the previous day.

The fifth and sixth days after hatching: development situation basically similar to that of the previous day.

Seventh day after hatching: total length, 12-13.5 mm; caudal fin begins to fork; bony rays appear in dorsal and anal fins; ventral fins just begin to grow; air-bladder divides into two chambers, anterior chamber small and round, posterior chamber oval; gill-rakers increase to 30, 180 μm in length, with serrated lateral projections on two sides; first coil appears at anterior portion of intestine; principle foods are Cladocera, Copepods and Rotifers.

The tenth day after hatching: total length, about 18 mm; all fins except ventrals are more developed; caudal fin rays begin segmentation; swimming actively; number of gill-rakers increased to 54-59, with 33-35 lateral projections; intestine coils twice; feeding habit similar to that of the previous days.

The thirteenth day after hatching: total length, 24 mm; all fins are developed and appear like those of the adult; gill-rakers increased to 105-129; lateral projections well developed; ear-shaped thin membrane appears between the gill-rakers, which forms a connecting membrane for the inter-gill-raker slits (this is the bridge-over form of the sieve-like gill-rakers of the adult); intestine conspicuously elongated; principal food begins to change to phytoplankton.

The seventeenth day after hatching: total length, 27 mm; scales begin to appear; thin gill-raker membranes have mainly connected to each other and formed a sieve membrane; intestine more elongated; principal food is phytoplankton. At this time, the juvenile fish are similar to adults in both external appearance and internal structure.

The above observations on the development process of fry and juvenile fish were made under water temperature conditions of 28-29°C. The speed of development is largely related to the water temperature. When the water temperature is high, development is fast; when the water temperature is low, development is slow.

Ecological Conditions for Embryonic Development

The investigation and understanding of the ecological conditions for the embryonic development of fish and the provision of the most suitable conditions for egg hatching are the most important steps in improving the egg hatching rate.

Much work on the ecology of embryonic development of fish has been done by foreign scholars, especially by the Russians, who have done research on the embryonic development of sturgeons. Before Liberation in our country, there was no research on the ecology of embryonic development of the four farm fish. In recent years, though, many research institutions in our country have carried out work in this field, particularly the Shanghai Fisheries Institute. The results of research on the ecology of embryonic development of farm fish obtained by various research institutions in our country are discussed in the following subsections.

Dissolved Oxygen: Experiments have proved that the amount of dissolved oxygen consumed during the process of embryonic development varies with the stages of development. The amount of oxygen consumed reaches its peak before and after the hatching of the fry, especially during the fry stage, and gradually decreases thereafter, as shown in Tables 27-29.

Tables 27-29 show that when the tail appears during the embryonic stage of Silver Carp, the consumption of dissolved oxygen suddenly increases to twice the amount consumed in the earlier stage. When they grow to the fry stage, dissolved oxygen consumption reaches the peak of the life cycle, 8-10 times that of the earlier embryonic stage. Thereafter, oxygen consumption gradually decreases. This clearly indicates the importance of dissolved oxygen to the development of embryo. Silver Carp in the fry and embryonic stages not only consume their greatest amount of dissolved oxygen, but also have the least tolerance for a low-oxygen condition, as shown in Table 30.

Silver Carp in their embryonic stage consume more oxygen because of their physiological needs and respiratory processes (the exchange of gas with the outside), in which gas has to pass through a 2 μm thick layer of egg membrane and the fluid of the penivitelline space. Moreover, the embryonic yolk contains very little carotenoides, and the Silver Carp lack the ability to move and thus to avoid a low-oxygen environment. These facts explain why they cannot endure a low-oxygen condition and why they need suitable slow-flowing water for egg hatching.

After years of practice, farm fish artificial propagation units in Kwangtung, which score the highest hatching rate, have become concentrated at the Pearl River delta or near a reservoir, and all of them use flowing water for hatching. These water areas, such as the lower course of the Pearl River, have not only good quality and flowing water but also a high dissolved oxygen content. The dissolved oxygen content is 3.65 mg per l in summer and reaches as high as 8 mg per l in winter.

Water Temperature: The reaction of fish embryos to their thermal environment is largely a reflection of the species adaptation to thermal conditions in the development process. For example, the suitable temperature range for embryonic development of cold-water species such as Salmon is 3-14°C; however, for warm-water fish, such as the farm fish in our country, the range is 18-31°C. All these reactions determine the future suitable temperature range for their body development.

The speed of embryonic development of farm fish is similar to that of other fish. If other factors (dissolved oxygen, light and water quality) are normal, the speed of development is directly controlled by water temperature; i.e., at high water temperature, the hatching process is fast, and vice versa. For example, at 18°C water temperature a Silver Carp embryo takes 61 hours to hatch, but at 28°C it takes only 18 hours. If the water temperature is excessively high (nearing its upper limit), there is little difference in the hatching period. For example, at a water temperature of 27°C the hatching time is 19 hours and 10 minutes, while at 30.2°C it is 16 hours and 10 minutes. Thus a difference of 3.2°C in the water temperature results in a difference in the hatching period of only 3 hours. But when the water temperature is nearing the lower limit, the difference in hatching period is great. At a water temperature of 18°C the hatching period is 61 hours; at 22°C it is 35 hours; thus a difference of 4°C in the water temperature makes a difference in the hatching period of 26 hours (Figure 21).

The effect of temperature on the speed of embryonic development is more pronounced at the late stage (appearance of myotomes) than at the early stage (before gastrula).

The speed of embryonic development of the three farm fish is fairly fast, and of the three species, Silver Carp is the fastest, with Bighead and Grass Carp slightly slower.

Experiments have proved that at a water temperature of 15°C, the early-stage embryos of Silver Carp are able to develop very slowly; however, most of them stop half-way (mainly at the gastrula stage) and die. At a water temperature of 16°C, a portion of the embryo may still be able to proceed, but development is extremely slow and the deformity and mortality rates are very high. Although a small percentage of the embryos are able to develop to the "twisting" stage, most of them are unable to hatch, and the normal survival rate is very low. At a water temperature of 17°C, some of the embryos are able to hatch normally, but the survival rate is not high. At a water temperature of 18°C, the developmental process is generally normal, but the time required for hatching is longer. When the water temperature is 31-32°C, the majority of embryos can develop normally. According to a report by the Shanghai Fisheries Institute, at a water temperature of over 31°C, although the fish larvae are able to hatch, high mortality occurs during the fry stage, and very few can survive to the stocking stage. At a water temperature of 32°C, abnormal embryonic development occurs, and both mortality and deformity rates are extremely high.

Therefore, the upper and lower water temperature limits for embryonic development of farm fish should be between 18°C and 31°C. The most suitable water temperature range is 22-29°C. The best is 26°C, plus or minus 1°C. Under the most suitable water temperature range, both the efficiency of the hatching operation and the quality of the fry are high. According to preliminary observations, if sudden changes in water temperature occur during the course of hatching, (i.e., a change of plus or minus 6°C within a 30-minute period), no adverse effects on the normal development of embryos are noticeable.

Light: According to preliminary results obtained by the Shanghai Fisheries Institute, different colours of light have a great effect on the embryonic development of Silver Carp. Light-coloured light (white, pale-yellow and pale-red), especially white and pale-yellow light, gives good hatching results. Its effect on the egg-hatching rate is even better than that of natural light. Dark-coloured light (green, blue and red), on the other hand, gives very bad effects on the egg-hatching rate, reducing it to only about 40% of the compared (or controlled) rate (Figure 22).

Apart from the above, the Institute has also observed the effects on the embryonic development of Silver Carp of continuous darkness. In the first trial, the embryos developed to the "tail-appearing" stage; there was no more development after that and they died. In the second trial, about 45% of the embryos stopped their development at the twisting stage, and 15% of them hatched, although the deformity rate was high and the larvae died within one hour after hatching.

In the summer when light is strong, the water depth of the hatching box has a certain influence on the embryonic developing of Bighead. Experiments indicate that a hatching box placed 26.5 cm under the water surface results in a hatching rate about 30% higher than the rate achieved with a box placed at a depth of 16.7 cm, as shown in Table 31. (The difference is, in fact, due to light intensity, because water temperature and dissolved oxygen conditions are the same.)

The above experiments show that the embryonic development of Silver Carp and Bighead has an intimate relationship with the amount and intensity of light. It seems that their embryonic development requires a certain suitable range of light conditions, and will suffer undesirable results when light conditions are beyond that range. This special relationship reflects, to a great extent, the long history of adaptation of farm fish embryonic development to the turbid river waters. Therefore, it is very important to continue investigating the exact relationship between the control of the embryonic development period (such as night and day) and light in order to increase egg-hatching rates.

Predators: The results of research by the Applied Biological Research Institute of Academia Sinica indicate that the Water Flea (Thermocyclops oithonoides, Friesland) is a great predator of Silver Carp embryos and fry. The degree of predation is directly related to the period of contact and the density of water fleas, as shown in Tables 32 and 33.

Tables 32 and 33 show that water fleas are more dangerous to fry than to pre-hatched embryos. If there is one water flea in every 4 ml of water, they will cause great harm to the fry, but it would take 10 times that density of water fleas to harm the embryos.

We once placed 265 Silver Carp eggs and 8 small shrimps in a small container, and after 4 hours all the eggs were eaten by the shrimps. The experiment clearly indicated the serious danger that small shrimps pose to eggs.

Experiments conducted at the Shanghai Fisheries Institute proved that shrimp larvae, tadpoles and small fish are all very destructive to embryos. Five shrimp larvae of 1.5 cm body length can cause the injury and death of 20 embryos in 10 hours. Ten tadpoles can devour 200 embryos in 6 hours. Thirty-five Rasbora fry (Pseudorasbora parva) of 3 cm body length can eat up to 200 embryos in 5 hours and 30 minutes.

The above experiments clearly show that animal predators are extremely dangerous to fish embryos and fry. Therefore, in the egg hatching process the prevention of predators should be the first priority.

The Natural Resources of Farm Fish Fry

The most important regions for farm fish fry production in our country are the Yangtse River and Pearl River systems. Other rivers, such as the Amur River, Huai River, Tsientang River, Weiyuen River, Han River and Nandu River, are producing some fry, but their quantities are small and economically insignificant. The total production of farm fish fry in our country in 1957 was 234.05 billion.

As shown in Table 34, total fry production in our country in 1957 was 4 times higher than that in the pre-war year of 1936, which is recognized as one of the good years.

The production of Silver Carp and Bighead fry is more concentrated in the Yangtse Drainage area, such as in Anhwei Province, where Silver Carp and Bighead fry constitute 50% and 25-30%, respectively, of total fry production. In Kiangsu Province, Silver Carp and Bighead fry combined total about 25-30% of production. Hupeh Province produces mainly Silver Carp fry.

The species of farm fish fry produced in the West River (Pearl River system) are mainly just the opposite of those produced in the Yangtse River. While Silver Carp and Bighead fry production is small, Mud Carp fry production in the West River is large. The second largest is Grass Carp fry production (Tables 35-37).

Apart from the West River, where farm fish fry are produced in great quantities, other rivers in Kwangtung Province, such as the Han River, North River, East River, Nanliu River and Nandu River, also produce farm fish fry, but the quantities and species produced in them are far less significant than those produced in the West River, as shown in Table 38.

Table 38 indicates that with the exception of the West River, rivers in Kwangtung produce only very small amounts of fry, and their species ratio is much different from that of the Yangtse and West Rivers. These rivers produce predominantly Mud Carp fry, which constitute about 95% of total fry production. Silver Carp and Grass Carp fry each make up about 2% of production. Bighead fry are produced only in the East River, but are few in number, constituting just about 0.046% of output.

On the production of adult fish, the West River, especially at its middle and upper courses, produces mostly Mud Carp, which constitute about 30-40% of the total fish production. Grass Carp production makes up about 10-20%. Silver Carp and Bighead are produced at the lower course in the delta area and account for about 5-10% of the total fish production.

On the production of fish ponds, according to statistics provided by the Kwangtung Fisheries Products Supplies Company, Silver Carp and Bighead constitute some 50-55% of total pond-fish production; Mud Carp, about 30-35%; and Grass Carp, 10-15%.

On production in reservoirs, Mud Carp make up the biggest share of total output, followed by Silver Carp and Bighead, with Grass Carp and Common Carp in third place. Table 39 gives figures on fish production in the Hupsui Reservoir.

CHAPTER II

ARTIFICIAL PROPAGATION

Rearing of Brood Fish

The material basis that determines success in the artificial propagation of fish is the ability to produce large quantities of good quality, mature brood fish. Therefore, the rearing of brood fish is most important and is the decisive link in the artificial propagation of farm fish in ponds. Although Silver Carp, Bighead and Grass Carp are now able to reach sexual maturity (male fish, Stage V; female fish, late Stage IV) in ponds, wild rivers and reservoirs all over the country, there are considerable differences in their gonadal development at different latitudes, or at the same latitude but under different rearing methods, or in different water bodies. At the same time, we should be able to use the most logical method for rearing brood fish so that we can effectively influence the maturity stage and maturity rate of brood fish. Furthermore, we should also be able to influence their egg-laying rate, egg-hatching rate, and even fry survival rate. Therefore, the methods used for rearing brood fish must conform to the basic rules of farm fish biology so as to achieve our aims of early maturation, high maturity rate and vigorous reproductive power in brood fish.

Conditions for Selecting Rearing Pond and Pond Site

A fish pond is the living environment of fish. Its condition has a direct influence upon the growth and development of farm fish and is related to the economic returns of the business. Therefore, when selecting a fish pond and site for rearing brood fish, careful attention should be paid to the following conditions.

Site: A selected site should satisfy as far as possible several conditions. It should have a good water source. There should be no danger of flood or drought. It should be within easy reach of communication links. The soil should retain water well and be easy to work. The ponds should be concentrated for easy management and should be in an open space with good sunshine and a rather peaceful environment.

Area: The area required depends on the scale of production. If conditions allow, the ponds should be divided into two types: brood fish ponds and reserved brood fish ponds. The former should be bigger in area, 6-15 mu, for the benefit of growth and the fattening of farm fish. The reserved brood fish ponds are for ease of catching fish and controlling water quality; their suitable area is 3-6 mu. Grass Carp favour clear, fresh water, so the fertilization of the pond water is not necessary; the pond area can be larger, provided it will not cause difficulty in catching fish. Bighead have more endurance in fertile water, and their natural food (zooplankton) is propagated in large quantities in fertile water. Therefore, the area of the Bighead pond can be smaller.

Ponds over 5 mu in area should be rectangular in shape for ease of catching fish.

Depth of Water: Water in the reserved brood fish ponds should be deeper and be maintained at 2-3 m, for the purpose of fattening. Brood fish ponds can be 1-2 m deep. In the autumn fattening period, the water should be deeper; in the gonadal development period in spring, the water should be shallower.

Bottom Materials: The bottom of ponds must be flat, especially those for Grass Carp, or for a mix of Mud Carp and Common Carp, because these fish usually hide in the cavernous parts or holes when frightened and are not easy to catch.

The bottom materials of Bighead and Silver Carp ponds should consist of some humus to ease the adjustment of water fertility. In general, the recommended thickness of soft mud at the pond bottom for Bighead is 30-40 cm; for Silver Carp ponds it is 20-30 cm. Fishermen in Kwangtung consider the so-called pond-bottom cultivation very important for increasing fertility in water. But the humus layer cannot be too thick, because it would often degrade the water quality in the pond during summer or in unfavorable weather. A good Grass Carp pond should have little humus.

Water Quality: Silver Carp, Bighead and Grass Carp, like other fish, demand good-quality water in all stages of their development. Because of their feeding habits, Bighead and Silver Carp, demand fertile water for the propagation of plankton in great quantities. Therefore, we should use lean-water ponds with slow-flowing water mainly for rearing Grass Carp, ponds with medium fertile water for Silver Carp and Grass Carp in principle, and ponds with fertile water mainly for Bighead.

Treatment of Pond Before Stocking

Pond Clearing: Ponds with excessive silt and decayed food deposited at the bottom must be properly cleared before stocking. The reason is that these sediments decompose rapidly when the water temperature becomes high and produce such poisonous materials as organic acids, hydrogen sulphide and methane (marsh gas). Ponds which had dead fish in them should be disinfected to prevent the disease from recurring. Grasses and other aquatic plants growing at the pond edge should be cut frequently (with the exception of Grass Carp ponds). Snake and rat holes should be plugged.

After a pond has been repaired, select a clear day to disinfect the pond in order to kill off the remaining germs and predators in the pond. Quick lime and tea-seed cake are generally used for pond clearing or disinfection. If the former is used in ponds equipped with sluice gates, the depth of the pond water should be lowered to 6-10 cm, then a thick quicklime solution spread on the pond; thus the lime is distributed evenly in the pond water and the amount of the lime used is considerably reduced as well. Generally, the amount required is 70-75 kg per mu; for ponds with less silting the amount needed is 50-70 kg. For ponds without a good water source, a thick lime solution can be spread directly. The dosage is

3 cubic m of water to 1 kg of quick-lime (222 kg to 1 m mu of pond water); i.e., a concentration of 138-210 mg of calcium hydroxide to 1 litre of water will be produced, and that will kill the wild predatory fish and harmful bacteria. The normal practice is to dig a small pit at the bund side, put the quick-lime in the pit and add water. As soon as the lime is dissolved in the water, and while it is still hot, the solution is spread evenly in the pond. Using another method, the quick-lime is put in a basket and hung in the water at the side of a small boat. When the lime has dissolved, the small boat is moved and at the same time the basket is shaken so that the lime solution is spread in the water. Eventually, the bottom mud is stirred with a rake in order to accelerate the disintegration of the lime which has settled on it. After the application of the quick-lime, the hardness of the water and the calcium ion concentration in the water will rise gradually. One to four days after liming, the total hardness is generally over 7; thereafter it will fall and generally remain within a range of 5-8. The pH value varies from 7 to 11, showing a weak alkaline property. This water quality is very suitable for growth and development of farm fish.

Tea-seed cake is the residue of tea seeds after the oil has been extracted. The tea seeds come from tea plants, namely, Camellia oleosa, C. sasanqua or C. semiserrata. They contain insecticide called Saponin ($C_{32}H_{54}O_{18}$). For pond clearing purposes, the dosage used is generally 20 cubic m of water to 1 kg of tea-seed cake (3.3 kg to 1 m mu of pond water). The tea-seed cake is crushed into fine grains and immersed in water for 24 hours. The solution together with the residue is placed in a small boat in the fish pond, and more water is added to the solution, which is then spread evenly in the pond.

Using quick-lime for pond clearing not only destroys parasites and germs and reduces the chances of an outbreak of fish disease, but also improves to a certain extent the quality of bottom soil and increases the calcium fertilizer (liming should not be used in ponds with alkaline bottom soil). The disadvantage is that when used in ponds deeper than 1 m, it may not kill the wild fish totally and the amount required is quite substantial. Tea-seed cake is more effective in killing wild fish, but is not so effective in neutralizing the acidity in the humus and in preventing the spread of fish disease. In order to compensate for the shortcomings of using tea-seed cake, after a pond is cleared and 10 days before stocking, quick-lime can be applied to the pond at the rate of 15 kg to 1 m mu of water to increase the average total hardness of the pond water from 3-4 to 5-7.6 (generally 10 mg of quick-lime added to one litre of water will increase the water hardness 1 degree and will kill off the wild fish and improve the water quality).

Water Quality Adjustment: If the ponds are to be used for rearing Silver Carp and Bighead, fertilizer should be applied after clearing to adjust the water quality. Human night-soil and urine, green manure and various kinds of oil-seed cakes are often used.

The amount of fertilizer to be used depends on the amount of humus in the pond bottom; generally, 150-250 kg of night-soil and 300-400 kg of green manure are used for 1 mu of pond. The method of application is as follows. The fertilizer is placed in the pond (water, 30-40 cm deep), and exposed to strong sun-light for 3-5 days in order to accelerate decomposition. Then fresh water is let in. The water inlet should be screened with fine-mesh net or split bamboo fence to prevent the entrace of wild fish. After another 3-5 days, plankton will appear in the pond in large quantities. The physical, chemical and biological indicators for ideal pond water are these: organic matter oxygen consumption, 15-25 mg per l; transparency, 30-35 cm; phytoplankton, 3,500,000-4,500,000 per l; zooplankton, 25,000-40,000 per l; pH, 7-8; and minimum dissolved oxygen content, above 2.5 mg per l.

Rearing of Silver Carp and Bighead Brood Fish

Practical Examples of Rearing Silver Carp and Bighead Brood Fish and an Analysis: In order to describe and compare the methods of rearing Silver Carp and Bighead Brood fish, several practical examples, which are quite typical of the methods used for this purpose, are listed in Tables 40 and 41.

On the basis of the results shown in Tables 40 and 41, a preliminary analysis is given below.

Water Type: Table 40 shows that for the purpose of gonadal development of Silver Carp and Bighead a water type with intermittent inflow of "new" (fresh) and good quality water is considered best. For example, the No. 4 pond at the Southsea Fisheries Research Institute is where Silver Carp and Bighead grow rapidly and have a high maturity rate. Another example is the No. 11 and No. 12 Ponds at the Chekiang Freshwater Fisheries Research Institute, where brood fish are reared (the fish in the two ponds are identical in age and size, so the fertilization conditions can be compared.) In Pond No. 11, owing to the intermittent inflow of new water, 100% of the brood fish mature. In Pond No. 12, because the water is not changed properly and is of bad quality, the Silver Carp brood fish do not mature. The contrast between these two ponds is very distinct. However, we should not regard still-water ponds as bad for the gonadal development of Silver Carp and Bighead. Experiments have proved that generally brood fish will develop normally and attain maturity in still-water ponds if the water is not too fertile (polluted), such as the No. 1 and No. 2 Ponds at the Southsea Fisheries Research Institute, which are still-water ponds. The brood fish maturity rate in these ponds is only slightly lower than that of the No. 4 Pond.

Area: Table 40 indicates that the area of a rearing pond has very little effect upon the gonadal development of Silver Carp and Bighead. In ponds from 2 or 3 to 40 mu in area, all the brood fish are able to develop and reach maturity. However, to facilitate the controlling of water quality and the catching of fish, the pond area should not be too big; 3-6 mu is more suitable.

Stocking: Because Silver Carp and Bighead feed on plankton, which have a certain production rate in a given area of water, the amount of food available for the brood fish in a pond that is over-stocked will be relatively reduced. Table 40 indicates that in the rearing pond of the Experimental Biological Research Institute at Shangyuen, which has the highest stocking density of 25 brood fish per mu, the growth rate of Silver Carp in the pond is not satisfactory, but their gonads are well developed. Many experiments show that when the stocking density is just right, brood fish grow rapidly and develop well (both the maturity rate and the egg quality are high). In general, the standard stocking rates for brood fish are these: Silver Carp (principal species), 10-20 fish per mu (can mix with about 10% Bighead); Bighead (principal species), about 10 fish per mu (can mix with 1-2 Silver Carp).

Fertilization: Table 40 shows that organic manures, whether human or animal dung and urine or a mix of green manure and cow dung, give a very high maturity rate to Silver Carp and Bighead.

The rearing practices of the Southsea Fisheries Research Institute and of many other communes in Kwangtung indicate that the fertilizer that is more suitable for Silver Carp ponds is mainly green manure mixed with night-soil. It will provide better water quality (not easily polluted) and at the same time produce a good amount of phytoplankton, especially those that are easily digestible. Bighead ponds require the mass production of zooplankton, and so more human night-soil can be used. In short, the fertilizers used should be of many varieties to provide greater assurance that every fertilizer element needed is in the pond.

The amount of manure used varies according to the place. At the Southsea Fisheries Research Institute the amount of manure used in the experimental ponds is quite small, averaging about 500-750 kg of mixed manure per mu per month. The highest amount of manure used is in the experimental ponds at the Chekiang Fisheries Research Institute, where the average amount per mu per month is about 2,500 kg plus about 11 kg of superphosphate. It seems that the amount of manure used at the Chekiang Institute is somewhat excessive because the water in No. 12 Pond becomes polluted (TN: entrophication) when the water is not refreshed at the right times. Such conditions are not conducive to the growth and development of brood fish. On the other hand, the No. 1 and No. 2 Ponds at the Southsea Fisheries Research Institute are also still-water ponds. Because the amount of manure used is not excessive, the water quality remains good throughout the year. The quantity and quality of plankton as well as the gonadal development of brood fish are normal. In view of the above, the amount of manure used should be based on the total condition of the pond, such as the water quality, stocking situation, weather and other factors. A rate of 800-1,200 kg per mu per month is considered more suitable.

Water Chemistry: Among all the factors of water chemistry, the fertility and dissolved oxygen content of water have the greatest influence on the growth and development of Silver Carp and Bighead.

The main chemical indicators of water fertility are organic matter oxygen consumption and nitrate and phosphate levels.

Table 41 shows that the pond with the highest fertility is the experimental pond of the Experimental Biological Research Institute (organic matter oxygen consumption, 26.525 mg per l; nitrate, 0.398 mg per l; phosphate, 0.627 mg per l). The pond with the lower fertility is the No. 4 experimental pond of the Southsea Fisheries Research Institute (organic matter oxygen consumption 8.622 mg per l; nitrate, 0.0999 mg per l, phosphate, 0.198 mg per l).

Those two experimental ponds are similar in water type; for instance, they have intermittent inflow of river water and are fairly small. The only differences are that the water in the Southsea Fisheries Research Institute pond is of better quality, does not have excessive fertility, and has a lower stocking intensity. Experiments indicate that there are big differences in the growth rate of Silver Carp brood fish in these two ponds, but the maturity rate is about the same. See Table 42.

Table 42 suggests that excessive fertility in pond water and high stocking density are not favourable to the growth of farm fish and that they often cause the early maturation of small individuals.

The chemical indicators of correct fertility are yet to be decided because of a lack of experimental data and because it is a rather complicated matter. However, Table 41 shows that their amplitudes are rather large: organic matter oxygen consumption, 8.6-26.5 mg per l; nitrate, 0.09-0.39 mg per l; phosphate, 0.027-1.57 mg per l.

Plankton: Because Silver Carp and Bighead feed solely on plankton throughout their life, the quantity and quality of plankton in the pond have determining effects upon their growth and development.

Table 41 shows, preliminarily, that the quantity of phytoplankton in the experimental ponds of the Southsea Fisheries Research Institute and the Chekiang Fisheries Research Institute is basically the same. It seems that the correct quantity of phytoplankton should be 3,000,000-4,000,000 individuals per l, 50-70% of which should comprise digestible species; the quantity of zooplankton should be 20,000-30,000 individuals per l.

There is often a certain adverse relationship between an absolute increase in the quantity of phytoplankton and the quantity of digestible phytoplankton species. In a fertile water area, phytoplankton can propagate in great quantities, but the digestible species often occur in relatively lower numbers. In other words, the absolute increase of phytoplankton quantity is in direct ratio to fertility; however, a relative increase of the digestible species group does not generally require fertile water. In order to describe this phenomenon, the relationships among various water types, fertilities and quantity and quality of phytoplankton are listed in Table 43.

Table 43 shows that in a water area of low fertility, both phytoplankton and zooplankton are low in quantity, but that the phytoplankton quality (digestible species group) is relatively higher. In contrast, in excessively fertile still-water ponds, both phytoplankton and zooplankton quantities are very high, but the quality of digestible phytoplankton is relatively lower. These results, along with much practical experience, indicate that the water quality in a Silver Carp pond should not be too fertile, but for Bighead the pond water fertility can be much higher in order to produce zooplankton food; phytoplankton (including blue-green algae), bacteria and organic particles can appear in great quantities only in water of high fertility.

Major Arrangements for Rearing Silver Carp Brood Fish:

Stocking: Recommended stocking rate is 15-20 Silver Carp brood fish per mu. Each fish should be 2.4-4 kg in body weight. The total weight of the fish should be about 50 kg.

In addition to the Silver Carp, 2-3 Bighead should be released to control the production of excessive zooplankton. It is best to use male Bighead. There should also be 10-15 Grass Carp (reserved brood fish or brood fish), 40-50 kg in total weight, so that every space in the pond is fully utilized, and the fertility and movement of the water body are improved. There should be 50-100 Mud Carp having a total weight of 15-20 kg (either food fish or brood fish; Mud Carp can be replaced with male Common Carp) and 20 Common Carp weighing 5 kg. Finally, there should be several carnivorous fish such as Red-eye Chuan (Sgualiobarbus curriculus) and Bass (Siniperca chuatsi). The total stocking weight is 120-140 kg per mu.

The mixed or separate rearing of males and females has no distinctive influence on the gonadal development of the fish. Separate rearing is easier for the arrangement of feeding and fertilization, because during their gonadal development period male fish require less food and good water quality. However, separate rearing increases the number of fish catching operations. This is a disadvantage.

All selected brood fish, either reserved brood fish or ones reaching maturity in the same year, should be big individuals, because big brood fish have a good growth foundation and generally bear more eggs and produce better quality eggs. Further, strong fish have a good body-form and are never infected with disease.

Culture Management: Culture management centres upon fertilization and water quality adjustment. The mass production of food for Silver Carp requires fertile water. Some people consider that the maintenance of good water quality and high fertility simultaneously poses a contradiction which is very difficult to resolve. However, this is not so in practice. In general, the timely application of fertilizer in a suitable quantity together with the timely intake of new (fresh) water will solve the problem completely. The ecological condition for the propagation of digestible phytoplankton, e.g., golden brown algae, yellow-green algae, Peridinium and diatoms, generally demands fresh and clear water, water not excessively high in fertility, especially in nitrate. These ecological conditions and the ecological condition needed by Silver Carp for growth and development are not basically contradictory. Therefore, when reared in water areas with good water quality and optimum fertility, Silver Carp grow and develop particularly well. Once these ecological conditions are understood, the rational application of fertilizer should not be difficult to carry out.

Fertilization: In rearing Silver Carp brood fish, fertilization, supplemented by feeding, is of primary importance. The main fertilizer used is green manure supplemented by night-soil or other manures. The amount of fertilizer required for one mu of pond is generally 50-100 kg of green manure and 30-50 kg of night-soil applied every 4-5 days. Green manure is placed in the pond in piles or lineal piles; night-soil is generally spread in the pond. In endeavouring to achieve more rational fertilization, the following factors should be wisely used as guides:

Season: Owing to the higher water temperature in summer, fertilization should be strictly controlled in order to prevent "flood pond" (the mass mortality of fish due to oxygen deficiency). In spring and autumn, the water temperature is favourable, so these are the seasons for the best growth and development of fish as well as for natural food production. Fertilization should thus be more frequent (for South China region).

The colour and transparency of water reflect to a certain degree the quantity of plankton in it, the composition of various species groups, and the fertility of the water body. If the water colour is too blue-green and if the transparency is low (below 30 cm), this indicates excessive fertility. The non-digestible, blue-green algae dominate the pond water, and fertilization should be less frequent or stopped and some new water should be let in. Good water is coloured pea-green, yellow-green, yellowish-brown or light soy-sauce colour; these colours indicate optimum fertility, good water quality, and a better composition of the planktonic groups. Suitable transparency in a still-water pond is generally 30-35 cm; higher or lower than this is not suitable. When the water colour turns pale and the transparency increases, more fertilizer should be added to the pond.

Dissolved oxygen content: As mentioned in the previous chapter, when the dissolved oxygen content drops to about 1 mg per 1, farm fish stop feeding and begin to surface. In practice, the lower limit of dissolved oxygen content is indicated by inspecting the pond at dawn. If there is no surfacing of the pond fish or only slight surfacing (when frightened or when the sun comes up the fish will stay under the water surface), this indicates no oxygen deficiency. If the fish continue to surface, fertilization should be stopped immediately and a suitable amount of new water should be let in.

Weather: In hot weather or on cloudy days or under low atmospheric pressure, fertilization should be less frequent or stopped.

Furthermore, when Grass Carp are used in polyculture, fertilization can be reduced because the fish produce a fair amount of dung and food residue. This explains very clearly this maxim of fish culture in our country: "one T'sao (Grass Carp) feeds three Lien (Silver Carp)".

Feeding: Generally, if the pond water is sufficiently fertile and the stocking density is proper, the feeding of Silver Carp is seldom necessary. But under adverse situations, artificial feeding is necessary. The most common feeds used in Kwangtung are rice bran and wheat bran. The amount of feeds used should be based on the growth and development of the fish, the stocking density and the availability of natural food. In general, the amount of feeds given each day equals 1-2% of the total weight of the Silver Carp. For example, the fish at Lilok Farm in Sinfui District (Kwangtung) are fed additional rice bran during the fattening stage (autumn), about 60 g for each brood fish.

If Grass Carp are used in polyculture, the amount of fodder grass required by the Grass Carp per day is about 30-50% of their total body weight. If the Grass Carp are brood fish or reserved brood fish, a further 2-3% (of total body weight) of fine food - rice bran, wheat bran, silk-worm pupae, bean cake and corn flour - should be given.

For Mud Carp and Common Carp in polyculture, additional feed is not necessary. They can feed on benthos and other food residue.

Water Quality Adjustment: It has been pointed out previously that Silver Carp and their natural food both require good water quality. Thus, in the culture process, depending upon the water quality, composition of planktonic groups, activity of pond fish, weather and seasonal factors, new water must be added to the pond at certain intervals. The general method used is to let in new water at 1-2 week intervals, each time letting in from 1/5 to 1/4 of the total water capacity of the pond. In the following situations, more water should be let in and more frequently: when the water is overly fertile; when it has a low dissolved oxygen content; when there is abnormal surfacing of farm fish; when the water has low transparency; and when non-digestible groups of phytoplankton dominate. The amount and the frequency of the water let in should be greater in the summer, decreasing gradually from autumn to winter. The letting-in of water should begin in early spring and continue with increasing frequency. Especially when the gonads of brood fish have fundamentally developed, the amount and frequency of water let in should be further increased in order to hasten the brood fish's gonadal development and maturation. Generally, in ponds of larger size (over 10 mu) and with some underground water seeping in, the water intake and frequency can be less, but the water depth should be maintained at a reasonable level.

Pond Fish Examination: The frequent examination of the pond fish should be avoided as far as possible. The reason is that the catching operation has adverse effects on the growth and development of pond fish, especially on brood fish injured during the catching operation. Generally, two examinations can be made. The first is in late autumn, when the pond fish are transferred into the wintering pond, or at the time of pond clearing, when the fish are transferred to other ponds. At this time the fish's growth condition can be examined so as to determine future culture arrangements for the fish. The second examination is in early spring, when the brood fish are graded (according to their degree of growth and development) for culture in separate ponds.

Major Arrangements of Rearing Bighead Brood Fish:

Stocking: For one mu of pond, stock 7-10 Bighead brood fish with a body weight of 5-10 kg and a total weight of about 50 kg. Apart from Bighead, other fish can be mixed in the pond: 1-2 Silver Carp brood fish (there should not be more than this number, because an excessive number of Silver Carp will have an adverse effect on the Bighead brood fish); about 10 Grass Carp (reserve brood fish or food fish) with a total weight of about 20-30 kg; and about 100 Mud Carp 1/3-1/2 kg in body weight and with a total weight of about 40 kg. If Mud Carp are not used, they can be replaced by 100-200 male Common Carp, each over 250 g in body weight, and several carnivorous fish. The total stocking weight per mu is 100-120 kg.

The topics of mixed or separate rearing of males and females and the conditions for brood fish selection are similar to those of Silver Carp.

Culture Management: The main management considerations for Bighead brood fish culture are basically similar to those for Silver Carp, i.e., the timely intake of new water and the suitable application of fertilizer. However, the feeding habits of Bighead are basically different from those of Silver Carp. The former feed mainly on zooplankton, which in turn feed mainly on bacteria, phytoplankton and organic particles. Bacteria and phytoplankton (including blue-green algae) demand these ecological conditions: fertile water, a relatively still water body, higher water temperature and ample sunshine. Therefore, in the mass production of food (zooplankton) for Bighead, the water should be sufficiently fertile and not be flowing or changed too frequently.

Fertilization: For the mass production of bacteria and phytoplankton so as to raise the propagation rate of zooplankton, the fertilizers used should be those organic manures comprised of more nitrogen and phosphorus elements, such as manures (human night-soil, animal dung and urine), oil cakes (soy-bean cake, ground-nut cake and vegetable-seed cake), sundry fertilizers (fish meal and soy-sauce residue), and all kinds of green manure. If Grass Carp are not included in the polyculture, raw sewage water and even decomposed garbage can also be used.

Fertilizer should be applied intelligently in accordance with water quality, dissolved oxygen content, plankton quantity, seasonal factors and water colour. Generally, every 4-6 days apply 60-100 kg of night-soil and 30-40 kg of green manure. Fish farmers in most areas in Kwangtung use these two kinds of manure and obtain excellent results. Some individual areas also use some oil cakes for fertilizer.

Feeding: Under conditions of suitable water fertility and stocking density, Bighead seldom need feeding. But in adverse conditions, some rice bran and wheat bran are used as additional feeds. The amount used is about 2% of the total body weight of the Bighead.

If Grass Carp are used in polyculture, they must be fed a sufficient amount of grasses every day.

With Mud Carp and Common Carp, no feeding is necessary, because benthos and food residue are generally more plentiful in the Bighead pond.

Water Quality Adjustment: Because more manure is needed for production of zooplankton, and because Bighead are more tolerant of fertile water, the water fertility of the Bighead pond should be higher than that of the Silver Carp pond. But the timely intake of sufficient new water is still a necessity. Especially because the over-application of organic manure and the pollution of water quality can easily occur, more attention should be paid to changing the water. The ecological conditions for the gonadal development of Bighead and Silver Carp do not seem to be much different from the aforementioned rearing practices of Silver Carp and Bighead brood fish. However, there are some differences. For instance, in a big bo y of fairly lean water, the gonads of Silver Carp can generally develop and reach maturity, but on many occassions Bighead cannot develop to maturity or mature very late. In some small brood fish ponds for polyculture of Bighead and Silver Carp, such adverse phenomena would also appear if the stocking density or the proportion of Silver Carp was too high.

To summarize, in rearing Bighead brood fish one should intelligently use the contradiction of the following two maxims of fish culture in Kwangtung: "water old (meaning polluted), fish never big" and "lean water, never big head (Bighead)" (meaning Bighead will never grow well in lean water). We should reconcile the two contradictory requirements through water quality adjustment and fertilization. Lastly, it must be strongly emphasized that in rearing either Silver Carp or Bighead, if a good water source is lacking, one should select a bigger pond and at the same time apply a small amount of fertilizer more frequently, or reduce the amount of fertilizer so as to avoid the sudden deterioration of water quality and being trapped in a helpless and passive situation.

Rearing of Grass Carp Brood Fish

Practical Examples of Rearing Grass Carp Brood Fish and an Analysis: To facilitate a comparison of the rearing methods for Grass Carp brood fish, various rearing methods which are used in Kwangtung and which have achieved fairly good results are listed in Table 44.

A preliminary analysis of the methods listed in Table 44 follows.

Water Type: Table 44 shows that when Grass Carp brood fish are reared in fertile water, in sufficiently fertile still-water ponds, or in ponds with a frequent intake of new water and good quality lean water, all the fish are able to develop to maturity. However, comparing their effectiveness, the ponds with good quality water and an intermittent inflow of new water produce better developed brood fish. For example, the Grass Carp in the No. 4 East Pond and No. 4 West Pond at the Southsea Fisheries Research Institute develop better than those in No. 13 Pond. At the Sinti Fry Farm in Shuntak District, the brood fish in No. 6 Pond mature earlier and have a higher maturity rate than those in No. 1 Pond.

Area: Table 44 shows that the area of rearing ponds in which all brood fish are able to develop to maturity ranges from 0.75 to 9 mu. However, because Grass Carp are big and more adaptable to areas of good water quality, the more suitable rearing pond area should range from 4 to 6 mu with water 1.5 - 2 m deep.

Stocking: Table 44 shows that at stocking rates of 5-17.5 fish per mu, all brood fish are able to develop to maturity. It seems that a stocking rate of 10-15 brood fish per mu, with each fish 4-10 kg in body weight is more suitable. All examples given in Table 44 are polyculture of various farm fish. This is very appropriate. It not only permits full use of the productive potential of the ponds, but also enables other farm fish to utilize indirectly the fertility of the ponds and to adjust the water quality.

Feeding: Appropriate feeding is the key to the successful rearing of Grass Carp brood fish. The fact that all units listed in Table 44 are able to obtain satisfactory results is due to appropriate feeding, i.e., a good combination of fine and coarse foods, and to uniform feeding. In recent years, many places have failed to achieve good results in rearing Grass Carp brood fish. The main reason was insufficient feeding.

Table 44 proves that in the fine food category, silk-worm pupae, soybean cake and ground-nut cake are best. The next best are corn flour and rice bran.

Preliminary experiments show that grain sprouts, owing to the richness of their vitamin E content, have certain favourable reactions on the gonadal development of brood fish. Adding table salt in the feeds seems to produce similar effects.

Age, Body Length and Body Weight: Figures 23-25 show that the majority of brood fish spawn at 5 years or older, and that their body weight is over 5 kg. In 1963 we conducted many experiments and observations to investigate further the first sexual maturity age, and the relation of age, body length and body weight to egg-laying rate, egg-laying quantity (number of eggs laid) and egg-hatching rate of Grass Carp in Kwangtung. The results are briefly described below.

Based on the identification of scales of 212 estrualized brood fish in Kwangtung in 1963, the age of brood fish used for artificial propagation consists of six year-groups, ranging from 4 to 9 years old. There were five 4-year fish, or 2.36% of the total, and ninety-one 5-year fish (the biggest year-group), or 42.9%. The number of 6 year, 7-year and 8-year fish gradually decreased. There were only two 9-year fish, or 0.94% (Figure 23).

The preliminary conclusion was that in the Kwangtung region female Grass Carp mature at 4 years of age and male fish may mature in 3 years. But these conclusions have yet to be proved. The reproductive capability of the 8 to 9-year old brood fish does not appear to degenerate. Both their egg-laying rate and fecundity are fairly high.

According to currently available data, the relationship between age and egg-laying rate is basically in proper ratio, i.e., the older the age, the higher the egg-laying rate.

The relationship between age and absolute egg-laying quantity is also basically in direct ratio, but there seems to be no clear relationship between age and relative egg-laying quantity (number of eggs laid per kg of body weight).

It seems that there is also no distinctive pattern in the relationship between age and egg-hatching rate. The highest egg-hatching rates are obtained from brood fish 5 to 7 years old; eggs from the 4-year old fish were not fertilized and hatched (only one fry hatched, so the result cannot be considered reliable). This may have some connection with first-time sexual maturity. The egg-hatching rate of the 8 to 9-year old brood fish, however, shows a downward tendency. It must be pointed out, though, that the egg-hatching rate is very much influenced by many environmental factors as well as by the quality of the eggs and the sperms; so it is not easy to discover objective rules.

To sum up, the reproductive potential of brood fish shows an upward tendency in relation to age and body weight.

Body length and body weight. The following figures are based on an analysis of data obtained from 358 estrualized brood fish in Kwangtung in 1963. The smallest Grass Carp brood fish measured 58 cm; the biggest, 91 cm. The majority of them, 65.9% of the total number, measured between 72 and 84 cm (Figure 24).

Body length and egg-laying rate do not seem to have any clear relationship. A peak appears only at the range of 80-88 cm, but this should not be regarded as a rule.

Body length and absolute egg-laying quantity (quantity of eggs laid by each fish), however, are clearly in direct ratio, but they do not seem to have any connection with the relative egg-laying quantity.

According to our preliminary observations, there is no connection between body length and egg-hatching rate.

On the aspect of body weight, according to an analysis of data on 358 estrualized brood fish (Figure 25) in Kwangtung in 1963, the minimum body weight of brood fish was 3,250 g and the maximum was 13,750 g, with majority (60.5% of the total number of fish) ranging from 6,000 to 10,000 g. The 8,000-9,000 g group formed a peak.

Body weight and egg-laying rate do not appear to have any regular relationship. However, fish weighing more than 10,000 g show a slightly higher egg-laying rate.

The relationship between body weight and egg-laying quantity is clearly in direct ratio, irrespective of absolute egg-laying quantity or relative egg-laying quantity.

Body weight and egg-hatching rate do not seem to have any connection.

A Practical Example of Rearing Grass Carp Brood Fish With Excellent Results: The Shinnin Fry Station of the Kwangtung Aquaculture Company obtained excellent results for two successive years, 1963-1964, in the artificial propagation of Grass Carp. The brood fish maturity rate attained was 100%. The egg-laying rates were 83.3% (1963) and 95.4% (1964). The egg-hatching rates were 87.5% (1963) and 93% (1964). The average numbers of fry produced by one brood fish were 450,000 (1963) and 760,000 (1964). The method used in this station for rearing brood fish is described below.

Fish Pond and Stocking: One pond 6 mu in area was used; the water was 1.2 m deep; the pond was provided with inlet and outlet facilities.

In September 1962, after the disinfection of the pond, 34 Grass Carp, 18 females and 16 males over 7.5 kg in body weight, were selected and released in the pond. The average number of Grass Carp per mu was 5.7. In addition, 17 female and 20 male Silver Carp and 3 female and 3 male Bighead were also cultured in the pond. The total weight of the fish was 475 kg; the average weight of the brood fish per mu was 80 kg.

Feeding: Feeding was strictly regulated. A "4-fix" system was used: fixed time, fixed quality, fixed quantity and fixed position. This was divided into two stages in accordance with the seasons and the growth and development condition of the brood fish. In Stage I, from September to February, the fish were fed with more fine food; in Stage II, from March to May, mainly green fodder was used.

The "4-fix" method. (1) Fixed position: A rectangular bamboo frame was built at a deeper part of the pond on the north side to store green fodder. Four mobile feeding tables made of bamboo mat were placed in the middle-lower layer near the bamboo frame for the green fodder. (2) Fixed time, fixed quality and fixed quantity: From September to February, fine foods such as paddy sprouts, wheat sprouts, ground-nut cake and cooked soybean were given. The average daily quantity given was 150-250 g (dried weight) per brood fish, or about 2-3% of their total body weight. Suitable amounts of green fodder were also given. After February, the amount of fine food fed to the fish was gradually reduced (to about 50-100 g per day per fish). Enough green fodder was given, but not an excessive amount. The total amount of food given to the 34 Grass Carp brood fish, from September to May was as follows: paddy sprouts, 144 kg; wheat sprouts, 125 kg; soy-bean, 37.5 kg; bitter lettuce, 3,250 kg; and grass and aquatic weeds, 2,500 kg. Within this period, every brood fish obtained, on average, 9.5 kg of fine food and 165 kg of green fodder.

Water Quality Adjustment: Generally, no new water is added in autumn and winter unless the pond water level drops. In spring (March), when the gonadal development of the brood fish has reached the late stage of the major growth stage, new water should be let in 5-6 times per month. The frequency of letting in new water should increase as the season progresses. The water should be let in for about 2 hours each time so as to hasten the gonadal development of the brood fish.

Apart from the above procedures, precautions against fish disease were taken during the rearing period. Four small bamboo baskets containing bleaching powder, copper sulphate and ferrous sulphate were hung at the feeding site.

Analysis of the Ecological Factors in Ovary Development of Brood Fish: Experiments show that the most important ecological factor for Grass Carp ovary development is nutrition. Other conditions such as pond environment, polyculture and stocking density seem to be only of secondary importance.

Nutritional Conditions: The development of an individual fish is similar to that of any other animal. It is carried out according to its hereditary foundation and requires a certain quality and quantity of food to guarantee its normal progress. The Grass Carp is mainly a herbivorous fish, though it also feeds on a mixed diet. Under domesticated conditions, its growth and development are entirely dependent upon artificial feeding. Therefore, the quality and quantity of food and the feeding method can, to a large extent, affect the ovary development of brood fish.

From Table 45 one can discern the following:

1. All the feeding materials and methods used in Table 45 have brought about the development and maturity of brood fish.
2. Different feeding materials and different feeding methods have distinctive effects upon the development of brood fish. Feeding with fine food has an excellent effect in hastening the development of brood fish. However, the selection of fine food is very important. For instance, the Latliu, Shinnin, Chiunan and Lilok Farms use high quality fine food, such as silk-worm pupae soy-bean, ground-nut cake, corn, wheat and rice bran, and both the fecundity and egg-laying quantity of brood fish in these farms are very high, more than twice that of the fish in the Chungshan Farm. It seems that, in the fine food category, silk-worm pupae, ground-nut cake and soy-bean (rich in protein) give the best results. The next best are rice bran, corn, wheat and crushed rice. The worst is tares. When a mixed fine feed material is used, as at the Shinnin Farm, it provides a well rounded nutritious meal, and also gives the best results in propagation.
3. The proportion of fine and coarse foods is also important. If the relative proportion of fine food is too high, it will have an adverse effect on brood fish, such as at Chiunan Farm where the proportion of fine and coarse foods used was 1:1.54. As a result, the egg-laying rate and egg-hatching rate were both lower than those of other farms, although the fecundity (ovary coefficient 25%) and egg-laying quantity were high. According to the data in Table 45, the suitable proportion of fine and coarse foods is 1:10-17.

4. Green fodder generally consists of grasses and green vegetables. However, at Shinnin Farm the fish were fed heavily on vitamin E - rich bitter lettuce and paddy sprouts. The result was excellent, the best in Kwangtung Province (there were, of course, other factors besides the vitamin E). Therefore, vitamin E and its effect on propagation is worthy of further investigation.

Insufficient feeding (only some green grass was given every few days) and a lack of fine food had very unfavourable effects on the ovary development of a batch of brood fish. The fish had spawned in 1960 and were being reared at the Southsea Fisheries Research Institute. In June 1961, 6 brood fish were dissected for examination. The ovaries were not well developed. The maturity coefficient was 1.1-6.4%. The development of the oocytes was not uniform. The percentage of Stage IV eggs was not high. Most of the eggs stayed at Stage II-III, as shown in Table 12.

It has been proven that feeding methods should be wisely applied and based upon the characteristics of the brood fish's sexual cycle and the overall requirements of the fish, such as plumpness. Generally, after spawning and before winter, rearing must be intensified. More fine food should be given (generally about 2-4% of body weight) in order to hasten the recovery of the fish after spawning as well as to allow the fish to store nutrient materials in their bodies. In spring, when the water temperature rises gradually (17-22°C), oocytes of the brood fish begin proceeding to the major growing stage. If at this time the brood fish are reasonably plump, the feeding of fine food should be gradually reduced, and the feeding of green fooder should be relatively increased, so as to avoid over-plumpness of the brood fish and to accelerate the transformation of the nutrient materials in their bodies, which improves the propagation results.

It can be said that through the important factor of controlled feeding, we can ensure excellent ovary development of brood fish. This has been achieved at Shinnin Farm, where all brood fish mature and show excellent propagation results.

Environmental Factors of the Pond (Table 46): Table 46 shows that rearing ponds 1,200-5,994 square m in area, 0.8-2 m in water depth and 0.15-0.3 m in silt thickness have no distinctive effect on the ovary development of brood fish. However, the rearing ponds which give the highest propagation results, such as those at Shinnin Fry Farm and Latliu Fry Farm, are 2,000-4,000 sq m in area. It seems that this is the suitable size. If the area is too big, it will be difficult to catch the fish; if it is too small, the water quality can easily deteriorate.

Table 46 also shows that the fertility of the water does not have any clear relation to brood fish ovary development, as indicated by the results of observations on the relationship between water fertility and development of brood fish in Litung No. 6 Pond and Litung No. 3 Pond. Litung No. 6 Pond is a still-water pond and its water is relatively fertile, while the water in Litung No. 3 Pond has a lower fertility, and new water is let in 6-8 times a month. The results show that all brood fish in these two ponds are able to develop to maturity. The only differences are that the fish in Litung No. 3 Pond show a higher egg-laying rate but a lower egg-hatching rate.

On the question of changing water, we recognize that in the late stage of brood fish development (in Kwangtung, March to April, i.e., the major growing stage of oocytes), if sufficient renewal of pond water is applied (new water let in 4-8 times per month, each time for 2-3 hours and 1/5-1/4 of pond water volume) it can hasten and improve the brood fish's late stage development and thus better the propagation results. Many units, such as Shinnin Farm, Nantao Farm, Lilok Farm and Siolam Farm, have proved this point in their rearing practices.

Table 47 shows that the stocking density of Grass Carp brood fish, whether 6 fish or 16 fish per mu, has no clear relationship with the propagation result. On the contrary, a higher stocking density (16 fish per mu) shows slightly better results. This differs from the case of Silver Carp and Bighead in which ovary development relates, to a certain degree, to stocking density. Silver Carp and Bighead feed mainly on plankton, which have a limited reproductive rate, but the growth and development of Grass Carp depend mainly on artificial feeds, which are not limited by pond conditions. It seems that the more suitable stocking rate is 10-15 fish per mu.

Polyculture has no undesirable effect on Grass Carp development. It seems that if the total stocking weight does not exceed 150 kg per mu and if good water quality (chiefly the dissolved oxygen level) is always maintained, polyculture will be safe.

At Chiunan Fry Farm in Kwangtung, experiments on the monosex culture and mixed culture of brood fish were conducted to compare the effects on development. The results showed that there were no significant differences.

Major Arrangements for Rearing Grass Carp Brood Fish:

Stocking: For one mu of pond use 10-15 brood fish having a body weight of 4-8 kg and a total weight of about 60-80 kg; 8-10 Silver Carp brood fish having a total weight of 20-30 kg; and 1-2 Bighead brood fish having a total weight of 8-10 kg. The total stocking weight per mu is 90-120 kg.

The pond used has an area of 4-6 mu, a water depth of 1.5-2 m and water inlet and outlet facilities.

Culture Management: Culture Management for Grass Carp brood fish is concentrated on feeding. The essential part of feeding is the combination of fine and coarse foods and the regularity of the meals. Next in importance is water quality adjustment.

Feeding: As mentioned in the previous chapter, because of a lack of cellulose enzyme in its digestive system, and because its intestine is relatively short (in relation to herbivorous fish), Grass Carp's ability to digest grasses and its rate of absorption are not high. In practical brood fish rearing, apart from the feeding of grasses, a suitable quantity of fine food is added which will clearly improve the maturity rate, fecundity and egg quality of the brood fish. Many examples have been cited in the various preceding paragraphs to illustrate this point.

Feeding must be persistently on fine and coarse food combinations, and feed should be provided evenly. Because Grass Carp are different from the plankton-feeding Bighead and Silver Carp and from the benthos-feeding Mud Carp and Common Carp (they can obtain a certain amount of natural food, provided the water body they live in has a certain degree of fertility), under pond culture conditions, they must be constantly and sufficiently fed with artificial foods in order to attain good growth. A fish culture maxim of our country is: "one day no eat (feeding), three days no growing". This points out the adverse effect of uneven feeding upon the growth and development of Grass of Carp. Even though this is true, many people still often neglect this point.

Feeding in relation to seasons: In autumn when the water temperature is suitable for fattening and when the gonadal development of Grass Carp has begun, feeding must be intensified. At this period, the amount of feeding per day is generally as follows: green fodder, 20-40% of total body weight; and fine food, 2-4% of total body weight. In winter when the water temperatures are low, the appetite of Grass Carp declines, but some fine food may be given.

Beginning in early spring, water temperatures gradually rise and the Grass Carp, after going through winter, undergo a slight decrease in body weight. They gradually regain their appetite. At this stage, the amount of feeding should be gradually increased. After about one month of vigorous feeding, when the fish have regained their normal plumpness, the feeding of the fine food can gradually be reduced (1-2%) and the feeding of green fodder should increase suitably (40-60%). Summer is the reproductive season, and the amount of feeding should be reduced. But after artificial propagation, brood fish must be fed with good food.

The green fodder, in this context, consists of aquatic plants and land plants. Aquatic plants commonly used for this purpose are these: Vallisneria spiralis, Potamogeton malainus, Potamogeton maackianus, Potamogeton crispus, Hydrilla verticillata, Najas minor, Spirodela polyrhiza. Wolffia arrhiza, Alternanthera philoxeroides, Ipomoea reptans and Azolla pinnata. Land plants commonly used are as follows. Grass Family (Gramineae): Echinochloa crus-galli, Setaria viridis, Pennisetum alopecuroides, Eleusine indica and green rice plant; stems, leaves and seeds of Legume; Chrysanthemum Family: Lactuca sativa and Taraxacum officinale; and various other decaying vegetable leaves, cucumber and melon leaves and vines, etc.

The fine foods that are commonly used are silk-worm pupae, rice bran, wheat bran, corn meal, wheat flour, crushed rice, ground-nut cake, bean cake, snails and clams. If animal food is lacking, a suitable amount of table salt can be added to the feeds (0.7-1% of total fine food). When using fine food materials, one should pay attention to the selection of a suitable combination of animal and vegetable materials. For example, in Kwangtung the common combination is silk-worm pupae and rice bran, which gives excellent results. When using grains, the best way is to germinate a portion of them in order to increase the vitamin E content and accelerate the brood fish's gonadal development.

Feeding frequency and time: In accordance with the nocturnal feeding habits of Grass Carp, the best feeding schedule is as follows: green fodder in the evening and fine food in the morning.

In order to train Grass Carp to take food at a fixed feeding place and also to make it easy to clean up uneaten food, a feeding frame is built on the water surface 2-3 m from the shore at a deeper part on the north side of the pond. The frame will keep floating food, such as duckweed and grasses, from being dispersed by the wind. It can be made from bamboo; It should have a rectangular or triangular shape and an area of about

20 square m. There should be one per 3-4 mu of area. Also in order to prevent foods which sink (such as oil-seed cake) from being dispersed and lost or from sinking into the mud, a feeding platform should be constructed. Feeding platforms are generally made of bamboo mat or thin wooden boards, square or round in shape, attached to bamboo poles and fixed near the feeding frame at a middle-lower level.

Water Quality Adjustment: Grass Carp are more suitable for culture in clean and fresh water. In this type of water, they are healthy and have a low rate of disease, and moreover they grow and develop better. In general, no fertilizer is applied to Grass Carp rearing ponds. But the great amount of dung and uneaten food left by the fish often results in the water quality gradually becoming too fertile, so one should frequently observe the water colour, transparency, the weather and fish activity and let in some new water to adjust the water quality as and when required. Especially in early spring, when brood fish are at their rapid gonadal development stage, more new water should be let in so as to promote good gonadal development. The frequency of letting in water is 6-10 times per month, and each time one should let in 15-25% of the amount of pond water. The merit of this system of water quality adjustment has been confirmed through many years of practice.

Catching and Transportation of Brood Fish

Catching of Brood Fish (method used in Kwangtung):

Fishing Net: Construction of Net: the net consists of netting, rope, floats and sinkers.

Netting is the main component of the fishing net. It is rectangular in shape and each piece is 10.8 m long and 6.5 m high. The mesh size is 4-6 cm, generally 480 mesh long. It is made of ramie, cotton or nylon twine. In Kwangtung, ramie twine is usually used. Its size is generally about 1 mm diameter; double strands right twist, using flat-knot. When fishing, several pieces are joined together, depending on the size of the pond.

Rope is mostly made of palm fibre. Its diameter is generally 0.7 cm, consisting of 2 or 3 strands of palm-fibre cords.

Floats are usually made of cork, Chinese fir (Cryptomeria) wood and tung (Aleurites) wood. They are flat and rectangular in shape, 10 cm long, 9 cm wide and 6 cm thick. They are dip-dyed in tung oil or Tzuliong (TN: *Dioscoria bulbifera*, a plant containing Tannin) extracts.

Sinkers are not specially prepared. During fishing, depending on the objective, pieces of stone, broken bricks or lumps of hard clay are attached temporarily to the ground rope and between pieces of nets.

Net preservation: In Kwangtung, Tzuliong is usually used for dying nets. The Tzuliong is first crushed and then immersed in clean water 1-1.5 times its amount. After filtering out the residue, the juice is used for dye. In the dying operation, nets are immersed in the juice until they turn brown. Then they are taken out and dried in the sun. New nets are dyed 3-4 times; old nets are redyed 2-3 times. After the dying process, the nets are placed in a steaming vat for 4-6 hours, then taken out for cooling, immersed again in clean water for 2 hours, and then dried. The amount of Tzuliong used is as follows: 2 kg of Tzuliong for 1 kg of new netting, half this amount for old nets.

After the net is used, it must be washed and cleaned thoroughly. It is best to use clean water, then to sun-dry or wind-dry the net and repair all damaged parts. It should be stowed in a dry and ventilated place.

Catching Operation: The method used in Kwangtung for catching fish in ponds is very simple. While its efficiency is quite high, its disadvantage is that the fishermen must work in water.

In the beginning of the catching operation, a site for hauling up the net is selected (flat, not much silt and suitable depth). At each end of the net, a stout bamboo pole (about 2 m long) is tied to the opposite ends of the head and ground ropes. This is to stretch out the net. A tow-rope is tied at the middle of the bamboo pole. Two workers in the pond hold the bamboo poles (popularly called: "net-head pole") in vertical position at each end of the net and keep the net open. The end of the tow-rope is held by several workers (depending on size of the net) on the bund. They pull the net slowly ahead along the bund. The pulling speed should not be too fast so as to prevent the ground rope from being lifted off the bottom. When they arrive at the hauling site, the workers in the water pull in the head and ground ropes slowly and at the same time use their feet to press into or release the ground rope from the mud as they work in order to prevent it from lifting off the pond bottom. When the net has been hauled in a suitable way, the two workers in the water simultaneously work the ground rope along the bottom and lift it up to the surface. The brood fish are thus concentrated in the net.

Generally, for catching Silver Carp, the head rope is supported by bamboo poles or wooden frames. A cover-net is added, or the upper part of the net is lifted up above water in order to prevent the fish from jumping and escaping.

There are two kinds of equipment for transporting brood fish short distances: (i) an oval-shaped wooden vat, 100-120 cm long, 60-70 cm wide at the centre, and 35-40 cm high, in which 3-4 fish can be accommodated at one time; and (ii) a cloth clamp (Figure 26). The cloth clamp is shaped like a big document file. The outer layer is made of coarse cloth, and the inner layer is made of waterproof nylon cloth. It is 100 cm long and about 30 cm high. The width of the upper opening is about 20 cm (mounted on bamboo or wooden sticks). It can accommodate 1-2 brood fish at one time, depending on the size of the fish.

Transportation of Brood Fish: In Kwangtung the carriers of brood fish can be divided into three types: train, lorry and "live-water" boat. These three methods of transportation are described in the following paragraphs, along with some actual examples.

Train Transportation: Train transportation is suitable for long distances. We forwarded brood fish from Canton to Peking and to People's Democratic Republic of Korea in 1958 and 1959, respectively. The actual methods used on these two occasions are briefly described below.

Equipment: (i) Railway freight car: At present there are two types of freight car for transportation of live fish in our country: "Shanghai No. 1" and "Shanghai No. 2". The former has a small capacity; it is only good for fish fry and is not suitable for brood fish. The latter has a larger capacity and is suitable for both fry and brood fish. The one we used was an ordinary luggage car (for the consignment to North Korea it was equipped with air-conditioning). (ii) Wooden vat: The wooden vat used was conical in shape. Its mouth (rim) diameter was 1.2 m; base diameter, 1.7 m; height, 1.7 m; capacity, 3.47 cubic m (actually it contained 2.5 cubic m of water). To prevent the brood fish from injuring themselves, the inside of the vat was lined with a protective white cloth, 10 cm from the vat wall. (iii) Aerator: One 2-4 HP air compressor and one hand-operated aerator, with air tubes and sand filters, were used. (iv) Other tools: Siphonic tube for dirt, small wooden basin and fishing net.

A Brief Account of Transportation Procedure: (i) First occasion (from Canton to Peking): In August 1958, 6 Bighead (4 females and 2 males) and 13 Silver Carp (8 females and 5 males) were transported from Shuntak .o Canton. After 10 days of temporary rearing and conditioning, the fish were placed in the wooden vats (no protective cloth wall was installed). The journey to Peking started on September 8 at 6 a.m. The water in the vats was changed (partly) at Shaokwan, Chianshien, Chuchew, Hankao, Changchew and Shikchiachuang stations. During the transport period, the minimum water temperature was 18.5°C; the maximum 30°C; and the average, 23.8°C. The pH was 6.8-7.4; dissolved oxygen content, 1.334-6.5 mg per l; chlorides, 14.84-36.48 mg per l (see Table 48).

The consignment arrived in Peking on September 10 at 10 a.m. The journey took a total of 52 hours. Mortality: Silver carp brood fish, 10 (♀ 6, ♂ 4); Bighead brood fish, 2 (♀); total, 12 fish (see Table 49). Survival rate, 36.8%. The reason for such a heavy mortality rate was that the conditioning and transporting work was not sufficiently refined. A large number of brood fish were injured to various degrees during the journey, and this caused their death.

(ii) Second occasion (from Canton to Pyongyang, North Korea): In October 1959, we received one batch of brood fish from neighbouring districts. On November 27, after about one month of temporary rearing, we selected 12 Grass Carp, 14 Bighead and 6 Silver Carp, a total of 32 fish. Their average body weight was about 7 kg. All these fish had been carefully conditioned and were placed in wooden vats; each vat held 5 brood fish. The journey began at 9 a.m. The changing of water took place at Shaokwan, Chianshien, Chuchew, Yaoyang, Hankao, Sinyang, Chinho, Changchew, Sinshiang, Kandan, Shikchiacheang, Paoting, Peking, Tientsin, Shanhaikwan, Shenyang, Antung and Ichuan, Tingchew, Anchew and Pyongyang in North Korea. During the journey both the manual aerator and the mechanical air compressor were used for aeration. The stop-over at the Peking Railway station took 13 hours. The water temperature during transport was a minimum of 8.5°C and a maximum of 20°C (when the brood fish were released into the pond at their destination, the pond water temperature was 2-3°C). The pH was 7-7.2; the dissolved oxygen, 1.489-9.678 mg per l; chlorides, 3.555-104 mg per l (see Table 50).

The fish arrived in Pyongyang on December 2 at 1400 hr. The trip lasted a total of 125 hours. Three Silver Carp and 1 Bighead died on the way. The survival rate was 87.5%. The excellent result on this occasion is mainly due to the fact that the brood fish were carefully and fully conditioned before the journey and to suitable management and refined treatment of the fish during transportation.

Work during Transportation: (i) Measurement of the chemical and physical characteristics of the water. The workers operated on shifts during the journey, inspecting the activities of the brood fish periodically, and also randomly checking the dissolved oxygen content, pH value, water temperature and chlorides content during the changing of the water. Decisions on aeration and changing of the water were based on these factors. Data recording was also done very well. (ii) Aeration: Based on the situation of the dissolved oxygen content of the water and wisely applied aeration, workers tried to maintain the dissolved oxygen content above the 3 mg per l level. (iii) Changing of water: Owing to metabolic processes of the brood fish, the water quality deteriorates as the duration of transport lengthens. The water must be changed at certain times. Water changes should be only partial and based on the water quality condition at the time. Attention must be paid to the concentration of bleaching powder and to the temperature of the new water. Special attention should be given to the pre-arrangement of water supply at all railway stations involved.

Road Transportation: In areas where water transport is lacking, the transport of brood fish by lorry is common. Wooden vats or canvas bags are used to hold the brood fish in the lorry. The results are generally good.

On May 20, 1959, we used conical-shaped wooden fry transporting barrels. They were 150 cm high, had a mouth diameter of 76 cm and a base diameter of 94 cm, and each barrel held 2-3 brood fish (depending on the size of fish). There were 6 barrels to one lorry. The fish were dispatched from Canton to Fuiyang, a distance of 160 km. It took 6 hours. There was no changing of water, nor was there any aeration or beating of water. The survival rate was 100%. During transportation, the maximum air temperature was 29.5^{o}C; the minimum, 26.8^{o}C. The maximum water temperature was 27^{o}C; the minimum, 26.8^{o}C. The brood fish had been preconditioned before shipment.

"Live-water" Boat (perforated hull tank boat) Transportation: Live-water boat transportation has been commonly in Kwangtung for a long time and is a most effective method for transporting mature live fish. The structure of a live-water boat is basically similar to that of any ordinary boat. The only difference is that it has a deeper hull with many small holes (3-4 cm in diameter) in its sides. These small performations provide for the continuous changing of water in the hull while the boat is moving. Thus the water is always clear and fresh. When this method is used for transporting brood fish, the stocking density can be slightly higher, and the survival rate is generally high.

In April and October of 1959, we used a live-water boat to transport brood fish and had excellent results. On all three occasions, the survival rate was 100% (see Table 51).

When transporting Silver Carp brood fish by live-water boat, the water level in the hull should be raised as high as possible so that it almost touches the cover, or a protective net (use net or cloth) should be installed about 10 cm below the cover. These measures will prevent the fish from jumping and injuring themselves. During transportation, pay attention to the quality of the river water, especially at or near a city. Watch out for polluted industrial water which affects the quality of the river water.

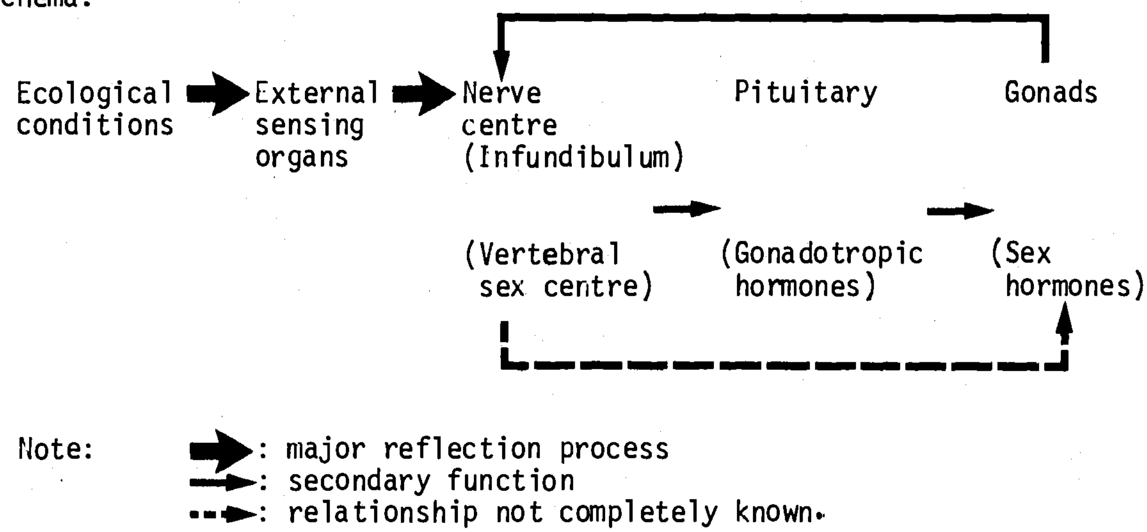
Estrualization

The Basic Principle of Estrualization and Studies on the Ovulation Process

The Basic Principle of Estrualization: The organic body of an animal and its internal environment must always maintain an equilibrium with its external environment. The organic body can survive only in this way. This equilibrium is maintained by the organic body's nervous and endocrinal systems, which regulate all necessary functions of the body.

The gonadal development process of fish is largely controlled by the pituitary gland. The pituitary secretion activity is, in turn, mainly controlled by relative external factors through the nerve centre.

It has been mentioned in the previous chapter that for farm fish in the wild state, rapid gonadal development from the relatively stagnant Stage IV to the spawning stage of Stage V is entirely controlled by certain external motion factors. The process can be summarized in the following schema.



The above diagram indicates that the spawning process of farm fish is actually not a conditioned reflex of sexual activity. To explain this in detail, when a certain ecological condition stimulates the external sensing organs of farm fish, such as the lateral line, skin, visual and auditory organs, the nerves of these external sensing organs produce impulses which are immediately sent to the nerve centre and transmitted to the pituitary gland. When the pituitary gland has been excited by the stimulation, it answers or reacts by secreting gonadotrophic hormones. These hormones are transmitted by body fluids and cause certain physiological changes. When the hormones reach the gonads, the gonads in turn become stimulated and begin rapidly to develop and mature. Ovulation begins, and simultaneously a sex hormone is secreted. This sex hormone acts in coordination with the gonadotrophic hormones, and this arouses sexual desire in the brood fish. Thus the fish engages in active sexual activities - laying eggs and exuding milt.

The basic principle of artificial estrualization rests on the general biological principle of natural propagation of farm fish. Because of the shortcomings of the ecological conditions in fish ponds, which cannot fulfill the propagation requirements of the brood fish, artificial methods of injecting gonadotrophic hormones (pituitary gland or chorionic gonadotropin) into the fish body are used. These injections supplement the secreting function of the pituitary gland in the live body; on the other hand, they also hasten the secreting activity of the pituitary gland and thus induce the brood fish to lay eggs or exude milt.

Some people think that under artificial propagation conditions, the ecological conditions "may or may not be essential". This is not correct. Experiments have proved that in estrualized brood fish which are able to lay eggs, the pituitary gland (interstitial cells) appears to have a distinctive secretion activity basically similar to that of the naturally spawning wild farm fish. However, in those estrualized brood fish which fail to lay eggs, the pituitary gland generally appears to have no secretion activity. Therefore, estrualization can only substitute for part of the required ecological conditions for the spawning of farm fish. The demands for endocrinal physiological activities within the body and for suitable ecological conditions still exist.

Inquiry About Ovulation Process: Not very much research on the ovulation process of fish and the controlling mechanisms has been done so far. In recent years some research was conducted on *Oryzias latipes* (Robinson and Rugh, 1943), *Cobitis biwae* (Kawamura and Motonaga, 1950), *Oncorhynchus heta*, *Clupea pallasii* and *Lampetra japonica*. For farm fish, some research was done on the cytological aspects by the Experimental Biological Research Institute and on gonadal histophysiology of estrualized brood fish by Fukien Normal College. On the basis of research by various scholars in this field and of materials we gathered during our observations and experiments on artificial propagation of farm fish, we offer the following preliminary analysis of the ovulation process and the controlling mechanism in farm fish.

As pointed out previously, when the gonadal development of the brood fish has reached late Stage IV, no matter whether in natural conditions or under artificial estrualization, when the fish have received a certain concentration of gonadotrophic hormone within a certain period of time (generally from 8 to slightly over 20 hours), their physiological situation will undergo a certain degree of change. According to the results of experiments by the Moscow Fisheries Institute, the more distinctive physiological change is the definite increase in the number of uni-nuclear white blood corpuscles and multiform-nuclear white blood corpuscles. The reasons for the increase in white blood corpuscles are that, on the one hand, the activity of the blood-manufacturing organs has been intensified and, on the other hand, these white blood corpuscles seep out from the blood and large numbers of uni-nuclear white blood corpuscles appear in the egg fluid. At the same time, gonad tissue blood vessels are enlarged. At this moment, the gonads are under nervous and endocrinal reactions, especially the reaction of the gonadotrophic hormone, and the follicular cells rapidly develop to maturity. These include the cells of the inner layer of the follicular membrane, which expand rapidly, become cube-shaped and secrete fluid (egg fluid). Many vacant cavities appear, and later these vacant cavities often break off. Meanwhile, the ovary tissues clearly expand, generally by about 35%, as shown in Table 52.

Because of the action of ovary fluids, and because the uni-nuclear white blood corpuscles in the egg fluid can secrete a kind of enzyme, which may have some relationship to the rupture of follicular cells, the gelatinous layer between the eggs and egg follicles is dissolved. The eggs are now in direct contact with the follicular cells and the egg fluid secreted by the cells. Possibly through the action of osmotic pressure, the eggs absorb the egg fluid. Their volume and weight rapidly increase. For example, before estrualization, the eggs of Bighead weigh, on average, 938 eggs per g. while a mature egg averages 690 eggs per g. That is to say, the weight of a mature egg increases 36% compared with its weight some hours before in the immature stage. After the eggs have absorbed these fluids (and possibly there is also enzymatic action), rapid physiological changes occur, and the eggs swiftly enter the maturity stage. Characteristically, the yolk melts, the ooplasm moves towards the animal pole, and the nucleus begins to polarize and proceeds to maturation division, etc. At this time, owing on the one hand to the physical action of the increased egg volume and on the other to enzyme chemical action, the ovisac tissue bursts at the weakest point - the follicular pore, through which the eggs are released. Meanwhile, the brood fish enter their peak stage of estrus. Because of the intensified sexual activity, the constrictor muscle of the oviduct suddenly relaxes due, most possibly, to the relative contractile action of the ovary sac, the movement of stomach muscles, etc. These combined actions finally cause the release to the body's exterior of the mature eggs which have gathered in the ovarian cavity.

From practical examples of artificial propagation, it seems that the ovulation process can be demarcated into two aspects: the maturation of the ovisac and the maturation of the eggs. With wild farm fish spawning naturally, the maturation processes of the ovisac and eggs should be harmonious. However, under artificial propagation conditions, the maturation process of certain individuals appears not to be so harmonious. The Department of Biology at the Fukien Normal Institute has conducted research by section examination on the ovary tissue of brood fish which failed to spawn. They found two types of eggs: (i) Eggs which had already left the ovary. The ovary was in Stage V-VI of maturity. Some of the eggs or a large portion of them had left the ovary; the majority of these "left-ovary" eggs had suffocated. In brood fish of this type, the porus genitalis was generally blocked. An examination of ovary tissue sections at the blocked porus genitalis showed that most of the eggs, which were not mature but had left the ovary, stay at late Stage IV. (ii) Eggs which had not yet left the ovary. The abdominal portion of the brood fish was distinctively swollen. A section examination showed that the ovary was in Stage V. A large portion of the eggs had not yet left the ovary, but they generally showed the water absorption phenomenon and had reached Stage V. Some eggs appeared to have a small perivitelline space, and their diameter had increased slightly.

In view of the above, when conducting artificial propagation, apart from carefully selecting the brood fish, one should also try to avoid injuring the fish during the course of operation. Moreover, the ecological conditions of the spawning pond and the estrualization technique should be carefully observed and improved. This is the only way to achieve a harmonious ovulation process of the brood fish and thus improve the normal egg-laying rate and egg-hatching rate.

Spawning Pond

Locality: Spawning ponds should be located at places within easy reach of communication links and near brood fish rearing ponds. This will reduce body injury to brood fish during transportation. The water supply and drainage system should also be considered. One should try to utilize natural water whenever possible.

Area: At present the spawning ponds being used in various places are not of uniform size. They vary from 90 to over 100 square m. An area of 100 square m (more or less) is considered more suitable. Too small an area will affect the normal estrus and spawning of the brood fish. Too big an area is inconvenient for catching fish.

Shape: Round or pear-shaped spawning ponds are considered more suitable. Square or rectangular-shaped ones can be adequate. Practical experience in natural spawning indicates that the pear-shaped spawning pond can accelerate the flow of fertilized eggs into the egg collector, thus improving the efficiency of egg collecting and shortening the production time.

Depth of Water: Water depth of about 1.5 m is more suitable. In letting in water, the depth should be gradually increased to about 2.0 m. Water too deep will increase the difficulty of catching the brood fish and collecting the eggs. Water too shallow will influence the activity of brood fish and will easily effect changes in water quality and temperature which are not beneficial to the spawning of brood fish.

Bottom Materials: If the spawning pond is an earthen pond, the pond bottom should be paved with granular sand 6-10 cm thick so as to reduce the turbidity of the pond water. In ponds made of cement or bricks, the paving of the bottom with sand is not required. The pond bottom should be flat and slope slightly from the water inlet to the water outlet to facilitate the collecting of eggs.

Water Inlet and Outlet: For natural spawning in pear-shaped ponds the water inlet and outlet can be positioned at opposite sides of the pond. For artificial insemination in round ponds, the position of the water inlet should be diagonal to the side of the pond so as to cause a circular water current. The size and number of water inlets and outlets are determined by the size of the pond and the required current speed. Generally, the water pipes used are 20-30 cm in diameter. There can be 1 or 2 water inlets positioned about 1 m above the pond bottom. There should be 2 water outlets, one positioned 40-60 cm higher than the water inlet to control the water level, the other positioned at the pond bottom for draining and cleaning purposes. If natural spawning methods are used, a special outlet for egg collection should also be installed.

Flow of Water: When the natural spawning method is adopted, there should be ample water supply. Reservoirs, rivers or lakes are good water sources and most suitable for propagation purposes. The filling and draining of water is best done by the force of gravity; otherwise the installation of a dynamic force will be required. Even when artificial insemination is used, the spawning pond should also be located near the water source so as to facilitate the changing of water and the adjusting of water quality when necessary.

The water quality requirements are that the water be clear and fresh, slightly alkaline, devoid of any poisonous elements, and have a high dissolved oxygen content.

Speed of Flow: When the natural spawning method is adopted, a certain speed of flow in the spawning pond must be provided; otherwise production will be adversely affected. The speed of flow used for this purpose is generally between 0.3-0.8 m per second at the water inlet. Too slow a speed will lower the number of eggs collected; too fast a speed will use up too much of the brood fish's body energy, and that will have unfavourable effects.

Protective Installation: To prevent brood fish from injury, a protective net is installed inside and around the spawning pond, especially near the water inlet. It is placed 15-20 cm away from the inner wall. A nylon net is best for this purpose. At the water inlet and outlet a coarse filter should be installed to prevent wild fish, shrimps and other unwanted materials from flowing into the pond.

Working Platform and Working Shed: When the artificial insemination method is adopted, a working platform should be provided at the net hauling site near the edge of the spawning pond for use in the artificial insemination operation. It is best to build a small working shed near the spawning pond in order to facilitate management work.

At present, spawning ponds which are being used in various places may generally be classified into two types: artificial insemination spawning ponds and natural insemination spawning ponds. The former are equipped in a simple manner. Only a few have flowing water. Their sizes are fairly small, generally 60-80 square m. The latter are better equipped. All of them have flowing water, and their sizes are slightly larger, 100-180 square m. In order to make full use of flowing water, flowing water spawning ponds are generally used in a series formation; i.e., a series of two or three ponds are connected.

Currently, the better and most logically arranged farm fish spawning ponds in Kwangtung Province are those at the Shinnin District Fry Farm (see Section 4 of this chapter).

Selection of Brood Fish

Differentiation between Male and Female: When fish, as well as many other vertebrates, are approaching sexual maturity, secondary sex characteristics appear due to a physiological reaction to a kind of sex hormone secreted by the gonads. This is especially conspicuous on male bodies, a fact which has enabled us to distinguish between male and female more conveniently.

The methods of identifying male and female farm fish in our country are basically similar. The fish are identified mainly by the pectoral fins of sexually mature individuals. The important characteristics of male and female farm fish are listed in Table 53.

Age Determination: Experiments by the Experimental Biological Research Institute found that the age of Silver Carp and Bighead can be determined by examining their scales and fin rays. The methods used are as follows:

Scale Determination Method: The scale method of determining age is relatively simple, and the collection of a sample is also convenient. Pluck off a few scales from the fish's body (any part of its body), soak them in warm water for a short time, thoroughly clean them with a soft cloth, and then examine them under a low-power microscope. On the scales there appear complete circular lines (named: O annular lines) and incomplete, opened, semi-circular lines (named: U annular lines). In a group of annular lines, the lines of the inner layer are longer than those of the outer layer, and collectively they constitute a crescent-shaped form. Its major body is positioned at the anterior region of the scale. Its two points (the tips of the crescent) extend towards the post-lateral region of the scale. The O annular lines and U annular lines are alternately arranged; the U annular line group encircles the O annular line group. At the border region of these two line groups, the direction of the lines appears to be uncoordinated, and the lines are cut diagonally (Figure 27). The appearance of one series of diagonal cuts indicates one year. This phenomenon, apart from appearing at the post-lateral region of the scale, can also be seen at the lateral or even at the antero-lateral region, but it must be a series of fairly well arranged and orderly diagonal cuts and be symmetrical on both sides.

Fin Ray Determination Method: Take the first fin ray of the pectoral fin. Cut a 2 mm section from the basal part of the ray using a fine saw. Grind it into a thin section about 0.2 mm thick using a water grindstone or grinding wheel until the centre of the lines can be seen by the naked eye. Under a low-power microscope, the alternately arranged, dense, non-transparent zone and the clear, semi-transparent zones can be distinguished (Figure 28). One semi-transparent layer indicates one year. Thus the age of a fish can be counted. If the above two methods are used simultaneously and compared to each other, they will increase the accuracy of calculating a fish's age.

The above methods were used by the Hunan Normal College, and were found to be accurate means of checking the age of Grass Carp.

Selection of Mature Brood Fish: The accurate selection of mature brood fish can improve the results of artificial propagation. To date, a more complete and highly accurate selection method is still lacking. The method used at present is based on the external characteristics of the brood fish in conjunction with the seasons. Although this method is rather crude, it generally gives good results.

Conditions for selecting female fish: In the early propagation period, (generally from late April to early May in Kwangtung), the majority of brood fish have not yet reached a maturity stage suitable for estrualization. Therefore, when selecting female brood fish one must choose only large-bellied individuals, especially those with soft post-abdominal portions. Because these individuals are generally maturing earlier, artificial propagation can also be conducted earlier. In this period, the external characteristics of the brood fish's cloacal opening do not seem to provide much clue to the degree of maturation. However, it would be better if it shows a trace of pink colour and is slightly protruding.

In the peak of the propagation period (in Kwangtung, generally from middle and late May to late June), because the gonads of a majority of brood fish have reached an appropriate degree of maturation, the conditions for the selection of brood fish can be slightly relaxed. Generally speaking, any individual with a big belly and a soft post-abdominal portion will do. If the genital aperture is slightly protruding and relaxed and tinged with pink colour, so much the better. In this period, the abdominal portion of brood fish is generally more buxom; if it is too buxom, the fish should not be used, especially in the case of Silver Carp (this is not so important in Bighead and Grass Carp). The fish should be kept in a rearing pond with clear, fresh water for a few days before estrualization.

In the late propagation period (in Kwangtung, generally after mid-July), the standard of selection of brood fish should be lowered, because at this time the available brood fish are generally slower developing individuals. Their ovary coefficient and plumpness are lower. If a brood fish has a slightly enlarged belly, it must also have a soft post-abdominal portion in order to be usable. In this period, the genital aperture of some brood fish (especially Silver Carp) often shows a reddish brown colour and the phenomena of congestion and even inflammation. If these phenomena appear in individuals with very full and plump bellies, the fish should be kept in the aforementioned rearing pond for a few days before estrualization.

When choosing brood fish, the best choices are those that are older and larger; this applies especially to Grass Carp. It has been proved that the egg-laying rate, egg-laying quantity and egg quality of female fish that have matured sexually for the first time are generally lower than those of older and bigger-bodied fish.

Apart from the above, brood fish should be healthy and free of injury. Female fish that are not so healthy or slightly injured are only suitable for artificial insemination.

The above notes on brood fish selection apply to Silver Carp, Bighead and Grass Carp. However, because Grass Carp are big eaters, they exhibit false big bellies when their stomachs are full. For this reason, choosing female Grass Carp should be done after two days without feeding. Secondly, because Grass Carp have a thicker body cavity wall, bigger scales and generally a lower ovary maturation coefficient, the external appearance of the abdominal portion of a mature female does not appear as full and plump as that of a Silver Carp or Bighead, in which abdominal enlargement is readily recognizable. During selection, female Grass Carp should be placed belly up. If both sides of the abdominal portion show the contour of the ovary, and if the lower point of the ovaries in the post-abdominal portion feels soft, the fish is then considered as meeting the selection standard.

The present method of female fish selection is still not perfect. To remedy the defects of the above method, especially in the case of Grass Carp, we always use a double injection method. That is, a second injection is given 8-12 hours after the first one if a brood fish's reaction is normal (belly slightly swollen and soft), indicating clearly that the fish's degree of maturation is basically fit for estrualization. However, if a brood fish reacts abnormally (there is either no reaction or the belly shrinks and becomes hard), this indicates that its degree of maturation has not yet reached the required level. These brood fish should not be given a second injection, but should be returned to the rearing pond for intensive cultivation for a certain period before the next selection.

The criteria for selecting mature male fish are simple. One only has to press the abdominal portion lightly near the testes. If milt flows out from the cloacal opening and if the body is healthy and active with no external injuries, the fish qualifies for use.

Treatment of Brood Fish Before Estrualization

As mentioned before, farm fish in the wild state must pass through a period of spawning migration during spawning season. During the spawning migration, their gonads continuously develop and mature.

The full maturation of the gonads (polarization of egg nucleus) of pond-reared farm fish also appears to undergo, to a certain degree, the above process. For example, the gonads of farm fish reared in ponds in which the water is constantly affected by tides are comparatively well developed during the spawning season, possibly through the flow of water caused by tidal movements. Their abdominal portion is generally softer, the egg nuclei of some individuals begin to polarize, the quantity of milt is greater, and the egg-laying rate and egg-hatching rate are generally higher. In contrast, farm fish reared in still-water ponds for a prolonged period generally fall behind in physiological maturation, although during spawning season their gonads are fully developed. For example, the egg nuclei generally do not begin to polarize; the quantity of milt is less, etc. Before estrualization, the egg-laying and egg-hatching rates of brood fish in this latter category are generally lower without proper training or the provision of weak flowing water and good water quality treatments.

The treatment of brood fish with weak-flowing and good quality water before estrualization has proved to be an effective production practice. For instance, we used intermittent weak-flowing water (0.2-0.5 m per sec) to treat brood fish for 7 days before estrualization, and it improved greatly the effects of estrualization (see previous chapter). Practical experience at the Nantao Fry Farm, Chungshan District shows that the rearing of Silver Carp and Bighead brood fish in a clear water tidal pond for a few days before estrualization will improve their egg-laying and egg-hatching rates. Experience at the Shuntak Lunkao Fry Farm indicates that if Silver Carp reared in fertile still water have bodies that are too plump and bellies that are too big, they must be kept in a clear water pond for a few days before estrualization. This will increase the brood fish's egg-laying rate and reduce the mortality rate. Experience at the Sinfui Lilok Farm has shown that prior to estrualization brood fish must go through a period of "training" to strengthen their endurance so as to raise the egg-laying rate and egg-hatching rate, as well as to reduce the mortality rate. The training method used by the Farm is as follows. One or two days before the brood fish are selected, a simply constructed snake-head (Ophiocephalus argus, popularly called "live-fish") catching tackle, called a "live-fish board", is used for training the brood fish. This fishing tackle is made from a line 20-30 m long. Each end is tied to a bamboo pole. At intervals of 25 cm along the line, a white-coloured bamboo or wooden blade 25 cm long, 4 cm wide and 0.5 cm thick is attached (Figure 29). In using the tackle, two persons, each holding the bamboo pole at opposite sides of the pond, drag the line back and forth along the pond, thus causing the white bamboo blades to vibrate continuously in the water. The fish are frightened and run wild; thus the aim of the training is achieved. Training is normally done twice a day, once in the morning and once in the afternoon. Each time the "live-fish board" is dragged back and forth in the pond 3-4 times. This training (exercise) for 2-3 days basically causes the brood fish to stop feeding, eject faeces, consolidate body tone and strengthen body endurance. The fish are then suitable for artificial propagation operations.

In some areas a seine net is used for training brood fish. Before estrualization, the fish are rounded up (but not caught) with a net and then released back in the pond. Others use the net to encircle the brood fish in a small area (about 1/4-1/5 the area of the pond) and keep them in this small circle for a few hours before releasing them. Brood fish selection and estrualization are done after one or two such "training" exercises. The shortcomings of this method are that a larger labour force is required and the brood fish are more easily injured. The method has, however, produced good results.

Based on the above-mentioned practices, brood fish, especially those reared in still water ponds for a long period, should undergo training for 1-2 days (this applies especially to Silver Carp, the mortality rate among which can be clearly reduced), and then be treated in good quality water, preferably weakly flowing water in rearing ponds or spawning ponds for another 1-2 days before proceeding to estrualization. This treatment has brought about good results in artificial propagation. The results are even more distinctive in the early propagation period due to imperfect egg-maturation.

To facilitate the observation of the brood fish, we use the following tagging methods before estrualization. (i) A fine, coloured plastic line is tied to the base of the first dorsal spine of a brood fish. (ii) A small metal stick is used to write serial numbers on the head over the parietal bone. This will not affect the brood fish. The numbers can remain readable for about one month. (iii) A silver tag (Figure 30) is attached close to the basal part of the first dorsal spine of the brood fish.

The first two methods are temporary and easily applied. The third method is suitable for long-term observation, but the tags occasionally drop off.

Estrualizing Agents

Kinds of Estrualizing Agents: As already pointed out in the previous chapter, the reaction of fish to various kinds of hormones of higher vertebrates is not uniform and lacks any rules. For example, fish generally react positively to the growth hormone and thyroid hormone of higher vertebrates. They generally react negatively to the sex hormone, and react favourably to the human chorionic gonadotrophic hormone only.

We tried using pro-adenohypophysis extract from mammals for estrualization experiments on farm fish, but obtained no reaction. Many times we used amphibian (frog) pituitary extract, but also got no result. However, it did yield good estrualization results on a loach (*Misgurnus anguillicaudatus*). We tried pituitary of Tilapia (*T. mossambica*) on farm fish, but the result was again negative. The Hydro-Biological Research Institute tried pituitary of Coilia (*C. ectenes*) for estrualization on farm fish, but it yielded no result. However, the pituitaries of many Cyprinids, such as Common Carp, Goldfish, Silver Carp, Bighead, Grass Carp, Snail Carp and

Red-eye Chuan, produce good results for estrualization of farm fish.

The above experimental data indicate, preliminarily, that while the pituitaries of fish of different species have no distinctive effects on the gonadal physiological function, the physiological function of the pituitary is clearly becoming more specialized to a certain extent because of the constant evolution of species. For this reason, in closely related species such as the Cyprinids, the pituitaries generally can be used alternatively, and the estrualizing results are good.

The most important farm fish estrualizing agents used in our country nowadays are Common Carp pituitary and human chorionic gonadotropin. They are described separately below.

Common Carp Pituitary: Collection and storage of pituitary gland. It is best to select sexually mature individuals. Both sexes are usable. Dead fish which have not passed the rigor mortis stage can also be used. It is better still to use brood fish which have never spawned.

First, cut off the head of a Common Carp (Figure 31, A). Set the head on its cut surface, with the snout facing upward. Use a knife to cut from the nostrils to the upper edge of the eyes to remove the fronto-parietal bone which is about 4-5 cm long and 2.5-3 cm wide (Figure 31, B). The fish's brain is now visible. Use a pair of pointed forceps to hold the olfactory nerves and to lift the whole brain backward and upside-down. The pituitary gland, yellowish brown in colour, the size of a green-bean, and lenticular in shape, is now in sight. It is buried deep in the sphenoid (Figure 31, C). At this stage, use a pair of forceps carefully to clear the surrounding membrane attached to the gland and slowly remove it from the bottom. If the pituitary gland is to be used immediately, it is crushed and then used. Otherwise, it can be treated with pure acetone or absolute alcohol (the amount used should equal about 15-20 times the volume of the pituitary gland) to remove water and fats (by acetone). After two treatments (each time it is immersed for 1-2 hours), the gland is preserved. There are two storage methods. (i) Keep the dried pituitary gland in a small coloured glass container and seal it properly. Write on the label the fish's name, date of collection, weight of the gland, etc. and store the container in a cool place. (ii) Keep the gland immersed in the fluid used in the second treatment in a coloured glass container. Seal the container properly and store it. Both methods give good results and can effectively preserve the gland for about one year. Some researchers have tried preserving pituitary glands by these methods for several years and have found that the glands were still effective.

Chorionic Gonadotropin Extraction: The human chorionic gonadotropin was first discovered by the German scientists Zondek and Aschheim in 1927. It is a hormone which is secreted from the chorionic membrane of placenta of pregnant women, and which passes through the blood and kidneys and is discharged. The chorionic gonadotropin extraction method succeeded in 1928. The method has continually been improved since then. In 1958 the Biological Research Institute of Academia Sinica used this hormone for Silver Carp and Bighead estrualization with good results. At present the ready-made material available in the market is the "veterinary gonadotropin". It is in the form of white or pale yellow powder. When dissolved in water, the solution is colourless or a clear pale-yellow. It does not dissolve in common organic solvents. The aqueous solution of this material is very difficult to preserve. The preservation period should generally not exceed 24 hours. Heat and excessive acid or alkali will render the material or its aqueous solution totally ineffective. The material should be sealed in a container and stored in a cool, dark place. Generally, it remains effective when stored at room temperature. There are many methods of extraction, and they are briefly described below:

(i) Simple benzoic acid method - Use urine from women 2-4 months pregnant. After the urine is filtered, it is mixed with acetic acid or hydrochloric acid to lower the pH to 5.0. Slowly add 75 ml of saturated benzoic acid solution(1) to every 1,000 ml of urine. Stir continuously in order to allow the benzoic acid to become evenly distributed in the urine. Then store the solution at under 10°C in a container. After one night, filter it once more; use 95% alcohol(2) to dissolve the sediment. At this time the protein begins to separate and precipitation occurs. After about 2 hours, when precipitation is complete, pour away the upper layer of clear fluid; centrifuge out the sediment; discard the bottom layer of sundry material of the sediment(3). Wash the sediment two times in absolute alcohol(4). During each washing note carefully that any remaining sundry material be discarded. The sediment (final product) is then vacuum-dried(5).

(ii) Chinese medicine gall-nut and Pasania nut skin (Pasania caspidata) methods - Use urine from women 2-4 months pregnant. After the urine is filtered, it is mixed with acetic acid or hydrochloric acid to lower the pH to 4.0-5.0. Put 20-25 g of Pasania nut skin or gall-nuts in 150 ml of 95% alcohol and heat to the boiling point. To prevent the alcohol from evaporating, the flask mouth is first connected to a condensation tube in order to let the condensed alcohol vapour drop back to the flask. The boiled fluid is first allowed to cool, and is then poured into the urine slowly. Keep stirring so as to cause precipitation. In about 2 hours, after the precipitation is complete, centrifuge away the upper layer of clear fluid; wash the sediment in 95% alcohol once; then wash it once again in absolute alcohol. The final sediment is then vacuum-dried.

(iii) Highland clay method (Highland clay is also known as white pottery clay or white "rock-fat") - Use urine from women 2-4 months pregnant. Filter the urine and discard any sundry material. Use 25% hydrochloric acid to adjust the pH to 4.0-4.5; in every 50 ml of urine, add 10 ml of 5% Highland clay; shake the container sufficiently. Store it in a refrigerator overnight and stir constantly. The next day, discard the upper layer of clear fluid. Centrifuge the sediment. For every 50 ml of sediment, add 5 ml 0.1 N sodium hydroxide and stir continuously. After one hour, centrifuge to discard the upper layer fluid. Use 25% hydrochloric acid to adjust the pH to 7.0. For every 10 ml of solution, add 85 ml of 95% alcohol, stir well and set for precipitation. After the sediment is settled, centrifuge. The final sediment is then washed twice with pure alcohol and dried.

(iv) Alcohol precipitation method - Use urine from women 2-4 months pregnant. Filter and discard the sundry material. Use 25% hydrochloric acid to adjust the pH to 4.8-5.0; add 95% alcohol to 50%; allow precipitation. Centrifuge to discard the sediment. Add again 95% alcohol to bring the concentration of alcohol to 80%. Allow precipitation; wash the sediment twice in absolute alcohol; allow final precipitation; then dry.

1. Preparation of saturated alcohol benzoic acid solution: Add benzoic acid to 95% pure alcohol until it stops dissolving. This is a saturated solution.

2. For every 1,000 ml of urine, use about 80-90 ml of 95% pure alcohol.

3. There are two layers of sediment. The upper layer is gray in colour and the lower layer is brown or grass green. Use the upper layer and discard the lower layer.

4. To wash with pure alcohol, pour the alcohol into the sediment. After the mixture is well stirred, it is then centrifuged to discard the sundry material of the sediment. The remaining sediment is washed again with pure alcohol. The sediment now obtained by centrifuge can be dried.

5. If a vacuum-drying facility is not available, the sediment may be spread out in a dry ventilated place, so that it will dry faster. Never use heat or put the sediment under the sun to dry.

Dosage:

Normal Dosage: (i) Pituitary dosage: the dosages of Common Carp pituitary used for estrualization of various species of farm fish are basically similar. Generally, the amount used is 2.5-4.5 pituitary glands per kg (of body weight), 3-4 glands per kg being more common. The dosages used at the Southsea Fisheries Research Institute and at the Sinfui District Lilok Farm in Kwangtung are listed in Table 54.

(ii) Chorionic gonadotropin dosage: For Silver Carp and Bighead estrualization, the amounts of gonadotropin used are basically the same. The dosage ranges from 500-2,200 international units per kg, but generally it is 800-900 units per kg, as shown in Table 55.

Tables 54-55 indicate that the largest Common Carp pituitary gland dosage is 9.75 glands per kg; the smallest is 2 glands per kg. A suitable dosage is 3-4 glands per kg. The largest chorionic gonadotropin dosage is 4,666 units per kg; the smallest is 428 units per kg. A suitable dosage is 800-1,100 units per kg.

There is no difference in the Common Carp pituitary gland dosage used among the three species of farm fish. However, when using gonadotropin, Grass Carp need a larger dosage.

Relationship between Dosage and Various Factors: (i) Relationship between dosage and seasons: Early in the propagation season, use a slightly larger dose. During the height of the propagation season, use a slightly smaller dose. Late in the season, the largest dose is generally used. This is related to the gonadal development process of the brood fish.

(ii) Relationship between dosage and body size: Brood fish of smaller body size generally take a relatively higher dosage, and vice versa. For example, at the Shakao Fry Farm (1961) in Kwangtung, Shuntak District, the dosage used for Silver Carp brood fish averaging under 3 kg in body weight was 810 units per kg. When the body weight was over 3 kg, the dosage was 654 units per kg. For Bighead brood fish under 7 kg in body weight, the dosage was 1,298 units per kg. When the body weight was over 7 kg, the dosage was 884 units per kg. The results were very good.

(iii) Relationship between dosage and number of injections: Generally the dosage for one injection is smaller than that for two injections (see Figure 32).

(iv) Relationship between dosage and ecological conditions: In spawning ponds with good ecological conditions, the dosage can generally be reduced. The dosage for artificial insemination in still-water spawning ponds is generally larger than that for the natural insemination flowing water pond. For example, at the Yangtse River Fisheries Institute (which uses the flowing water natural spawning method), the maximum dosage of pituitary gland used for Silver Carp estrualization is 2.2 glands per kg; the average is 1 gland per kg. The dosage of chorionic gonadotropin used for Silver Carp and Bighead estrualization is 500-800 units per kg, which is lower than that generally used for still-water spawning ponds in Kwangtung.

The fresh pituitary gland is generally applied in smaller dosages than the dried gland.

Relationship Between Dosage and Egg-Laying Quantity: (Tables 56 and 57) According to data in Tables 56 and 57, there is no regular relationship between dosage and egg-laying quantity.

Relationship Between Dosage and Egg-Hatching Rate: On the basis of currently available data, it seems that there is also no distinctive relationship between dosage and egg-hatching rate. For example, the Shuntak Shakao Fry Farm uses smaller dosages. The average dosage of gonadotropin for Silver Carp brood fish is 1,360 units per kg; for Bighead it is 1,776 units per kg. The average annual egg-hatching rate is 42.31%. The Sinfui Lilok Farm uses larger dosages. The average dosage of gonadatropin for Silver Carp brood fish is 2,392 units per kg. The average annual egg-hatching rate is 42.66%. Thus there is very little difference in the egg-hatching rate between the two farms.

Comparison of Effectiveness of the Above Two Estrualizing Agents:

Relationship Between Estrualizing Agents and Egg-Laying Rate (Table 58): Table 58 indicates that there are no noticeable differences between the two estrualizing agents and the brood fish egg-laying rate.

Relationship Between Estrualizing Agents and Egg-Hatching Rate (Table 59): Table 59 indicates that using the pituitary gland can improve the egg-hatching rate. However, it should be clearly noted that the pituitary gland was used for the estrualization of Bighead at the Farm before mid-July, and that after that period gonadotropin was used. The different results obtained may have some relation to the season.

Relationship Between Estrualizing Agents and Egg-Laying Quantity (Table 60): Table 60 indicates that pituitary gland is distinctly more effective than gonadotropin in improving the relative egg-laying quantity of brood fish.

Relationship Between the Effectiveness of Two Estrualizing Agents and the Seasons: Experiments conducted at Hangchow University proved that for estrualization of Silver Carp, pituitary gland is more effective in spring; in summer gonadotropin is better. The results of the experiments are shown in Table 61.

In Kwangtung many production units recognize that using pituitary gland for estrualization in spring and gonadotropin in summer can increase the effectiveness of estrualization (see Figure 33).

Seasons (water temperature) have a certain influence upon the effectiveness of the two estrualizing agents. The reason may be that the pituitary gland contains two kinds of hormone, the follicle-stimulating hormone and the lutein hormone. Some scholars recognize that the former hormone causes a further step in the maturation of eggs and ovulation, and that the latter can cause only ovulation. Human chorionic gonadotropin contains only the hormone of the latter kind. Therefore, this may be the reason that in early spring the brood fish's gonads are not completely mature and that the pituitary gland gives better results in estrualization. Secondly, these kinds of estrualizing agents' biochemical reaction in the fish's body may demand different optimum temperatures. Gonadotropin reacts faster and better under higher temperature conditions. This may be because gonadotropin comes from the higher temperature human body, while pituitary gland comes from warm-water fish which live in an appropriate temperature range of 20-30°C.

Injection

The Number of Injections: At present, in the estrualization of farm fish, some farms use a single injection and others use two separate injections. Both methods can achieve satisfactory results.

From the results of artificial insemination in Kwangtung in the past few years, it seems that the dual-injection method gives better results. For example, in Kwangtung at the Shuntak District's Shakao Fry Farm and the Sinfui Lilok Farm, the dual-injection method is generally used. Their production results are better than others in Kwangtung. Their egg-laying rates and egg-hatching rates are higher (see Table 62).

In 1962, the Shinnin Fry Farm in Kwangtung used the dual-injection method for Silver Carp estrualization on some 20 brood fish. All the fish spawned, and over 8 million fry were hatched. This was the best artificial propagation record for Silver Carp in Kwangtung.

Why are two separate injections generally more effective than a single injection? As pointed out in the previous chapter, we recognize that the propagation process of farm fish works largely through the directive of the central nerve and the secreting functions of the pituitary gland, and that it is restricted by external conditions. When fish propagate naturally in rivers and streams, although the ecological conditions of the spawning ground satisfy the needs of the spawning brood fish, they still require the stimulation of those external conditions for 1-2 days and nights before they proceed to spawning. That is, the maturation process of farm fish eggs (from late Stage IV to Stage V) should have a suitable bridge-over period. Moreover, as also pointed out previously, if farm fish under domesticated conditions have undergone a prolonged period in still water, their physiological situation is generally not fully prepared for the bridge-over to spawning if no suitable treatment is given before estrualization. We have emphatically pointed out in the previous paragraphs that before estrualization brood fish should be given suitable "hasten-maturation" treatment so as to raise production. For the same reason, if a single full-dose injection is given to those brood fish which are considered physiologically not yet fully prepared to bridge-over to spawning, it will generally bring about a certain unfavourable condition. It will cause an excessively rapid physiological reaction in the brood fish and upset the reproductive function, causing for instance, excessively rapid swelling or over-swelling of the belly (especially in the Silver Carp); the result will be a reduction in both the egg-laying and egg-hatching rates. Furthermore, if the dual-injection method is used, the first injection can also be used as a final indicator for brood fish selection. This point has been discussed previously.

The above analysis does not deny that certain aspects of the single-injection method are more desirable. Under certain circumstances, it is necessary to adopt the single-injection method. It saves labour and can reduce the injury and mortality rates of brood fish, especially in the case of Silver Carp.

Based on our experience over the past several years, we now suggest some basic principles that can provide guidance in making decisions on the number of injections to give.

Principle No. 1 - In the early propagation period (in Kwangtung, before early May), because part of the brood fish's gonads are not sufficiently developed and mature, the dual-injection method should generally be adopted. During the height of the propagation period, because the majority of brood fish are basically mature, especially those which have received pre-estrualization treatment, the single-injection method can generally be used.

Principle No. 2 - Irrespective of the season, if the brood fish are considered well mature, the single-injection method can be used. Otherwise, use the dual-injection method.

Principle No. 3 - For brood fish which react well in the pre-estrualization treatment, the single-injection method can be used. Otherwise, use the dual-injection method.

Principle No. 4 - Generally, if the ecological conditions of the spawning pond are excellent, use the single-injection method (similar to the natural spawning method). Otherwise, the dual-injection method might be more suitable.

Principle No. 5 - Generally, for estrualization of Silver Carp and Grass Carp, the dual-injection method gives more reliable results.

When the dual injection method is used, the estrualizing agent used in the first injection is, ideally, a mixture of pituitary gland and chorionic gonadotropin. The dosage used is generally 10-15% of the full dose.

Injection:

Preparation of Injection Fluid: (i) Preparation of pituitary gland suspension injection. Put the required number of fresh or preserved pituitary glands in a small grinding mortar (if the pituitary glands used are preserved in liquid, they should be taken out of the liquid and placed on filter paper to dry for 10-20 minutes before use) and grind them thoroughly. Then add a physiological salt solution (the formula for the physiological salt solution: sodium chloride, 7.5 g; calcium chloride, 0.35 g; potassium chloride, 0.2 g; distilled water, 1,000 ml; or 0.7% sodium chloride solution). Every 10-15 pituitary glands are mixed with 1 ml of the physiological salt solution to form a suspension fluid. Then slowly drain the fluid into an injection syringe, which has been sterilized in boiling water. It is now ready for use (size of injection-syringe used: 1-5 ml; size of needle: Nos. 16-20).

(ii) Preparation of human chorionic gonadotropin injection: To date, the ready-made human chorionic gonadotropin produced in our country, and available in the market, is called "Veterinary gonadotropin". It is packed in 500, 1,000, 2,000, 2,500, 5,000 and 10,000 units in serum bottles. The substance, which is in dry powder form and coloured white or pale yellow, is easily dissolved in water. To use, pierce the needle of a sterilized injection-syringe through the bottle's rubber stopper and inject some distilled water or physiological salt solution into the bottle. Wait until the gonadotropin is thoroughly dissolved, then draw the solution into the syringe. It is then ready for use. Injections should be freshly prepared so as to prevent the possible loss of the effectiveness of the gonadotropin when it is dissolved in water.

Injection Method: Trained or treated brood fish, after being transferred into the spawning pond, may be injected immediately, or they may be kept in the spawning pond for 1-2 days before injection.

During injection, a brood fish is held in a net or in a transporting vat or in a cloth clamp. Generally, it is held in a hatching box with a water depth of about 10 cm. An experienced worker can handle the injection job alone, but normally it is done by two people.

Two methods of injection are used: intraperitoneal injection and intramuscular injection. At present the former method is used by most production units because its effect is more stable. When making an intraperitoneal injection, first hold the fish in a belly-up position. Wipe off the water at the injection area (the majority prefer the inner side of the basal part of the pectoral fins; some prefer the basal part of the ventral fins). Point the injection needle towards the head at an angle of 45-60^{o} (Silver Carp and Bighead) or 80-90^{o} (Grass Carp) to the body's longitudinal axis and pierce the needle through the concave scaleless basal part of the pectoral fins 1.5 to 2.0 cm deep, injecting the fluid slowly. If the brood fish struggles, one should wait until it calms down before administering the injection.

An intramuscular injection is administered at the dorsal muscle between the lateral line and dorsal fin. Point the injection needle towards the head, lift up a scale slightly, pierce the needle between the scales to a depth of 1.5-2.0 cm, and inject the fluid slowly. After injection, press the injection aperture with a finger for a few seconds.

Injection time. If dual injection is adopted, the first injection is usually carried out at noon and the second at midnight in order to allow the brood fish to spawn at dawn. Some prefer to carry out the first injection at 6 a.m. and the second at noon to allow the brood fish to spawn at dusk. In short, one can wisely carry out the injection in accordance with water temperature, equipment arrangements and convenience of working conditions.

Matching of Males and Females: Experiments prove that under conditions of artificial propagation, the appearance of male fish seems to have no marked influence upon the maturation and ovulation of female fish. It does, however, have a certain influence on estrus and spawning of the brood fish. Therefore, when artificial insemination is adopted, the matching of male and female fish in a certain proportion is not required, but some male fish are still needed in the pond to stimulate the intensity of estrus and to facilitate the artificial insemination operations. Generally, a sex ratio of 1:1 is adopted by most people. In situations in which the male fish are not quite sufficient, some well developed male fish can be stocked in a rearing pond or fish basket so that milt can be collected when needed, and those male fish which are not well developed can be put into the spawning pond. In such cases, the female-male ratio can be lowered to 3:2, or even down to 2:1.

When artificial insemination is adopted, 2-3 matching groups of female and male brood fish can be put together each time in one pond. This "multi-group-at-one-time" method has its advantages and drawbacks. The advantages are that it speeds up production, utilizes the most suitable propagation season to complete or basically complete production duty, and improves production efficiency. It also induces, to a certain extent, estrus among the brood fish. A drawback is that because the spawning time of brood fish is not uniform, the estrus and spawning of late ovulating brood fish will often be affected when eggs are collected.

When natural fertilization is adopted, the ratio of females and males and the selection of male fish demand a higher standard. Generally, the ratio of females and males is 1:2; some use 2:3; it depends on the number of males available at the time and their state of development (quantity of milt). When there are more males, or when the males are not fully mature, the ratio of males should be higher. Otherwise, it can be lower.

When using natural fertilization 3-4 matching groups of female and male fish can be put together each time. If necessary, more groups can be added. This will not affect the propagation process of brood fish very much.

Depending on its health (chiefly on whether it is injured and on whether it still has a good amount of milt), a male fish, after being used, can generally be reused after intensive culture for 10-15 days.

Ecological Conditions for Spawning of Brood Fish

As described in the previous chapter, wild farm fish must undergo a certain stimulation by hydrological conditions before proceeding to propagation. In other words, these ecological conditions are an absolute necessity for reproduction. But are these ecological conditions (chiefly water current, water quality and water temperature) necessary for artificial propagation? On this question, there are no uniform views at present. Some people believe that under artificial propagation conditions, the ecological conditions are still necessary. Others consider that if the estrualizing agents have produced the decisive effects, the ecological conditions can be abated. According to our practical experiments over the past few years, the ecological conditions, strictly speaking, are still absolutely necessary for artificial propagation. For example, if the water temperature drops below 20°C or rises above 32°C, or if the dissolved oxygen content is lower than 1 mg per 1, the spawning of brood fish will be controlled. However, these conditions rarely appear. That is, in artificial propagation, the ecological conditions are not absolutely essential, but they do affect, to a certain degree, the results of artificial propagation. Therefore, in places where circumstances permit, one should create and utilize good ecological conditions, because they are able to raise, to a greater degree, the egg-laying and egg-hatching rates of brood fish. However, in places where suitable conditions are lacking, one should not try too hard to express the function of ecological conditions to the extent of "not eating because of hiccough". There are many places in Kwangtung where suitable ecological conditions are lacking, but where artificial propagation can still be successfully carried out. The efficiency, however, is slightly lower. It is beyond doubt that in artificial propagation the estrualizing agents do bring about the main function. At the same time, we should not overlook a fundamental principle: the activities of an organic body, especially those of the higher vertebrates which possess a well developed nervous system, cannot be separated from the influence of external environments. It has been proved through practice that among farm fish under artificial propagation, all the endocrine organs of normal spawners (the interstitial cells of the pituitary gland and nerve nuclei of the infundibulum) have strong relative endocrinal secretion responses. The endocrine organs in abnormal spawners, especially those that do not spawn, appear to have no normal endocrinal secretion. This indicates clearly that for fish under artificial propagation conditions, the influence of ecological conditions through the central nerves is still very important. Many years of practice have proved that under coordinated suitable ecological conditions, the physiological reactions of brood fish are more normal and a higher propagation of efficiency results. In contrast, unsuitable ecological conditions will repress, to a certain degree, the physiological reactions of the fish, thus resulting in lower artificial propagation efficiency.

Table 63 describes, in a preliminarily way, the influence of ecological conditions on the result of propagation.

Table 63 indicates that when brood fish are estrualized in a fish basket, although part of the oocytes can mature, both the egg-laying quantity and the egg-hatching rate are very low. Even though the efficiency of estrualization in still-water spawning ponds is conspicuously higher compared to that in a fish basket, it is still lower than that in a flowing-water spawning pond.

The relatively more important ecological factors for artificial propagation of farm fish are flowing water, water quality and water temperature. Those of secondary importance are the presence of the opposite sex, area, lighting, water level and bottom materials. These factors are now described separately:

Flowing Water: A certain flow speed, or in the general situation a sudden increase in flow speed, is one of the principal ecological factors for natural spawning of farm fish in rivers. Under artificial propagation conditions, flowing water has a certain function in raising the egg-laying and egg-hatching rates of brood fish, especially of Grass Carp, which demonstrate distinct estrus and lay more eggs in flowing-water spawning ponds.

Table 63 shows that flowing water brings about a marked improvement in artificial propagation, especially in hastening timely estrus and spawning. In elevating the fertilization rate and egg-hatching rate, the effects are even more distinct. For example, the egg-hatching rate for natural fertilization in flowing water is generally 65-75%; for still-water artificial insemination, it is generally about 40%.

Flowing water performs several main functions in artificial propagation. (i) It can stimulate brood fish to undergo timely egg-laying or milt-exudation, thus increasing the chances of timely contact between eggs and sperms, and thus effectively completing the natural fertilization function. (ii) To a certain extent, it can raise the quality and quantity of the sexual products. (iii) It enables the fertilized eggs to be suspended in water and to flow into the egg-collecting box. (iv) It can improve the dissolved oxygen content in the water of the spawning pond.

At present the water flow speed of spawning ponds varies greatly in different places. Generally, it varies from 0.1 to 0.6 m per sec. The areas and flowing speeds of some spawning ponds in various provinces are listed in Table 64.

When using flowing water to assist and hasten the spawning of brood fish, the intermittent method is generally adopted. That is, 2-4 hours after the brood fish are injected, the first letting-in of water begins, continues for 20-30 minutes and then stops. The second letting-in of water begins about 1-2 hours before the expected spawning time of the brood fish and continues until spawning is completed. A continuous and excessive flowing speed may cause unfavourable results, the so-called excessive repression.

Water Quality: The influence of water quality (chiefly high dissolved oxygen content) on the effectiveness of artificial propagation of farm fish is also quite distinctive. In 1960 the Southsea Fisheries Research Institute constructed 4 new spawning ponds. Because the water in them could not be changed frequently, their water quality was rather poor. The brood fish's egg-lay ng rate and egg-hatching rate in these new ponds were lower than those in the old ponds (in the old spawning ponds the water could be changed every day during high tide, so the water quality was good). Later the old spawning ponds were reused, and the brood fish's egg-laying rate and egg-hatching rate returned to a higher level.

Grass Carp are most sensitive to water quality during artificial propagation. For instance, one of the chief reasons why the Shuntak District's Sinti Fry Farm (1962) obtained higher efficiency in Grass Carp propagation was that it gave greater importance to changing the water in the spawning pond and thus keeping the pond water constantly in a fresh condition. It was discovered at the Farm that if the pond water was not changed for three days, the water quality would be poor. The estrualized Grass Carp reacted abnormally: they did not lay eggs. After the water was changed, their reactions returned to normal. In 1963, we experienced the same situation while working in villages. For example, when it was difficult to change the water in the spawning ponds at Shuntak District's Latliu Fry Farm, Chiunan Fry Farm, Sinfui District's Lilok Farm and Chungshan Farm, the water quality was rather poor and the egg-laying rate of Grass Carp was lower. However, if the difficulties were overcome by the constant changing of the water or the use of flowing water, ultimately the egg-laying rate was distinctly raised to a higher level. The reasons that natural spawning in flowing water is more efficient than artificial insemination in still water are as described above.

Apart from the flowing water factor, good water quality also seems to be one of the affecting factors. Therefore, when using still water artificial insemination spawning ponds, the water must be changed continually.

To date there are still insufficient data from which chemical indicators of water quality can be worked out for artificial propagation of farm fish. It is certain that one of the most important elements is dissolved oxygen content. Generally, water for spawning ponds is currently obtained from rivers and reservoirs. Water from these sources normally has a very high content of dissolved oxygen, between 4 to 8 mg per l. It is very suitable for propagation purposes. However, because the water quality in brood fish rearing ponds and still-water spawning ponds is generally more fertile, the water body is smaller and there is less dissolved oxygen. This water quality is not quite suitable for farm fish propagation. Practice has shown that if the dissolved oxygen content in the pond water drops to the fish-surfacing level (1.5-2.0 mg per l), the estrualized brood fish, in most cases, will not spawn. In contrast, when the dissolved oxygen content is high in the spawning ponds the brood fish, in most cases, proceed to normal estrus and spawning.

Water Temperature: As pointed out in the previous chapter, the propagation of wild farm fish is carried out within a certain water temperature range. In the Pearl River system the farm fish spawn within a water temperature range of 24 to 30°C. Under artificial propagation conditions, the water temperature has a certain influence upon farm fish propagation, but its amplitude seems to be greater. For example, we made brood fish spawn at 18-20°C and at 30-33°C. However, under these excessively high and low water temperature conditions, the egg-laying rate and egg-hatching rate of farm fish are rather low. The embryo deformity rate, on the other hand, is clearly high, and the end result is poor. A reason may be that under excessively low water temperature conditions (generally in early spring), the gonads of brood fish are generally not developed completely. A second reason may be that the water temperature, no matter how excessively high or low, is beyond the normal route of development (too fast or too slow) of the whole process of maturation of eggs, laying, fertilization and hatching; thus a higher rate of deformity appears. Therefore, to improve the results of artificial propagation, the production operation should be carried out as far as possible within the suitable temperature range (24-29°C). On this point, our fish farmers have accumulated some excellent experience. In early spring, when the water temperature is slightly too low, the brood fish are controlled so as to spawn in the afternoon when the water temperature is higher. In summer, when the water temperature is slightly too high, the brood fish are controlled so as to spawn at night or early in the morning.

The height of the farm fish propagation period is also the season of highest efficiency. Whether in natural river propagation or in artificial propagation, they all take place in the most suitable water temperature months of May and June. Therefore, artificial propagation for fry production should be arranged to occur in the most suitable temperature period.

Opposite Sex: In natural rivers, farm fish must have the companionship of the opposite sex in order to bridge-over to the spawning stage. In artificial propagation, the presence of the opposite sex still seems to have a certain influence in hastening the farm fish's egg-laying. In practice, it shows that with estrualized brood fish, after a few hours the male fish normally begin to chase the female fish for a certain period (about 1-2 hours) and then the female fish begin to spawn. It was discovered that under artificial insemination, female fish could also mature and proceed to ovulation (internal spawning) when male fish were lacking. Whether lone females will lay eggs voluntarily is unknown. We have not yet observed any doing so, and also there are no references on this matter. Judging from the above, in artificial propagation the existence of the opposite sex does not seem to have much influence upon maturation and ovulation of female fish. However, it still has a certain function with the female fish, causing her timely estrus and laying of eggs. We also discovered a very interesting mating phenomenon. When we put a female fish which received estrualization treatment before it had reached the mature ovulation stage (generally no appearance of estrus behavior) in a fish basket for observation, no male fish were observed to swim near the basket. Once the female fish reached the mature ovulation stage, we saw several male fish swimming excitedly around the basket and attempting to get near the female fish.

To sum up the above, during the propagation period male fish appear to have a constant desire to mate with female fish (this is consistent with their gonadal development to Stage V). Whether a female fish accepts the courting by a male fish will depend on her own physiological state (mature ovulation together with secretion of female sex hormone). Once a female fish has reached the mature ovulation stage, there may be a certain estrus "signal" which will direct male fish to approach her quickly and cooperate in the process of reproduction.

Lighting: In the previous chapter it was pointed out that during natural propagation periods, the highest rates of spawning activity among farm fish appear in the morning or at dusk when the light is generally fairly weak. Similarly, under artificial propagation, the spawning hours of farm fish are seldom at midnight or mid-day (of course this is largely controlled by man). To satisfy the possible lighting demands of brood fish during spawning, the fish should be made to spawn during the most suitable hours, namely, in the early morning or at dusk.

Water Level: A sudden rise in the water level has a certain stimulating function in natural spawning of farm fish, as mentioned in the previous chapter. In artificial propagation, the rise of the water level also seems to have a good influence in hastening brood fish maturation and spawning. For example, in many flowing-water spawning ponds, there is generally a rise in the water level before and after the letting-in of water. Furthermore, when the water level has risen, the volume of water and the pressure have also relatively increased. These may have a certain stimulating function for brood fish. Therefore, in places where such conditions are available, it is also best to raise the water level suitably while using flowing water.

Area: It was mentioned in the previous chapter that the minimum width of farm fish's natural spawning ground measured 8-10 m. Under artificial propagation conditions, it looks as if the area of the spawning pond can be reduced. For example, we made some estrualized female Bighead and Silver Carp eggs partially mature in a fish basket which was only 90 cm in diameter although the fish failed to lay eggs and the efficiency was not high. In some places in Kwangtung, owing to the limitation of the facilities, small temporary spawning ponds about 30-40 square m. in size and made of bamboo mat are constructed in ordinary fish ponds. This can cause some of the estrualized brood fish, especially Bighead, to reach mature ovulation and bring about the appearance of a normal estrus phenomenon. At present, most of the still-water spawning ponds used for artificial insemination in Kwangtung are generally 60-100 square m in size. Flowing-water natural spawning ponds are generally between 100 and 180 square m in area.

Thus the area of the spawning pond also seems to have some influence on hastening brood fish to mature ovulation, but the influence is not great. It has more influence in hastening the brood fish's natural spawning. This is easily understandable, because during spawning brood fish need a certain activity space. If a minimum activity space is lacking, their spawning activity will be restricted and their spawning delayed or stopped.

Bottom Materials: Among the various species of farm fish in Kwangtung, with the exception of Mud Carp, which spawn in the bottom layer, Silver Carp and Grass Carp are surface-layer spawners. Under artificial propagation, especially under good ecological conditions, Bighead, in many cases also spawn in the surface layer. Judging from these situations, the bottom materials of spawning ponds may not have much influence on farm fish. Many practical experiences prove that under artificial propagation conditions, all bottom materials of spawning ponds, no matter whether they are pieces of stone, sand grains or soil, provide normal spawning. However, to preserve good water quality, to prevent the water from becoming too turbid, and to eash fish-catching, the bottom of a spawning pond is better if it is paved with a 6-10 cm thick layer of coarse sand or bricks.

Estrus and Spawning

Response Time: After estrualization treatment and under normal conditions, brood fish will appear after a certain length of time, in a state of estrus. This period of time is called the response time.

The response time can vary slightly, depending on the season (water temperature), hormones used, the number of injections, the species of brood fish, and the ecological conditions. These relationships are now discussed briefly.

Relationship Between Different Seasons and Response Time: Because fish are cold-blooded animals, the intensity and speed of their biochemical reactions are largely controlled by the thermal environment. Therefore, in summer when water temperature is high, the response time is relatively short. In spring it is relatively long (Figure 34).

Relationship Between Different Hormones and Response Time: The response times of the different hormones used for the estrualization of farm fish are different. Even when the same type of hormone is used for estrualization of different species of farm fish, the response times are not at all similar. Generally, the response time for pituitary gland injection is slightly shorter and more stable than that for gonadotropin injection. Dosage and response time do not seem to be closely related.

Relationship Between Number of Injections and Response Time: With similar hormones, dosage and water temperature conditions, different numbers of injections have distinctly different response times (length of time from the last injection). The second injection induces a shorter response time than a single injection, but the total response time (length of time from the first injection) is longer, as shown in Table 65.

Comparison of Response Times Among Various Species of Farm Fish: Given the same hormone and dosage in the same season, the response time of various species of farm fish are generally similar. However, when compared more carefully, there are some slight differences. Generally, Grass Carp have the longest response time of the three farm fish, Bighead are next, and Silver Carp show the shortest response time, as shown in Table 66.

Relationship Between Ecological Conditions and Response Time: Generally, good ecological conditions can provide more accurate response times and a more distinctive display of estrus by the brood fish.

Estrus: After they have received the estrualization treatment, and if they react normally to the estrualizing agents, brood fish will generally begin chasing each other excitedly within the response time. This phenomenon is called estrus.

The beginning of estrus in farm fish is marked by the following principal characteristics. Some irregular ripples appear on the water surface. They are caused by the brood fish beginning to chase each other in the middle and bottom layers of the pond. This phenomenon should not be immediately taken as the normal beginning of estrus, because under many situations, unestrualized brood fish can occasionally cause the appearance of irregular ripples when they are reared in a small pond. If the above phenomenon continues intermittently, increasing in amplitude as time passes, it should then be regarded as normal estrus. However, in some cases only male fish display estrus. Sometimes female fish do not react normally (if for example, there is a conflict between the fish's internal physiological state and external conditions, or if the maturation process of the follicles and oocytes is out of harmony).

If the above phenomenon remains normal and continues to occur within a certain period (about 40-60 minutes from the beginning of estrus), female and male fish begin chasing each other close to the water surface (Figure 35). If the act is repeated 2-3 times within a short period of time (from a few minutes to ten minutes plus), then, without doubt, the brood fish's estrus is normal and they have already begun to spawn. If artificial insemination is adopted, the eggs should be collected immediately.

To summarize, the normal estrus and spawning of brood fish should agree with the following phenomena: (i) the intermittent estrus chasing should increase in frequency with time; (ii) the degree of excitement should be from low to high; (iii) both females and males should appear activated; and (iv) the chasing should start in the middle and lower layers and gradually develop into sustained chasing close to the water surface. The duration of estrus is generally from 30 minutes to 90 minutes.

The general phenomena described above apply to the estrus of Silver Carp and Bighead. In Grass Carp estrus the above phenomena occur only occasionally; in the great majority of cases, another set of phenomena appear. That is, at the beginning of estrus, female and male brood fish swim along the side of the spawning pond, appearing only slightly excited. Later, the degree of excitement and the swimming speed increase gradually. These phenomena should only be regarded as a sign that estrus is beginning, not as proof of true estrus. If these phenomena continue to develop normally, and if at the same time the brood fish become more excited in chasing each other to the middle of the pond, then this is true estrus. However, the degree of excitement in Grass Carp estrus is generally lower than that in Bighead, and in no way can it match that in Silver Carp. In a few cases, especially in a spawning pond with optimal ecological conditions, the female fish display a high degree of excitement and chase other fish vigorously near the water surface; they even shed eggs in a belly-up position and with shivering pectoral fins. Therefore, when artificial insemination is adopted, one should not judge the estrus activities of Grass Carp by the same general standard used for Silver Carp and Bighead. In order to avoid missing the right moment for egg collection, especially when ecological conditions of the spawning pond are not good, one should be especially careful.

Spawning: When using the flowing-water natural-fertilization method, after the female and male brood fish have appeared chasing each other at the water surface 2-3 times, female fish can, in many cases, be seen being closely chased by several male fish. At times they bang against the female fish's abdomen with their heads, sometimes even pushing the female fish out of the water. At this moment, both female and male fish are vigorously turning their bodies at the water surface, and at the same time shedding eggs and exuding milt. This kind of phenomenon is basically similar to that in natural spawning. The above phenomena appear mostly in the spawning process of Silver Carp. Owing to over-excitement, Silver Carp may sometimes even leap onto the shore during spawning. Sometimes male and female fish place their abdomens against each other's and swim from the middle to upper layer of water in a parallel formation and in a very intimate manner.

The spawning phenomena of Bighead are basically similar to those of Silver Carp, only the degree of excitement of Bighead is slightly lower. Among the Bighead we observed in a whirlpool during spawning were female and male fish passing their abdomens together and bending their caudal peduncles in a curve in the manner of an "embrace". This is a fairly rare phenomenon.

Generally, when a group of brood fish starts spawning, they gather to spawn once every few minutes to about 10 minutes plus. Normally, the spawning process is completed after 2-3 spawnings. Sometimes the whole spawning process may drag on for more than an hour.

The Question of Two Propagations Per Year: The spawning of bony fish is divided into two basic types: the "single spawning type" and the "separate spawning type". Which spawning type do the farm fish of our country belong to? To date, we still lack the detailed and accurate data needed to reach a conclusion. Some scholars base their observations on the uniformity of farm fish's oocyte development. That is, they conclude that because the ovaries are basically formed by Phase II and Phase IV eggs groups the night before spawning, the fish may belong to the single spawning type. Other scholars base their observations on the fact that in the Yangtse River the ovaries of brood fish still contain immediately after spawning a certain number of large eggs. Thus they conclude that the fish belong to the separate spawning type.

In recent years we discovered during the farm fish artificial propagation process that when Silver Carp, Bighead and Grass Carp were reared for another 50-70 days after their first artificial propagation and when those individuals which had a bigger abdomen were used for a second propagation, the results were excellent. Tables 67-68 show our records of second-time propagation for some brood fish in recent years using the tagging method.

Tables 67 and 68 show that the intervals between the first and second-time propagations were 66 and 77 days on the average; an interval of 3 months is also effective. The egg-laying quantities in the second-time propagation averaged 43% and 58% of those of the first time. The fertilization rate in the second time was 76% of that of the first time. The egg-hatching rate was 62% of that of the first time.

On the basis of the above facts, we recognize, preliminarily, that among pond-reared farm fish under artificial control, some brood fish belong to the separate spawning type or repeating cycle type (i.e. two sexual cycles per year). But are the eggs laid in the second-time spawning actually developed from Stage II and III eggs of the ovaries? Or are they developed from the remaining large eggs which were not laid in the first round? At present we do not have enough data on this question to draw a conclusion. At the moment it seems that both spawning types exist. According to a large amount of statistical data, a great majority of the farm fish, during artificial propagation, lay an average of 40-70% of their large eggs in the first round. Some individuals also shed all their eggs in the first round (see Table 26). There are three possible types of the remaining large eggs which have not been laid. Type No. 1: These eggs have either not reacted or reacted only lightly to the hormone. Therefore, within a certain period, if the brood fish are estrualized again, these eggs will be effectively laid, fertilized and hatched into fry. For example, some estrualized brood fish failed to lay eggs or laid only a small quantity of eggs (but their swollen abdomen indicated a certain reaction). But sometime later, the fish are estrualized once more, and in many cases they proceed to lay eggs normally and these eggs are effectively hatched into fry. Such situations belong to the first type. Type No. 2: The remaining eggs have reacted to the hormone; for instance, the polarization of the nucleus and even maturation division or the melting of the yolk and the polarization of the ooplasm have begun. This type of egg is like a machine which, once set in motion, cannot stop (it lacks the ability to reverse its reaction). In the end, the eggs are absorbed and transformed. Type No. 3: These unlaid large eggs do not change positively like the above two types. Only some of them reacted (such as the more mature ones or those nearer to a blood vessel); the rest did not react (we and the Russian experts dissected and examined the reaction situation of the eggs of the estrualized brood fish which failed to spawn, and found that the eggs belonged to this type). Section examinations of the ovaries of brood fish after spawning by us and the Fukien Normal College showed that the majority of the remaining large eggs degenerate and are absorbed. For example, one month after spawning, all the remaining large eggs in the ovary are completely absorbed. The Stage III eggs increase rapidly. These rapidly developed Stage III eggs, if under the influence of favourable external factors (chiefly nutrition and water temperature), will very likely continue to develop into Stage IV eggs and enter the repeating cycle. Therefore, given the present situation, the question of the spawning type of pond-reared farm fish is very complicated. The fish may react differently under different external conditions. To answer the question we need more scientific research.

Insemination

There are two insemination methods used in artificial propagation of farm fish: artificial insemination and natural fertilization. The former is done when the brood fish have reached a certain degree of estrus and are beginning to spawn. They are immediately fished out of the pond for artificial insemination. In the latter case, the brood fish are allowed to remain in the spawning pond, to carry out egg-laying and milt-exuding and to complete the fertilization process by themselves.

At present, the artificial insemination method is most widely adopted in Southern China Region, while the natural fertilization method is used mainly in other provinces and cities.

Artificial Insemination

Artificial insemination is based on the physiological characteristics of mature eggs and sperms, and uses suitable technical means to facilitate their timely contact so as to complete the function of fertilization. The aim is to obtain the highest fertilization rate. To obtain satisfactory results, the technical arrangement of insemination should agree with the biological characteristics of the eggs and sperms.

General Biological Characteristics of Mature Eggs and Sperms:

The Vitality of Mature Eggs: The eggs of farm fish mature during the middle stage of the second maturation division; then ovulation begins and the eggs wait to be fertilized. In this short period of time, their life expectancy varies considerably, according to different environmental conditions. For example, there is a great difference between the oocyte fluid and fresh water. In order to search deeper into this very important question as it relates to artificial insemination, we conducted an experiment to observe the effective duration (life-span) of mature Bighead eggs in oocyte fluid and in fresh water. The results are shown in Figure 36 and Table 69.

Figure 36 shows, preliminarily, that after leaving the fish's body and being kept in oocyte fluid, some mature eggs of Bighead could maintain their capability of being inseminated for over 140 minutes. More than 40% of these eggs could maintain it for over 60 minutes. More than half of the eggs could maintain it for over 20 minutes; and a great majority of the eggs could retain it for 10 minutes. The above results indicate, preliminarily, that the maturation process of the eggs of farm fish is not totally concurrent. This phenomenon has been proven in artificial insemination. For example, when the eggs are collected too early, the egg-laying quantity is very often low and the egg quality is poor. But a short time later (10-30 minutes), the egg quantity will continue to increase and egg quality will improve. This also explains why the egg-hatching rate is higher under natural fertilization: it allow the eggs to mature and to be laid continuously. Based on these characteristics, when using artificial insemination methods, one should work quickly in order to gain time. Especially during the hot season, the eggs lose their insemination ability (too hot) even faster. However, if for some reason the insemination time is delayed, one should not abandon the work and leave it half-finished, because when the mature eggs leave the body (generally within 40-60 minutes) about half of them still possess insemination ability.

Table 69 shows that when contacted by water, the micropyle of Bighead mature eggs is quickly blocked, owing to a revival action, and so eggs lose their insemination ability. After 90 seconds in water, a great majority of the eggs have lost their insemination ability. The average fertilization rate of the 30-second group is 50% lower than that of the controlled group. This clearly explains the reason why the dry method must be used in the artificial insemination of farm fish. It also explains why one must select strong, healthy, uninjured and milt-rich males in natural spawning. One wants to harmonize the egg-laying and sperm-exuding activities of the fish, so that a higher fertilization rate may be achieved.

The Vitality of Sperms: The sperms of farm fish, similar to those of other bony fish, are not active when they are in their spermatic tissues or when they are outside the body in the seminal fluid. When they are placed in fresh water, a physiological salt solution or the ovarian fluid, they proceed to different degrees of activity. Experience proves that the vitality of the sperms of Silver Carp and Grass Carp can generally be maintained up to 50-60 seconds in fresh water. In rare cases, some can live up to 1 minute and 40 seconds. In a physiological salt solution (0.6-0.7%), they are able to stay active up to 20-30 minutes. In the ovarian fluid they remain active even longer than when they are in physiological salt solution. Based on these characteristics and on the special behaviour of the sperms' oxidation metabolism, we tried to lower the temperature of the seminal fluid gradually by placing it in a low-temperature (-1^{o} to $2^{o}C$), germ-free environment, which would reduce the sperms' metabolic rate. As a result, we managed to keep the sperms alive for 4-8 days (see Table 70). This has brought great convenience to work in artificial insemination and hybridization.

When the sperms of farm fish enter water, they immediately start moving vigorously; in fresh water the whipping motion stage (like rolling waves) lasts about 20-30 seconds. In a physiological salt solution, they generally move from about 2 minutes and 30 seconds to 3 minutes and 30 seconds. Thereafter their moving ability gradually weakens. In the end, they display an oscillating movement and die.

How to Distinguish Good Quality Mature Eggs: Good quality mature eggs are normally transparent, full and even, with fresh and clear pigments. They are coloured yellowish green, grass green (such as Grass Carp's) and orange yellow (especially those of Bighead). They have high water-absorbing power, good surface tension, and their fluid appears glue-like. Good quality eggs are generally laid under the following conditions: accurate response time, normal and distinct estrus, eggs laid in proper sequence, and high egg-laying quantity.

Over mature eggs are characterized by their grayish white colour, dullness, low surface tension, and their fluid lacks the normal stickiness. They are produced in artificial propagation mainly due to the untimely collection of eggs or to the abnormal reaction of brood fish. In natural spawning, overmature eggs are mainly caused by the injury of brood fish or unfavourable external conditions.

In general, immature eggs are characteristically lower in transparency, have dull pigmentation and low water-absorbing power, are uneven in size, and have little egg fluid. During artificial collection, the eggs flow out intermittently in small quantities only.

How to Distinguish the Quality of Sperms: Good quality milt is like thick milk. It is milky white in colour, rich in quantity and easily dispersed when dropped into fresh water or a physiological salt solution. Under the microscope, it shows a high density of spermatozoa; all appear normal in shape and very active. If the milt quantity is low and thin or too thick like a paste, yellowish white or pale white in colour, with a low density of not-so-active spermatozoa, then the quality of the milt is low, and it is not suitable for artificial insemination.

Collection of Milt and Eggs: Given the physiological characteristics of mature eggs and sperms, in artificial insemination work one should collect sperms first and then eggs. If the man-power is adequate, it is best to collect the sperms and eggs simultaneously, especially in the hot season. This quick insemination method produces the best results.

When the brood fish begin chasing each other rapidly near the surface 2-3 times (this phenomenon seldom occurs with Grass Carp), the fishing should start. The female fish should be examined first as to the state of their pectoral fins and secondary sexual characteristics. The mature females (eggs flow out of them when they are lifted out of the water) are then placed in the hatching box or in a net (portion of a net used for this purpose) to await egg-collection. On the basis of the number and size of the brood fish, one estimates the possible yield of eggs (statistical data covering several years indicates that each kg of body weight yields about 50,000-60,000 eggs); and on the basis of the estimated egg quantity, one calculates how much milt is required (one ml of milt for about every 100,000-150,000 eggs). These estimates need not be very accurate; it is more important to avoid any delay.

For milt-collection, a male fish is placed in a hatching box (which is submerged in about 5-10 cm of water) or in a specially made milt-collecting frame. One worker holds the fish in a belly-up position and also prevents it from jumping. Another worker holds a clean rubber-head pipette or an injection syringe (without its needle) in his right hand. His left hand presses the fish lightly at the middle-lower position of the testes, moving towards the cloacal opening. The small amount of milt squeezed out the first time is discarded. Milt is then sucked into the pipette or the injection syringe at the cloacal opening (Figure 37). Basically, milt-collection work should be done only once to every male fish. It is best to use a separate pipette (or injection syringe) for each fish. After the milt is collected, the pipette is put in a small cup containing some physiological salt solution, which is placed so as to avoid exposure to the sun.

For egg-collection, select the female fish with the biggest abdomen and highest possible yield of eggs and work on her first.

Egg-collection methods adopted at present can generally be classified into two kinds.

Method No. 1: One worker holds the fish's caudal peduncle with his right hand and supports its snout with his left. The tail should be higher than the head (to prevent the eggs from flowing out) and above water. The other worker quickly wipes away the water with a moist towel (care should be taken not to wipe away the mucus), then sets out the insemination pan (usually a common, enamel hand-washing basin is used) and prepares for egg-collection. The first worker then aims the cloacal opening at the insemination pan and quickly turns the fish head-up. The mature eggs flow out continuously, owing to the force of gravity, into the pan. This is a common and simple method.

Method No. 2: When the brood fish are big and powerful (such as big Grass Carp), method no. 1 very often cannot handle the fish properly, and very often large quantities of eggs are lost due to the struggles of the brood fish, which can obstruct normal working procedures. To overcome this difficulty, an egg-collection clamp is used (Figures 38 and 39). The clamp is made of two layers of cloth; the outer layer is of coarse cloth and the inner layer of smooth nylon or plastic. The clamp has a large hole for discharging eggs. During egg-collection, one worker blocks the brood fish's cloacal opening with one hand to prevent the eggs from flowing out too early, and leads the fish into the egg-collection clamp. The other worker wipes away the water on the fish's body, then the hand blocking the cloacal opening is removed and the eggs flow into the insemination pan.

No matter what method is used, when the natural outflow of the eggs is about to stop, one can squeeze the abdomen lightly to get more eggs out. After egg-collection, if most of the mature eggs have been laid, the brood fish should be put back into the rearing pond for intensive culture. If a brood fish does not lay many eggs, it should be returned to the hatching box and allowed to wait for 10-20 minutes, and then egg-collection is resumed once again. Because a brood fish is very often just at the beginning of ovulation at the time it is caught, only a small quantity of eggs may be collected. However, after some time, the eggs continue to leave the ovaries, and it is possible to continue the egg-collecting operation. It was pointed out in the previous chapter that according to much statistical data, when artificial insemination is used the brood fish's egg-laying rate (i.e., the rate of eggs that have left the ovaries) is generally about 50%. Therefore, except in a few rare cases when the brood fish have laid all their eggs in a single round, one should undertake to subject the fish once more to intensive culture for 50-70 days in order to be able to carry out a second-time propagation.

<u>Artificial Insemination</u>: As pointed out before, all the eggs do not mature and leave the ovary at the same time. In other words, the effective fertilization period of the egg groups cannot be maintained at the same time, but egg-collection is generally done only once. Therefore, the insemination process must be done as fast as possible.

The artificial insemination method used at present is basically the dry method. Its procedure varies somewhat in different places. In Kwangtung there are four methods.

Method No. 1: After the eggs are collected, according to the quality of eggs, the undiluted milt collected earlier for this purpose is squeezed out from the pipette into a small cup containing physiological salt solution (about 10 times the volume of the milt). The mixture is well shaken and then evenly poured onto the eggs.

Method No. 2: In order to shorten the insemination time, milt diluted with physiological salt solution is put into the insemination pan before egg-collection. Then the eggs are collected immediately. During the egg-collecting process, the pan is rotated gently to facilitate the contact of the eggs and sperms.

Method No. 3: The simultaneous collection of the eggs and milt. At the same time the egg-collecting process is going on, another group of workers is collecting milt, which then is quickly poured onto the eggs. This method is best for saving insemination time, but its drawback is that it requires more workers.

Method No. 4: The eggs are collected first and then the milt is collected. After the eggs are collected, the milt is quickly poured onto the eggs. This method can reduce some milt-collecting time.

Of the above four methods, method No. 3 is the most efficient and the most suitable for the hot season.

Irrespective of what methods are used, when sperms and eggs are mixed together, they should be gently stirred with a clean domestic fowl feather to hasten the fertilization of the eggs. The stirring time is from 30-60 seconds. Next, clean, fresh water is added slowly while the mixture is stirred continuously for about 30 seconds. Then the mixture is left to settle for about 30 seconds; then more clean water is added to wash away the excessive milt, blood and egg fluid. After they are washed 2-3 times, the fertilized eggs are placed in the hatching box.

In case the milt collected from one fish is not satisfactory, the mixed sperm insemination method may be used; i.e., milt from two or more male fish is mixed together. When there are too many eggs and too little milt, the male fish's testes can be taken out and cut into fine pieces, washing out the sperms in physiological salt solution and filtering the washed-out fluid with a piece of gauze. The washed fluid from one testis is generally good for 700,000 to 1,000,000 eggs.

It is best not to inseminate more than 300,000 eggs at any one time. If the number of eggs exceeds this limit, the eggs should be divided into suitable lots and handled in separate insemination pans.

Methods for counting eggs: There are two methods for counting fertilized eggs: (i) the volumetric method and (ii) the weighing method. The former method is carried out best with a graduated insemination pan or a measuring cylinder. The amount of eggs can be worked out by the volume shown on the graduated scale (Silver Carp and Grass Carp eggs: about 650-700 eggs to 1 ml; Bighead eggs: about 600-650 eggs to 1 ml). The latter method involves the weighing of the eggs together with the insemination pan, then subtracting the pan's weight from the total weight; the remaining weight is the eggs' weight (Silver Carp and Grass Carp eggs: generally 600-650 eggs per g; Bighead eggs: 650-700 eggs per g). Egg-counting should be done after insemination but before washing. If counting is required for water absorbent fertilized eggs, it should be done after the eggs have fully absorbed water (after about one hour) and by the volumetric method (Silver Carp eggs: 100 ml to about 1,100 eggs; Bighead eggs: 100 ml to about 760 eggs).

Natural Fertilization

The working procedure of this method is as follows. The brood fish which have received estrualization treatment are released in the spawning pond, and 3-4 hours later the letting-in of water begins (flowing speed of 0.1 to 0.3 m per second) and continues for 30 minutes. About 2 hours before the expected spawn time, water is let in again at a flow speed of 0.2-0.5 m per second to stimulate the brood fish to spawn. After the display of estrus, the brood fish are allowed to lay their eggs and exude milt voluntarily and to complete the fertilization function. About 2 hours after spawning, the collection of the fertilized eggs may begin (if eggs are collected too early, the egg membrane will break easily). At present, there are two methods for collecting fertilized eggs.

First, remove the brood fish from the spawning pond, and then use a fine-mesh net, working back and forth, to collect the eggs. Continue the operation 4-5 times, after which nearly all the eggs in the pond should have been collected. Preferably, the net used for catching the brood fish should be made of small-meshed nylon netting (3-4 cm mesh size). It should be placed beforehand at the pond bottom. When in use, it is slowly pulled up on one side, gradually working to concentrate the fish in one corner of the pond. This method is very convenient and thorough and does not injure the fish's bodies.

With the second method, a trap-net is set at the water outlet (Figure 40) to collect eggs. The trap-net and its egg-collecting box are preferably made of cotton or silk gauze (mesh size, 1.0-1.5 mm). When it is being set up, the net should be carefully examined to see whether there are any holes in it. It should also be washed constantly in order to allow water to flow freely through it. In egg-collecting work, the tools should be refined, and the work should be done carefully and diligently. The egg-collecting box should not be raised above water.

Even though a filtering device has been set at the water inlet to prevent predators and pollutants from entering the pond, the eggs collected should be filtered (using a coarse filter) and washed once more to double check. The method involves the use of a round (about 30 cm in diameter) or square washing and filtering device (the bottom of the device is fitted with a sheet of 1.5-2.0 mm mesh cotton or silk gauge). The eggs collected are divided into smaller lots and put into the device one lot at a time. Washing is carried out in clean water by an up-and-down movement of the device (but it is not raised above water). Any small predators and pollutants mixed in with the eggs are filtered out. The eggs are then placed in the hatching box.

Comparison of the Two Insemination Methods

Natural Fertilization:

Advantages: 1. It conforms to the maturation process of eggs; i.e., egg-laying continues as maturation continues. Therefore, the fertilization rate and egg-hatching rate are generally higher.
2. Losses due to untimely egg-collection (too early or too late) can be avoided.
3. It has no adverse effect on the uneven spawning time of more than one brood fish in the pond.
4. There is less injury to the brood fish.
5. A smaller labour force (1-2 people) is required.

Disadvantages: 1. It requires more facilities and is more restricted by environmental conditions.
2. More time is consumed in the production process.
3. The fertilized eggs are often mixed with predators and pollutants.
4. There are more chances of injury to the eggs due to mechanical operations.
5. Hybridization work is difficult to carry out.
6. When the brood fish are injured or under excessively high water temperature conditions, the results of propagation are poor.

Artificial Insemination:

Advantages: 1. It requires only simple equipment and is less restricted by environmental conditions.
2. It is less time-consuming.
3. The fertilized eggs are devoid of predators and pollutants.
4. There is less injury to the eggs through mechanical handling.
5. Hybridization work is easy to carry out.
6. Generally, when the brood fish are slightly injured or under excessively high water temperature conditions, propagation can still be carried out with fair results.

Disadvantages: 1. Because egg-collection is only done once, it is difficult to fit it in with the continuous egg maturation process. Therefore, the egg-hatching rate is generally lower.
2. If the timing for egg-collection is not right, non-fertilizable, overmature eggs will be encountered.
3. The uneven spawning time of brood fish during egg-collection usually affects other immature brood fish's estrus and ovulation.
4. There are more chances of injury to the brood fish.
5. A larger labour force (3-4 persons) is required.

The above comparison shows that each of the two methods has its advantages and disadvantages. From the standpoint of production efficiency, natural fertilization gives a higher yield, but from the standpoints of equipment, installation and ease of expansion, artificial insemination has its good points. In selecting an insemination method, one should base the choice on the existing overall conditions. For example, if a large-scale production unit has a good water source (the major factor) and is better equipped, it should, in principle, adopt the natural fertilization method. If the opposite conditions prevail, it is better to use the artificial insemination method. When the former method is used, one should also consider using the other method in accordance with seasonal factors (such as water temperature) and the condition of the brood fish.

Hatching

Artificial incubation is based on the physio-ecological characteristics of the embryos so as to provide the most suitable incubating conditions and refined management techniques and to allow the embryos to undergo normal development, so that in the end high hatching rates will be achieved.

Hatching is the last link in the artificial propagation chain. Because it does not seem to require great technical skill factors such as the suitability of the site, the adequacy of the incubating conditions and the refinement of management techniques are often easily overlooked. This often results in failure to achieve final success in artificial propagation and in heavy losses. Hatching is therefore worthy of our attention.

To achieve good results, we should first have a relatively complete understanding of the biological characteristics of the embryo of farm fish, especially the ecological aspects. Practical data regarding this particular aspect are not available in detail at present. Preliminary data were summarized in Chapter I under the heading "Ecological Conditions for Embryonic Development."

At present, the artificial incubation methods used for hatching farm fish eggs in our country can be divided into indoor and outdoor types. Indoor hatcheries are being used in a few places for experimental purposes only, such as at Shinnin Fry Farm and Shanghai Chingpu Fish Culture Farm in Kwangtung Province. All the others are using outdoor hatcheries.

Outdoor Hatchery

Site Selection: The selection of a suitable site is of primary importance in the setting up of an outdoor hatchery. The most important condition for site selection is the matter of water quality. Much practical experience in the past few years has proven that lively water conditions or good water quality is the deciding factor in raising the egg-hatching rate. For example, one of the reasons that good propagation results are obtained in the Pearl River delta area in Shuntak, Sinfui, Nanhai and Chungshan Districts is that this area has a good incubation environment namely, the river. The river provides not only good water quality and stable water temperature but also a suitable rolling motion for the embryos, which is beneficial for the gas exchange of the embryos. A hatchery should be located in the best possible place, such as a slow flowing river or the outlet of a water reservoir. The speed of flow should not be too fast, generally 0.2-0.4 m per second. In places where flowing water conditions are lacking, one should select a bigger body of clear, lean water (over 5 mu in area). Fertile water ponds should never be used, because they contain more organic matter, larger biological quantities. They also have higher fluctuations in their dissolved oxygen content and more harmful gases. Thus they are not suitable for hatcheries.

If artificial incubation is carried out near a city, proper attention should be paid to the problem of polluted water, especially industrial wastes.

Furthermore, the selected site should not obstruct normal water transportation, but should be conveniently located for hatchery work.

Hatchery Tools: At present the most commonly used outdoor hatchery device in our country is a rectangular, floating net box. It is made of ramie cloth, cotton cloth, silk gauze or nylon (the best results are obtained from the latter two materials). The mesh size is generally 0.8-1.0 mm. The basic requirements are that it allows the free flow of water and prevents fish larvae from passing through it.

The size of the net box or hatching box varies from place to place. The more suitable dimensions are these: 80 cm long, 50 cm wide and 35 cm high (Figure 41). The upper side is open. The upper and lower four corners are connected with strings, which are tied to a rectangular wooden frame, thus stretching out the net box fully. The net boxes are arranged in series at the water surface (Figure 42).

To make the boxes more durable and to improve the free flow of water, new hatching boxes or ones that have been used many times (except for boxes made of nylon) should be dyed with Tzuliong or tannin extract. After 1-2 treatments and passing through steaming and washing processes, the boxes are ready for use.

In many places in Kwangtung double-layer netting is used to keep out voracious predators. The net boxes are surrounded with a layer of heavier netting with a mesh size of 0.25 mm (generally a fry-catching net is used).

Management: (i) The density of eggs used in hatching varies in accordance with the dissolved oxygen content, water type (moving water or still water) and water temperature conditions. Generally, with flowing water, high dissolved oxygen content and suitable temperature (below 8°C) conditions, the density is 4-6 eggs per square cm. If the hatching conditions are not so favourable, the density should be 3-4 eggs per square cm.

(ii) The hatching box should be examined for any damage or holes before it is used. When it is fixed in position, the bottom should be flat to prevent the eggs from gathering in one corner. The box should be placed in the water bottom-first, so that water comes in only through the bottom. Be very careful not to allow any predators to enter the box.

The utmost precaution should be taken against predators which could injure or eat the embryos. The common predators are small wild fish, shrimps, insect larvae, tadpoles and large water fleas. These predators often suck the fish eggs from outside the net, or climb into or bore through the net to eat the eggs.

Normally, there are more predators in still-water ponds than in rivers and streams. The degree of predation is even higher in ponds which have not been cleared and treated against predators and in hatcheries that have been used for a relatively long period, because the predators have already formed fish-egg eating habits.

To prevent predators, one should, apart from selecting a good hatchery site and using preventive equipment (such as double-netting), check the boxes constantly during the hatching process.

(iii) Protection against wind, rain and strong light. Strong wind often blows down the hatching boxes. Before this happens, the boxes should be moved to a place that shelters them and tied down securely.

Torrential rain, too, often causes some damage to embryos, including high mortality. Therefore, before the rain comes, the hatching boxes should be lowered to increase the depth of water (28-30 cm). If necessary, the boxes may be covered.

Experiments prove that strong light is harmful to embryos. Therefore, in summer when the light is strong, the depth of water in the boxes should be increased (24-28 cm), or arrangements should be made so that the boxes are not exposed to direct sunlight.

(iv) To provide better conditions for the exchange of gases for the embryos, one should wash away at appropriate times the silt which has gathered inside and outside the box. The eggs can be stirred gently with a plate (the fry-counting plate is usually used) about once every hour; at the same time the silt can be brushed and washed away. This should be done irrespective of whether flowing-water or still-water hatching is used.

(v) During the hatching process, the partial mortality of the fertilized eggs is inevitable. Dead eggs should be picked out and discarded in a timely way, because the decomposition process consumes large amounts of oxygen (experiments carried out by the Shanghai Fisheries College indicate that a dead egg consumes about 10 times more oxygen than a living one). The method involves making use of the slightly lower specific gravity of dead eggs to clear them out. If necessary, change the hatching box.

(vi) When the embryos are about to break out from the egg shell due to the action of the incubation enzyme, the egg shell gradually becomes thinner. To prevent the embryos from breaking out too soon, the hatching box may be moved to a place where water is flowing very slowly or where it is still, and then one may wait for the eggs to hatch.

(vii) After the embryos have hatched, one should consider whether the mesh size of the hatching box is able to prevent the fry from escaping. If the mesh size is too big, mesh of a smaller size should replace it. When all the fry are out of their shells, shell-clearing work should begin. The method commonly used is to empty a few boxes of fry with egg shells into a big basin. Because the newly hatched fry have a special habit of lying at the bottom, the egg shells, which are suspended in the upper layer, are poured out with the water into another basin, thus leaving most of the fry at the bottom of the basin. By repeating this process several times, the egg shells can be largely cleared out.

(viii) After the fry have hatched, the hatching box should be replaced by a new one if it has been in the water for many days. The old one should be washed and dried. Hatching boxes, after being used many times, should be treated again with a new preservative if the dye has come off.

(ix) In the period after the fry have hatched and before they are released in a pond, the caretaking work is similar to that of the embryonic stage. When the yolk sacs of the fry have completely disappeared and when they have started taking food (in Kwangtung it takes about 2-3 days), the fry may be released in ponds. Before releasing them in ponds, it is best to feed them once with hen or duck egg yolk (hard boiled). The time of release should be between either 9.00 and 10.00 a.m. or 4.00 and 6.00 p.m.

Indoor Hatchery

At present the indoor hatchery is in the trial production stage in our country. The incubators used are the hatching jar and hatching trough. They are described in the following sections.

Hatching Jar Method: This method was used at the Shanghai Chingpu Freshwater Culture Experimental Farm for one year in production trials and found to be quite good. The working technique is described below.

A funnel-type, flowing-water incubation glass jar is used. The capacity of the jar is 10.1. The bottom is fixed with a water pipe 0.5 cm in diameter (internal) for constantly letting in new water (Figure 43). The mouth is covered with a cloth jacket to filter the water and to prevent the fry from escaping. The water source is the river, which contains relatively fresh, clean and stable-temperature water. It is filtered to eradicate predators. The production procedure is as follows.

Preparation: Check the water source to make sure it is plentiful and clean. Check the water pipes. Fix the hatching jar's mouth cover and carefully check for any damage. If there are holes, they should be repaired before it is used.

Filling with Eggs: The eggs should be cleared of predators, such as small fish and shrimps, and of pieces of grass and leaves before filling the jar. The number of eggs varies in accordance with the water temperature. At a water temperature lower than 25°C, an average of 15,000 to 20,000 eggs per jar; at a water temperature above 25°C, 10,000 to 15,000 eggs per jar. When filling the jars, the egg-measuring cylinder should be submerged in water in the jar. Then pour out the eggs. Do not pour the eggs down from the jar mouth above water.

When the filling process is completed, the clip is then opened to let water in. Meanwhile, adjust the amount of water inflow in each jar to the extent that the force of the water inflow brings up the eggs gently to the surface, without any turbulent and rolling effect.

Inspection: To check whether there is the right amount of water in the jar and any blockage, special attention should be paid to dislocated joints, leakages and damaged mouth covers in order to prevent the eggs and fry from flowing out with the water. After the fry have hatched, and before the egg membranes have dissolved, special attention should be paid to the blockage of the mouth cover by egg membranes, preventing the water from flowing out under the cover. If the level of water in the jar is higher than the mouth by more than 3 cm, one should pat the cloth cover lightly by hand to cause the vibration of the water in the jar. The egg membranes will fall off the cloth cover, and the water will again flow through freely.

If fry die, or if they accumulate at the bottom of the jar, the clip should be closed. Let the fry sink and draw away the dead fry as soon as possible, or transfer the excessive number of fry to another jar. When the treatment is completed, the clip is immediately opened to let water in.

Record the water temperature at the appointed time during inspection.

Fry Taken Out of the Jar and Released in Ponds: When the fry start feeding, they are ready to be released in ponds. First, close the water supply clip and take out the hatching jar. Then pour out the fry. When the fry are poured out, some will stick to the jar or to the cloth cover. Wash the jar and the cloth cover with water, and then partly open the cover and pour out the washing water through the opening. Open the clip and pour out the fry remaining in the bottom tube. Fry taken out of the jar should be released in the pond immediately.

Cleaning the Hatching Jar: After the fry are poured out, the cloth cover is taken off, washed and dried in the sun. If the cover requires dyeing, it should be washed after dyeing before it is used.

The Shanghai Chingpu Freshwater Culture Farm (1961) used the method just described and obtained excellent results (see Table 71).

Hatching Trough Method: At present, this method is used for fry production at the Shinnin Fry Farm in Kwangtung. The layout of the hatching room, method of operation, production results and advantages and disadvantages are briefly described below.

Hatching Room Layout: The hatching room is small, about 300 square m in area. The whole system consists of three major components: the water filtering and storage pond, the spawning pond and the hatching room (see Figure 44).

Water filtering and storage pond: The water filtering and storage pond measures about 110 square m; the depth of its water ranges from 1.0-1.8 m, sloping slightly towards the water outlet. It is divided into two parts: the filtering part and the storage part. The filtering layer is constructed from coarse and fine gravel. The water passes through this gravel filter and flows into the storage pond. At the other end of the storage pond there are 4 water outlets. Outlet No. 1 leads to the egg-washing pipe of the spawning pond. Outlet No. 2 leads to the water inlet of the spawning pond. Outlet No. 3 is connected to a sedimentation pond, from which the water then goes to the hatching room for egg-hatching. Outlet No. 4 is the pond's outlet. Apart from these outlets, a sluice gate is installed to adjust the level of the water.

Spawning pond: The spawning pond is built from concrete. It is pear-shaped and about 110 square m in area. The depth at its posterior end is 1.0 m; at the anterior end it is 1.45 m. A 30 cm high ladder is installed at the side of the pond. In the pond, there are three water inlets for egg-drifting and one for estrualization. The latter points at an angle to cause the circular movement of the water when the inlet is in operation. Two water outlets (for adjusting the water level) are also installed, one situated 1 m and the other 30 cm above the pond bottom. The water inlets and outlets are 20 cm in diameter. On the opposite side of the water inlets, there are two egg conveyance pipes, 1.7 m apart, 16 cm in diameter. They are connected directly to the hatching room. At the inner wall of the pond two rows of small iron rings are installed at upper and lower positions. Each ring is 1.5 m from the others. There are a total of 48 rings. These rings are used for erecting the bamboo poles which hold up the protective net (Figure 45).

Hatching room: Hatching troughs are installed in the room. They are arranged in two (upper and lower) layers. There are a total of 8 units, 2 of which are used for egg-collection. The hatching troughs are made of concrete. At the anterior end there is a water storage tank in which water pipes are installed to connect the upper and lower troughs and to supply water for egg-hatching. At the centre of each trough, a flow-adjustment board is installed; it causes a difference in water levels between the anterior and posterior parts of the trough so as to increase the flow speed. The trough is 41 cm high; the distance between the upper and lower layers is 80 cm. At the posterior end of the trough there is a water outlet connected to the outdoor drain. This drain is equipped with a coarse gravel filter to prevent predators from swimming upstream to enter the room (Figure 46).

Method of Operation: The eggs used in this hatching room are produced by the natural spawning method. Prior to estrualization, open the sluice board of the filtering pond to allow the filtered water to pass through the storage pond and flow into the spawning pond. When the pond is filled, stop letting in water and carry out estrualization. For estrualization of Silver Carp, a protective net should be installed. About 2 hours before the expected effect of the estrualizing agent is to take place, the inlet pipe is turned on to create a circular flow in the spawning pond. The outlet pipe is also opened to let out excessive water. When the spawning of the brood fish is completed, stop letting in water and take out the brood fish. After about 2 hours, when the fertilized eggs have fully absorbed water and have swollen and their egg membrane has grown more elastic, the low level water outlet is opened. When the water has dropped to the lower level, open the water inlet pipes for drifting eggs and the sluice board of the egg conveyance pipes. The fertilized eggs will flow into the net box of the egg-collection trough in the hatching room through the egg conveyance pipes. The fertilized eggs are divided into lots and then transferred to the hatching boxes in the hatching troughs for incubation. During the incubation process, pay attention to the flow-adjusting board of the water storage tank in order to let water flow slowly into the hatching troughs. Also, stir the eggs about once every hour.

Production Results: The hatchery at the Shinnin Fry Farm began production operation in 1962, and within half a year it had already shown its superiority. The hatchery's production records and the results of artificial insemination are compared in Tables 72 and 73.

Advantages of Hatching Room: The hatching room has yielded excellent production results. It is much superior to artificial insemination outdoor hatching, as described above. The major advantages are briefly described below.

(i) Because the source of water has been filtered, the damage to embryos by predators is reduced.

(ii) The water source is the Hupsui Reservoir (over 6,000 mu in area) so the water is good in quality and stable in temperature. The water temperature in the spawning pond and hatching room is kept fairly stable (3-4°C variation). Therefore, in the summer months of July and August, when outdoor hatching efficiency is at its lowest, the hatching room remains in normal production and maintains high efficiency.

(iii) Outdoor hatching is often subject to the influences of weather, typhoons or strong light, which can cause unexpected losses. Indoor hatcheries can totally, or to a very large extent, eliminate these factors. With the above advantages, the indoor hatchery at the Shinnin Fry Farm has generally raised the egg-hatching rate by 50-70% over that of outdoor hatcheries.

(iv) In regard to work, the indoor hatching room reduces both the intensity and the amount of labour needed. During the incubation process, workers need not work in the water, under the sun or in the rain.

Comparison of the Two Hatching Methods

Indoor Hatchery:

Advantages: 1. Basically, indoor hatcheries can control the hatching conditions, such as the dissolved oxygen content, water temperature, water quality and lighting, and thus can provide stable and higher egg-hatching

rates (Table 74).
2. Indoor hatcheries can eradicate predators.
3. They can improve working conditions for the workers.

Disadvantages: The disadvantage is that the fry produced by this method are generally slightly weaker than those produced by an outdoor hatchery. According to an analysis by the Chingpu Culture Farm, this may be due to the continual beating of flowing water, which causes the over-consumption of body energy. Some researchers recognize that it may be due to an excessively high dissolved oxygen content, which affects the development of the respiratory system of the fry. This disadvantage does not occur when the hatching trough method is used. However, the use of hatching troughs is still new to us and is awaiting further improvement.

Outdoor Hatchery:

Advantages: 1. They are easy to install and the working techniques are simple. They facilitate fish handling and hatchery extension.
2. The fry are generally slightly stronger and healthier.
3. If the hatchery is located in a good environment, especially with flowing water and refined management, the egg-hatching rates can also be raised.

Disadvantages: The disadvantages are that during the production process, embryos are easily affected by external conditions and working conditions are not so good.

The above two methods both have their advantages and disadvantages. A selection of one of the methods should be based on the overall conditions. In places possessing good hatching conditions, such as flowing water or a large area of water, outdoor hatching may be used. When good hatching conditions are lacking, or for fairly large-scale production, indoor hatcheries can be considered.

At this point, the "circular-way hatching method" (TN: a round-shaped flowing-water hatching tank), created in recent years in our country, should be discussed. This method is designed in accordance with the hatching process of farm fish's embryos in natural rivers. Its structure includes the following parts: (1) Water storage pond. Its capacity depends on the requirements. It is positioned 1.5 m higher than the circular-way. (2) Filtering gate. The first layer is made of palm-fibre sheets; the second layer is a fine fibre-sieve. (3) Water inlet pipe. It runs from the water storage pond, passing underground, to the circular-way hatchery. Its height is 25 cm. The opening of the pipe points laterally so as to cause a circular flow. (4) Hatching pond. It is round. Its area depends on the requirements. A protective water outlet gate is installed at the upper part of the inner wall. The pond centre is a water-collecting pond. An outlet pipe is installed as well as outlet holes for the fry.

Generally, the flow speed used is 0.17-0.21 m per second. During the period when fry break out of their shells, the speed used is about 0.2 m per second. When the fry are able to swim freely, the speed is reduced to about 0.15 m per second.

Experiments prove that this method can raise egg-hatching rates by about 1-2 times and save labour by about 3-5 times. The major advantages are high productivity, high egg-hatching rate, labour-saving, saving of hatchery materials, low cost and good fry quality.

Rearing of Fry and Fingerlings

Comparison of Aritificial Fry and Natural Fry

Experience in practical production over the past few years indicates that artificial and natural fry are basically equal in body quality, growth rate and survival rate. However, there are also some differences. The superior and inferior points are summarized in the following sections.

Body Quality: In most cases, the endurance capacities of natural and artificial fry are not much different. In rare individual cases, however, the endurance of artificial fry is slightly lower and occasionally some individuals are deformed. A reason may be that those particular individuals are immature or influenced by unfavourable external conditions during the hatching process. Another reason is that natural fry are produced through strict natural and artificial selection processes; thus this body quality is more uniform. Artificial fry do not pass through those selection processes and so appear occasionally to be slightly uneven in body quality. However, this is not a common phenomenon. In contrast, artificial fry are sometimes even stronger and healthier than natural fry. Therefore, it is very necessary to culture brood fish to their best condition and to introduce more rigid selection procedures in the production of artificial fry.

Speed of Growth: In the fry stage, the growth rate of artificial fry is slightly higher than that of natural fry. Under similar rearing conditions, artificial fry can reach the "7th morning" standard (TN: 2.2 cm in body length) 2-3 days earlier. Because natural fry are usually mixed with a large number (2-40 times) of wild fish fry which have to be removed through a "skim off flower" process (using the low oxygen endurance characteristics of the wild fry to eliminate them the first time) before they are released in a pond. When they are in a pond, it is necessary to use the fat water (low dissolved oxygen content) and "net-in restriction" (high concentration treatment) methods to eliminate the wild fry a second time. Natural fry also have to be transported long distances. All these treatments directly affect the speed of growth of the natural fry.

In the fingerling and adult rearing stages, the growth rate of natural fry is not much different from that of artificial fry. In rare individual cases, the growth rate of natural fry may be slightly higher.

Survival Rate: Owing to the presence of the above man-made factors affecting the growth of natural fry, during the fry rearing stage, the survival rate of artificial fry is generally slightly higher than that of natural fry. As shown by the results of experiments at the Southsea Fisheries Research Institute, the survival rate of artificial fry is 85.4-99.7%. whereas that of natural fry is generally about 80%. Especially during the months of June and July, the survival rate of artificial fry is clearly higher. In other months, there is not much difference between the two.

In the fingerling stage and during its "living in winter" (TN: wintering), the survival rate of natural fry is generally higher. According to practical experience over the past few years, during the fingerling stage, the survival rate of natural fry is 80-90% while that of artificial fry is generally 70-80%.

Adaptability to Transportation: Probably because of strict selection processes and more complicated exercises, natural fry are more adaptable to transportation, and so their transportation survival rate is generally slightly higher than that of artificial fry.

Cost: With artificial fry, a great deal of expense can be saved in catching and transportation, because they are pure and not mixed in with other unwanted species. In addition, they can greatly reduce the amount of labour, fertilizer and feed required.

As a consequence of continuous improvements in artificial propagation (especially in the culture of brood fish), the economic factors (body quality, growth rate and survival rate) related to artificial fry will certainly surpass those of natural fry. This is inevitable once a wild animal has been domesticated.

Rearing of Fry

Pond Clearing: (see section in this chapter called "Rearing of Brood Fish").

Water Quality Adjustment: After a pond is cleared, clear water is let into it and the water quality is adjusted. Fish farmers in Kwangtung use "Big-grass" (grasses of Asteracea family: the major species used are *Artemisia apiacea*, *A. vulgaris*, *Ageratum conyzoides*, *Bidens biternata*, *B. pilosa*, *Erigeron canadensis*, *E. crispus*, and *Saussurea cartkamoides*) to adjust the water quality and to propagate plankton. Generally, "Big grass" are put into the pond 15-20 days before the release of the fry. The quantity used depends on the species of fry and the quality of the "Big-grass". Generally, for rearing of Bighead and Silver Carp fry, 1,200-1,500 kg per mu are used. The "Big-grass" are put into the pond once every 4-5 days, 200-250 kg at a time. The amount can be reduced 20-30% if it is for rearing Grass Carp fry. The method of application is as follows. In the earlier period use more and in the later period use less in order to avoid a drop in the dissolved oxygen content, which will affect the survival rate of the fry released in the pond. The grasses are laid about 1 m from the bund, heaped up along the bund like a ribbon. Generally, after 3-4 days (sunny days), the grasses begin to rot and the water gradually turns an oil-brown or oil-green colour. This colour of water is the best. It contains large numbers of Cladocereans, Copepods, Rotifers, Protozoa and many species of phytoplankton. Later the grass heaps are turned over and washed until only the non-decomposable grass residue remains (about 7-10 days) so that the decomposed materials can spread out in the water. Then the residue is cleared away.

The Institute of Hydrobiology, Academia Sinica, has conducted experiments using a mixed manure-heap method for rearing fry and has obtained excellent results. This method can generally avoid the deterioration of water quality and reduce the outbreak of fish disease. The method calls for the making of some pits at the side of a rearing pond to hold the mixed manure, which consists of 4 parts green grass, 2 parts goat dung, 1 part human night-soil mixed with 1% quick lime to form a liquid fertilizer. The quantity used is as follows. Two to three days before the fry are released, the pond is given the first basic dose of this liquid fertilizer at a concentration of 250 g per cubic m of water. After the fry are released, 150-200 g per cubic m are applied every day, half of the application in the morning, the rest in the afternoon.

When using the "Big-grass" fry culture method, the quality of pond water is generally less satisfactory. For instance, an analysis of water quality at the Southsea Fisheries Research Institute indicates that the organic matter oxygen consumption amounts to 40-50 mg per l; dissolved oxygen content fluctuates greatly between 0.6 to 4.6 mg per l; phosphate content is generally fairly low, only about 0.2-0.3 mg per l; and nitrates content generally ranges from 0.25-0.35 mg per l. When the mixed manure heap method is used, the quality of pond water is relatively better. The organic matter content is generally from 8.4 to 14.2 mg per l; dissolved oxygen stays between 2.0 to 9.6 mg per l, generally about 4.0-5.0 mg per l; and phosphates content is very high, between 2.48-68.4 mg per l. The survival rate is slightly higher in the latter case than in the former case.

Eradication of Predators: Predator eradication is one of the most important tasks in raising survival rates, especially when using the Kwangtung fry culture method. This is due to the use of "Big-grass" manure heaps in the pond, which attract some insects or aquatic insects to lay eggs or to live in the heaps. The most severe predators in the fry pond are the water centipede (Cybister sp.) and Tiger Frog tadpole (Rana tigerina rugulasa). Usually there are also large numbers of Notonecta triguttata, which are very harmful to the newly released fry. Other predators include dragon-fly nymphs (Odonata), Laccotrephes japonensis and the field bug (Kirkaldyia deyrolii). These are carnivorous insects which can eat fish fry, but their numbers are far smaller than those of the water centipede, Tiger Frog tadpole and Notonecta worm, and therefore they are less dangerous. The method used to kill Tiger Frog tadpoles is as follows. Two to five days before releasing fry in the pond, spray the pond water with a 25 ppm concentration tea-seed cake solution, and it will kill all the tadpoles in the pond. Tea-seed cake (TN: saponin) loses its medicinal property fast on sunny days, and slowly on cloudy days. In order to assure the safety of the fry, before they are released, a fish basket is put into the pond and a few fry are released in the basket for "water testing". The method used for killing water centipedes and Notonecta worms is as follows. Five to seven days before the fry are released, use a 1-2 ppm (700-1,200 g per mu in water 1 m deep) water soluble 666 solution to spray over all of the pond. This treatment is very effective for killing water centipedes, but sometimes it is not able to eradicate Notonecta worms. Dragon-fly numphs and other carnivorous insect larvae prefer to live along the edge of a pond. Before fry-rearing, use a hand net to catch them. This will, to a certain extent, clear them out effectively. The above aquatic animals prey not only on fry, but on the natural food in the pond. We must try our best to eliminate them.

Stocking: In Kwangtung, in order to exercise control over large populations of zooplankton in the pond and to maintain water fertility with ease, the traditional method used is as follows. Before the release of the fry, release some "water eating Bighead" (TN: feeding on the zooplankton-rich water). Generally, for fish 15 cm in body length, 150-200 fish per mu; 13 cm in body length, 300-400 fish per mu; and 11 cm in body length, about 500 fish per mu. They are fished out of the pond 1-2 days before the release of the fry.

The stocking density is closely related to the fry survival rate and growth rate. If the density is too high, the fry will grow slowly and have a low survival rate; if it is too low, it will increase costs and waste manpower and materials. The stocking density is generally based on the fry species and body quality, pond area, depth of water and season. These factors are taken into account in wise decisions on stocking density. In rearing Silver Carp and Bighead fry in Kwangtung, a density of 100,000 to 150,000 fry per mu is generally used. The fry will reach the "7th morning" standard (2.2 cm in body length) in 10-14 days. For Grass Carp fry, 150,000 to 200,000 fry per mu are used. The fry will reach the "7th morning" standard in 20-25 days. For rearing natural fry, use polyculture for Silver Carp and Bighead and monoculture for Grass Carp. It is best to adopt monoculture for artificially cultured fry because they are pure in terms of their species.

Culture Management: The central task in culture management is the control of water fertility (actually it is quantity of plankton) and the prevention of water quality deterioration.

Inspect the pond every morning at dawn and observe the surfacing situation of the fish and changes in water colour. Fish farmers in Kwangtung recognize that the standard of water fertility in a Silver Carp and Bighead pond should be judged by the slight surfacing of the fish in the morning for 1-2 hours. For Grass Carp, good water quality is indicated by their slight surfacing once every 2-3 days.

During the rearing period use, in accordance with the factors of fry surfacing, water colour, water temperature, rainfall and growth, 1,000-1500 kg of "Big grass" per every mu of Silver Carp and Bighead pond. Three days after the fry are released, use 200-250 kg every 1-2 days. During the rearing process, according to the stocking density in Kwangtung, the propagation rate of natural food is always insufficient to meet the food demands of the fry. Generally, after 6-7 days, the amount of plankton begins to show signs of rapid reduction. Therefore, in the late rearing period, a sufficient amount of ground-nut cake or rice bran should be given. The amount of grass used in a Grass Carp pond can be reduced to 30-40% of that given to Silver Carp and Bighead, but every 1-2 days add 10-15 kg of cow dung and 0.5-1 kg of ground-nut cake.

When fry have reached the "7th morning" standard, they should be thinned out into fingerlings for culture in other ponds. The fishing operation should be carried out on a clear day in the morning between 9:00-10.00 a.m.

Rearing of Fingerlings

Pond Clearing: see first section of this chapter.

Application of Basic Fertilizer: The area of a fingerling pond should be slightly greater than that of a fry pond; 2-5 mu in size is more suitable, with the water 1-2 m in depth. The method used in Kwangtung for rearing fingerlings is as follows. Two to three days after the pond is "poisoned", a basic fertilizer is applied (generally "Big-grass" and cow dung) at a concentration of 250-300 kg per mu to stimulate the growth of natural food.

Stocking: The fry used for stocking should be strong and healthy and uniform in size, so that they can easily achieve the aims of uniform growth and higher survival rate.

In Kwangtung, the rearing of fingerlings is generally divided into two stages. The first stage is rearing them from the "7th or 8th morning" size (2.2-2.5 cm in body length) to the "10th morning" size (5-6 cm in body length), which normally takes 15-20 days. The second rearing stage is from the "10th morning" size to 10-17 cm in body length, which takes from July-August to January of the following year.

The stocking density for the first stage is generally 30,000-35,000 fish per mu. For the second stage it is 7,000-12,000 fish per mu. Generally, the polyculture method is adopted. See Tables 75 and 76.

Based on the differences in the feeding habits of the fish and the strata in which they live, the best combination for polyculture is Grass Carp and Silver Carp or Grass Carp and Bighead. This method is generally adopted in Chewchiang in Nanhai District, Kwangtung, and in Linhu in Chekiang Province (see Tables 77 and 78).

Tables 77 and 78 show that these two famous places for fingerling production in our country use basically the same stocking system. The only difference is that in Linhu the variation in stocking density for Grass Carp is greater.

Culture Management:

Feeding and Fertilization: The principal task in rearing fingerlings is feeding them with artificial food. In Chekiang, *Wolffia arrhiza* is normally used, the amount given calculated on the basis of 20-40 kg per 10,000 fish per day. After 20 days the food is changed to *Lemna minor* or *Spirodela polyrhiza*. In Kwangtung, soft grass, rice bran and ground-nut cake are frequently used for rearing fingerlings.

For Bighead and Silver Carp rearing, the fertilization of the water is the principal task supplemented by feeding. In the first month of rearing, 200-300 kg of "Big-grass" is applied every 10 days. In the second month the same amount of "Big-grass" is applied every 5 days, along with a suitable amount of dung. In the third month, because the water temperature is gradually decreasing, the amount of grasses can be reduced. However, some fine foods, such as rice bran, soy-bean cake and ground-nut cake, should be given (2-3 kg for every 10,000 fish per day). The amount of fertilizer used for a Bighead pond should be 40-60% higher than that used for a Silver Carp pond.

Matters That Demand Special Attention During the Rearing Period:

Throughout the rearing process, there should be special, full-time managing personnel assigned to the job. The pond should be inspected every morning to observe the activities of the fish and changes in the water quality. At the same time, feeding must be done properly, according to the "four-fix" programme. Grass residue should be cleared periodically.

For a Bighead pond, owing to its fertile water qaulity, special attention should be paid to changes in water quality during seasons of higher water temperature. If the water quality turns bad, the water should be changed quickly and new water let in. Training exercises to promote growth and strengthen the body quality of the fish should be done 1-2 times every month by means of net dragging.

If too much rain makes the water quality lean, additional "Big-grass" and dung should be applied, or more fine food, such as ground-nut cake, should be provided.

The fish must be examined periodically to prevent the outbreak of disease. Special attention should also be paid to the eradication of predators.

In the central and northern regions of our country, preparations for winter should also be done well in advance.

CHAPTER III

ARTIFICIAL PROPAGATION OF MUD CARP

Mud Carp, or Ling Yü (Cirrhina molitorella), are one of the economically important freshwater fish in Kwangtung. More than 40,000 tons of Mud Carp are produced annually, constituting about 30% of the total freshwater fish production. The fish are also cultured in Kwangsi and the southern part of Fukien.

There are many advantages to the culture of Mud Carp. It is a sundry feeder and feeds chiefly on vegetable matter. It can withstand a high stocking density and provides a high yield. It is less susceptible to disease and its meat is tender and delicious. Because its feeding habits and the water stratum it occupies are basically different from those of Silver Carp, Bighead and Grass Carp, the fish pond's productivity in polyculture can be fully utilized and developed. At present, in some fish farming areas in Kwangtung, the traditional stocking system of "one Grass, three Silver (or Bighead), nine Mud Carp" is still in use. Therefore, Mud Carp are deeply appreciated by fish farmers in Kwangtung and many other places in southern China. We recognize that Mud Carp should be used as a bottom stratum fish in areas where culture conditions are suitable.

To help make the best possible use of this good quality fish for culture in all suitable areas, the biological characteristics and data regarding the artificial propagation of Mud Carp are now presented.

Morphology

Dorsal: 3, 12; anal: 3, 6; lateral line scales: 40, 8½/5½.

Head: 17.1% of body length; height: 31.7% of body length. Snout: 40% of head length; eye diameter: 22.8% of head length; interorbital space: 35.7% of head length.

Its body is rectangular and slightly compressed. Its head is small, with a blunt snout and a mouth inferior and transverse. It has one pair of maxillary barbels and one pair of mandibular barbels; the former are longer than the latter, or the latter are totally absent. The dorsal is situated in the middle of its body; the pectoral fin does not reach the ventrals. The lateral line is fairly straight. The pharyngeal teeth in the upper part are slightly oblique; the teeth surfaces are flat in three rows: 5, 4, 2/2, 4, 5. Its intestine is thin and long, 7-8 times its total length. The air bladder is divided into two parts. The gill rakers are fine and dense. The number of gill rakers on the first gill arch is 38.

Colour of adult: The top of the head is greenish gray to brown. The upper posterior part of the eye is light grayish yellow. The gill cover is silvery white. The fish's back is grayish yellow with a trace of greenish brown. The sides of the body are light greenish gray and shiny silvery white. The belly is silvery white. At the upper part of the pectoral fin at the 14th-15th scales is a crescent-shaped jewelry blue colour patch. The basal part of the scales at the sides of the body has stone green lines. All its fins are light purple in colour.

Biological Characteristics

Taxonomically, Mud Carp belong to Family Cyprinidae, Sub-family Barbinae, Genus Cirrhina. It is a sub-tropical species living in large rivers in Kwangtung, Kwangsi and Fukien in the Southern Region of our country. In the Pearl River system in Kwangtung, Mud Carp are distributed in the Han River, Kam River, Nanliu River and Hanyang River and on Hainan Island in the Nandu River and Chong River.

The Mud Carp is a bottom dwelling species, living in the bottom layer of warm rivers. It likes lively water and is an active swimmer. It cannot endure the cold and often dies at a water temperature of 7°C. In winter Mud Carp gather in the deep part of a river, where they stay until the cold season passes.

Under natural situations the Mud Carp feeds chiefly on vegetables, using the chitinous edges of its upper and lower jaws to graze on the diatoms, green algae and filamentous algae that grow on the rocks. It also feeds on the detritus of higher plants and decayed vegetable materials. Mud and sand and some Cladocereans and Copepods are often found in the fish's intestine.

Under pond culture situations, the Mud Carp has the habit of feeding on sundry materials, such as human and animal dung, various kinds of oil-seed cakes, wine-lees, rich bran, wheat meal, silk-worm pupae and the leftovers of all kinds of other feeding materials. It is therefore called the "Street Cleaner" of the fish pond.

Under pond culture and high stocking density (600-1,000 fish per mu) conditions, fry can grow to 10-14 cm in length and 15-30 g in weight in the same year they were hatched. One-winter year old fish reach 18-20 cm in length and 120-180 g in body weight. Two winter-year old fish are 24-28 cm long and 300-450 g in weight. Three winter-year old fish are 30-34 cm long and 600-900 g in weight. And four winter-year old fish are 36-38 cm long and weight 1,100-1,500 g. When Mud Carp are reared under low density conditions, their growth rate can be dramatically raised. In natural rivers and reservoirs, the biggest individuals might weigh 2,500-3,000 g.

Generally, Mud Carp begin sexual maturation at the age of 3 winter-years, when their body weight is 500-600 g. But some individuals, owing to poor rearing conditions, mature at 200 g body weight. Their spawning season commences slightly later than that of Grass Carp, Silver Carp, Bighead and Snail Carp, but it continues for a longer period. Generally, it begins in late May and continues until August or September. The spawning grounds are mainly situated on sand banks in the middle and upper reaches of rivers. In the West River, the major spawning grounds are located in Kwangsi Province, at the mouth of Wuming River and at Liangchun Bank in the Liu River.

The river in Kwangsi Province near Paksik produces only Mud Carp fry; other farm fish fry have not been found in this area so far. In the section of the river near Nannin, the number of Mud Carp fry produced is about 85% of the total farm fish fry production. Near Wuchew, the production of Mud Carp fry is about 80% of the total farm fish fry produced in the area. In the river near Shaoching in Kwangtung Province, Mud Carp fry account for about 60% of all the fry produced.

The propagation process of Mud Carp is similar to that of Silver Carp, Bighead and Grass Carp. It is a reflex activity. That is, special hydrological conditions, a certain speed of flow and flow quantity are required to stimulate propagation activities. It is very interesting that during their propagation process, Mud Carp often produce a low-tone "Ku ku" mating sound. This mating sound can be clearly heard when a spawning school is fairly large. Experienced fishermen can estimate the size of a spawning school and the approximate location of the spawning ground by this sound.

The sexual cycle of Mud Carp is basically similar to that of Silver Carp, Bighead and Grass Carp; only its timing is slightly later than the others. This may have some relationship to the fact that sub-tropical fish require higher water temperature for gonadal development.

In sexually mature individuals, the gonads are mostly in Stage II during the winter (Plate X). At this time the gonadal coefficient is very small, the ovary coefficient is generally 1%, and the testis coefficient is 0.1%. During the whole winter period the gonadal coefficient increases very slowly. In April of the following year (when the water temperature is about 26°C), their gonads begin their late major growing stage. The ovary coefficient distinctly increases and reaches 5-10%, and the testis coefficient increases to 0.3-0.8%. In mid or late May (when the water temperature is 28-29°C), the ovary completes Stage IV. Its coefficient is 18-20%. The testis reaches Stage V (Plate X) and is able to exude milt; its coefficient is 1.1-1.5%. At this time the brood fish proceed to spawning activities. After its eggs are laid, the ovary enters into Stage VI (Plate X). Its coefficient is 4.1%. During the autumn season it returns to Stage III and proceeds to the next sexual cycle (see Figure 47).

Because Mud Carp eggs are smaller than the eggs of other farm fish, the relative fecundity of the Mud Carp is slightly higher than that of other farm fish. On average, the number of eggs formed for every g of body weight is 184. The average number of eggs laid per g of body weight is 130. The fecundity of various species of farm fish in Kwangtung is indicated in Table 79.

Rearing of Brood Fish

Rearing Pond

The area of a rearing pond should not be too large, because such a pond makes difficult the catching of fish and the adjusting of water quality. Too small a pond, however, will affect the normal activities of the fish and the water quality. Generally, the most suitable size is about 2 mu. The water depth should be 1.5-2.0 m.

Although Mud Carp frequently feed on humus, which is rich in organic matter and benthos, it is not advisable to have too much humus in the pond, because too much humus will cause difficulty in controlling the water quality and add problems to the fish-catching operation. Moreover, it will affect the gonadal development of the brood fish due to their over-plumpness.

The pond bottom must be flat, with water inlet and outlet installations. Bunds should be well built to ease fish-catching operations and to prevent the fish from escaping.

Stocking

The brood Mud Carp pond should, in principle be used only for rearing Mud Carp. If the pond is difficult to drain, it is best not to mix the Mud Carp with other brood fish (but they can be mix-cultured with suitable numbers of other food fish). Fishing for Mud Carp in a pond which has no water outlet is a difficult job, so very often large quantities of grasses or wine-lees are used to cause a rapid reduction in the dissolved oxygen content of the water and, in turn, a surfacing of the fish, which can then be caught easily (this will also easily cause the death of other brood fish). The stocking rate for brood Mud Carp (a mix of males and females having a body weight of 0.5 kg) is about 200 fish per mu; and mix-cultured with suitable numbers of food fish (TN: fish used as food), Silver Carp (10-20 fish), Bighead (3-6 fish), and Grass Carp (30-50 fish).

Culture Management

Although Mud Carp can utilize benthos and other organic debris for food, the needs of Mud Carp brood fish for growth and development will be far from satisfied if they depend on only natural food due to their higher stocking density. For this reason, some fine food must be added. Practical experience in fish culture proves that feeding Mud Carp fine food helps their gonadal development. For example, in 1961 at Lilok Farm, Sinfui District, brood Mud Carp were not given fine food. As a result, the brood fish maturity rate and egg-laying rate were very low. Over 70 brood fish were estrualized, but only some 300 fry were hatched. The highest fertilization rate was only about 15%. In 1962, the intensive culture method for brood fish was adopted. Every day the fish were given fine food such as rice bran or wheat meal. As a result, propagation efficiency was distinctly raised. Between May and June, 9 lots comprising 66 brood fish were estrualized; 52 fish laid eggs; the egg-laying rate was 78.5%; the average fertilization rate was 88%; the total number of eggs laid was 3,440,000; 2,772,000 fry were hatched; the egg-hatching rate was 80%. The kinds of fine food commonly used are rice bran, wheat meal and soy-bean cake softened in water before being given. The daily feeding quantity is 30-40 g per brood fish, or about 5-8% of body weight. The amount of food given should be based on the growth and development requirements of the brood fish. This varies slightly with the change of seasons. Before wintering (September-November), feeding should be intensified in order to allow the brood fish to store up sufficient fats. In April of the following year, feeding should be reduced so as to hasten the transformation of the fats into gonads and to prevent the brood fish from growing too plump, which would affect the egg-laying rate.

Experiments prove that pond water should not be too fertile. For example, the Lilok Farm conducted observations to compare the effects of pond water fertility on brood fish gonadal development. The method used was as follows. In a lean water pond no green manure was applied during the rearing period; only fine food was given. The water quality was clearer and fresher and more transparent. In a fertile water pond, apart from giving the same fine food, 800 catties of green manure were applied every month. The water turned reddish brown in colour. The water quality was very fertile; brood fish surfaced occasionally. The results were as follows. In the lean water pond, the brood fish maturity rate reached about 80%, while in the fertile water pond it was only about 25%. Moreover, the fish in the fertile water pond matured about 25 days later than those in the lean water pond. The experience at the Nantao Fry Farm in Chungshan District also demonstrated that the water quality of brood Mud Carp ponds should not be too fertile. Therefore, during the fattening stage, new water should be let into the brood fish pond 2-3 times per month. In April of the following year, the letting-in of new water should increase to 6-8 times per month.

Because the endurance of Mud Carp in low temperature is quite weak, during the severe cold period in winter, and apart from the selection of a deep-water wintering pond, a cold shelter should be constructed. The method generally used is to construct a wind-break, using hay or sugar-cane leaves, mulberry branches, etc. at the north-side bund in order to fence off the north wind. During the wintering period, the brood fish should not be disturbed.

Estrualization

Spawning Pond

In Kwangtung, for the artificial propagation of Mud Carp, the natural fertilization method is chiefly used at present. The spawning ponds may be classified into three types: earth pond, net box and live-water boat.

When earth pond propagation is adopted, the ponds used are generally ones which were originally spawning ponds for Silver Carp, Bighead and Grass Carp, and which have been slightly modified. Two methods are used. Method No. 1 is to set a fine-meshed net, about the size of the spawning pond, in the spawning pond to hold fertilized eggs. Then another large-meshed net is set on top of it in order to fish out the brood fish after spawning. Method No. 2 is to install water inlet and outlet pipes and to drift the fertilized eggs into the net box.

When the net box method is adopted, the net box used is actually the "Da-min net tank" (a common name in Kwangtung; the tank measures: 10 chih long x 3 chih wide x 4 chih deep), which is normally used for holding fry. The estrualized brood fish are released in the "Da-min net tank", which is set floating in the river. After the brood fish have laid their eggs voluntarily, they are then fished out from the net tank and the fertilized eggs are later collected.

When the live-water boat method is adopted, the boat used is one that was originally the fry transportation live-water boat (also called the perforated boat). Fine-meshed netting is installed in the fish hull; the estrualized brood fish are then released into the fish hull. The fish are taken out after they have laid their eggs; then the eggs are collected.

Among the above three methods, the first and second methods are more commonly used. In places where a good water source is available, the first method is suitable. The second method is suitable for places situated near rivers.

Selection of Brood Fish

Brood fish catching: Because Mud Carp have the habit of hiding at the pond bottom when frightened, they are relatively difficult to catch. The most common method used at present for catching brood fish therefore, is the "surfacing netting method". Before the fishing operaton begins, large quantities of quick-acting fertilizers, such as wine-lees water, waste liquid from sugar factories or green grass, are put in the pond in order to cause a rapid decrease in the dissolved oxygen content. This forces the fish to surface, and then they are fished out by net. This method can improve the fish-catching rate, but the fishing operation must be carried out in a careful, delicate and fast way in order to prevent accidents. The other method is to lower the water level and to use a heavy-ground-rope seine net. It is also very effective. After the brood fish are caught, they should undergo "training" exercises prior to selection.

The brood fish are then released into a spawning pond with slow-flowing water, into the hull of a live-water boat with a slow current, or into a fish basket for temporary rearing for 1-2 days. If they are reared temporarily in a boat's hull, the cover board should be put on and the water surface should be kept near the cover board to prevent the brood fish from injuring themselves by jumping. When a fish basket is used, its lid should likewise be put on and the water level kept up to the lid.

Selection Standard: The pectoral fins of mature male fish have pearl organs similar to those of Grass Carp. They are coarse to the touch. When the abdomen is lightly pressed by hand at the testes position, milky-white milt will flow out. Select those individuals which have perfect integument, are healthy and active, and are rich in milt. A special characteristic of male Mud Carp is that their milt is thinner than the milt of other farm fish but more abundant.

In mature female fish, the abdomen appears slightly bigger and is soft (but not as distinguishable as that of Silver Carp and Bighead). if the lower abdominal portion is rather soft and the cloacal opening is slightly red and protruding, the fish is most suitable for use. Some brood fish bear a relatively small number of eggs. Even if the fullness of the abdomen is slight, as long as the lower abdominal portion is soft, the fish can be used.

Mud Carp over 3 full years of age have generally reached sexual maturity. Most brood fish which have been suitably reared for more than 4 years have well developed gonads. If estrualization is done on female fish whose gonads are not perfectly mature, the results will be poor; moreover it will often cause the protrusion of the ovaries outside the body, sometimes causing death.

The proportion of female to male fish is generally 1:2. For spawning ponds 60 square m in area and provided with flowing water, 40-50 females with the matching number of males can be put together at the same time for spawning.

Estrualization

Estrualizing Agents: At present, the only effective estrualizing agent for Mud Carp is the pituitary gland of Cyprinids (Common Carp, Goldfish, Silver Carp and Bighead). It is not effective if only the veterinary gonadotropin is applied. The dosage used is relatively larger than that given to Silver Carp, Bighead and Grass Carp. Normally, for a brood fish of about 0.5 kg in body weight, 1-2 pituitary glands of Common Carp are used. If the Silver Carp and Bighead glands used are obtained from smaller individuals (1-2 kg), the dosage given is generally slightly larger, 4-6 glands per kg of body weight.

Number of Injections: At present, for estrualization of Mud Carp, the single whole-dose injection method as well as the dual-injection method are used. Both methods can induce satisfactory spawning. For the dual-injection method, use about 20% of the whole dose for the first injection, with the remaining dose injected 4-8 hours later. It looks as if in the early propagation period the dual-injection method should be adopted; in the peak propagation period, or when the brood fish are well mature, the single-injection method may be used.

Response Time: The response time of Mud Carp is shorter than that of other farm fish. At a water temperature of 27-30°C, the response reaction occurs within 4 hours to 5 hours and 30 minutes after injection, though usually within about 4 hours and 30 minutes (other farm fish take about 8-12 hours). Some people may feel that the relatively short response time is perhaps due to the larger dosage of estrualizing agent used. However, no matter how large a dosage of estrualizing agent was used on Silver Carp, Bighead and Grass Carp, the response time was never shortened. On the other hand, when a smaller dosage is used on Mud Carp, such as one pituitary per kg, the response time is also the same. Therefore, the Mud Carp's response time can be regarded as its special reaction characteristic to the hormone.

Ecological Conditions for Spawning

Experiments prove that for the spawning of Mud Carp under artificial propagation conditions, certain ecological conditions are still needed. The major ecological conditions are discussed below.

Water Quality: It is very clear that during the propagation period Mud Carp demand good quality water. For example, the Shuntak District Chuenan Fry Farm (1962) used still-water spawning ponds for estrualization of Mud Carp. Because of the poor water quality, in addition to the excessively high water temperature, the fish did not spawn, even after many trials. Thereafter, propagation work was carried out in a live-water boat on the river where it succeeded. Experiences in other places also prove that the most important ecological condition for artificial propagation of Mud Carp is clear, good quality, slow-moving water. However, river water has certain limitations. For example, in 1964 the rivers in many production units in Chungshan District rose suddenly, and artificial propagation was carried out in very turbid water, with poor results. Subsequently, the rivers subsided to a stable level, and the water turbidity also decreased. When propagation work was again carried out, the results were good. This shows that under artificial propagation conditions Mud Carp have a certain range of adaptation to the physical and chemical properties of river water.

Water Temperature: Experiments have proven that the water temperature has a great influence on the spawning of Mud Carp. Brood fish often fail to lay eggs when the water temperature is too high; even if they do lay eggs, the fertilization rate and egg-hatching rate are very low. It seems that the suitable water temperature is 26-30°C. When the water temperature is over 30°C, the results of propagation are generally distinctly lower.

According to results of observations at the Lilok Farm, at a water temperature of 27°C, the fertilization rate is 95.5%; at 29.5°C it is 86.5%; and at 31°C it drops to 60%. Therefore, in artificial propagation of Mud Carp one should avoid working under high temperature conditions.

Flowing Water: In order to increase the Mud Carp's estrus and egg-laying rate, the spawning pond, net box or live-fish boat used should have flowing water. Experiments prove that fresh, flowing water can cause the distinct estrus of brood fish and raise the egg-laying rate and fertilization rate.

Estrus and Spawning

Four to five hours after being estrualized, Mud Carp enter the estrus stage. From the time the estrus begins to the time the fish start laying eggs can take from 42 minutes to 2 hours and 30 minutes, but generally it takes 1 hour and 24 minutes. The egg-laying time can last from 1 hour 30 minutes to 2 hours and 30 minutes (this is the average egg-laying time for 40 brood fish; the individual egg-laying time may not be that long). Ten to twenty minutes before estrus, the fish often produce a low-tone "Ku Ku" mating call; many air bubbles rise to the water surface. The mating call becomes louder following the climax of estrus. From an analysis of the tone of the mating call and the air bubbles, the sound seems to originate in the air-bladder and is produced by the males (if the estrualized females and males are separated, the mating call can be heard only from the male school). This mating call and the mating call made from the air-bladder by the Yellow Croaker (Psendosciaena polyactis) during spawing are similar. It should have a very important biological meaning to fish which spawn at the river bottom. Most of these fish gather near the pond edge or a water inlet and chase each other to spawn, but some of them also excitedly chase and splash in the middle of the pond to spawn. The climax of egg-laying occurs mostly about 40 minutes after the spawning begins; thereafter it gradually declines. The typical spawning act is as follows. One or two male fish repeatedly bump the female's abdomen with their heads. Before long the female begins laying eggs. The males, in most cases, bend their bodies and try their best to bring the two cloacal openings as close as possible and then exude milt.

Insemination and Hatching

There are two insemination methods: artificial insemination and natural fertilization.

The artificial insemination method calls for the collection of the eggs and milt when the brood fish begin to spawn, or according to the predicted response time. Then artificial insemination is carried out using methods similar to those used on Silver Carp, Bighead and Grass Carp.

With natural fertilization, the brood fish are allowed to lay eggs and exude milt voluntarily in the spawning pond and to complete the fertilization function. Then the fertilized eggs are collected.

Practical experiments in the past few years have proven that natural fertilization is better than artificial insemination. Therefore, at present almost all artificial fry production units are using the natural fertilization method.

Table 80 shows that in natural fertilization, except for the fact that the fertilization rate is slightly lower, the indicators are higher than in the case of artificial insemination.

The following three points are the main reasons any natural fertilization gives excellent results.

1. Natural fertilization can avoid the disadvantage of untimely egg-collection, which usually occurs in artificial insemination and results in lower egg quality.

2. Brood fish possess the special characteristic of continual spawning (1-2 hours), and natural fertilization can suitably adapt to this special spawning characteristic. In artificial insemination the eggs are collected only once, so it is difficult to provide timely insemination for all the eggs.

3. Because all brood fish in the same group do not lay eggs simultaneously, artificial egg-collection will certainly affect the normal estrus and egg-laying of other brood fish.

Besides the above, Mud Carp are small and active, and their scales come off easily. Artificial insemination can easily cause injury to brood fish. If natural fertilization is adopted, wait 2-3 hours after spawning until the fertilized eggs have absorbed water fully and have swollen and the elasticity of the egg membrane has increased. The large-meshed net is raised to take out the brood fish. Then carefully lift up the fine-meshed net, discard small fish, shrimps and other unwanted items, and transfer the fertilized eggs to the net box for hatching. It should be noted that the collection of fertilized eggs should not be done too early, because egg membranes break easily if the eggs have not fully absorbed water. If the fertilized eggs are collected by net, the collection should start not earlier than 1-2 hours after spawning.

The hatching site should be situated in a slow-flowing water body. The egg density used here can be 25-40% higher than that used for Silver Carp, Bighead and Grass Carp. Avoid excessively high water temperature during the incubation period, because it has a distinctly unfavourable influence on the egg-hatching rate. Because of the smaller size of the fry, the mesh-size of the hatching box should be small enough to prevent the fry from being filtered out.

Embryonic Development

The eggs of Mud Carp belong to the "End-Yolk egg" type. The mature egg measures 1.1 mm in diameter (slightly smaller than the eggs of Silver Carp, Bighead and Grass Carp) and is fresh bright yellow-green or golden yellow in colour. After fertilization, the perivitelline space forms gradually; the greatest diameter is 3.65 mm.

The embryonic development process of Mud Carp is largely similar to that of Silver Carp, Bighead and Grass Carp, except that it is slightly faster. Generally, the development time is shortened by 3-4 hours (see Table 81).

CHAPTER IV

HYBRIDIZATION OF FISH

A General Account of Hybridization of Freshwater Fish in Our Country

The culture of fish species of superior quality is one of the most important steps being taken now to improve productivity in aquaculture. For this reason, seed-stock culture should be listed as one of the most important tasks at present and in the future for fisheries production and scientific research. Hybridization is one of the effective means in seed-stock culture. Because the hybrid descendants generally show so-called hybrid vigor or heterosis, they can acquire a double dose of the superior qualities of the parents and be more adaptable to the environment than the parents. Under a "fixed-direction" culture condition, it should be easy to create species with behaviour patterns and characteristics that correspond to our preferences and needs.

Work on hybridization of freshwater fish in our country started in the years 1937-1941. At that time, our ichthyologists in Kwangsi, Kuiping, carried out hybridization of Silver Carp, Bighead, Grass Carp, Snail Carp (Mylopharyngoden aethiops), Bian Yü (Parabramis bramula) and Kan Yü (Elopichthys bambusa). A total of 9 cross-breedings was tried, and the preliminary results were as follows:

1. Silver Carp (♀) x Bighead (♂). The fertilization rate was 75% and the hatching rate was 80%; 1,500 fry hatched out, and they were healthy. Their body shape resembles that of Silver Carp, but their head is slightly bigger and the body colour is darker.
2. Bian Yü (♀) x Silver Carp (♂). The hatching rate was 67%; 1,070 fry hatched out. The body shape, swimming style and body resistance are very similar to that of Bian Yü fry.
3. Silver Carp (♀) x Grass Carp (♂). Experiments were carried out 3 times. The average fertilization rate was 60%; and the average egg-hatching rate was 37%. The total number of fry yielded was 2,620. Their body shape is very similar to that of Silver Carp.
4. Grass Carp (♀) x Snail Carp (♂). The fertilization rate was 70%, and the egg-hatching rate was 65%. More than 1,000 fry were hatched out. Their body shape is similar to that of Grass Carp fry, and the body is strong.
5. Grass Carp (♀) x Silver Carp (♂). Experiments were carried out 3 times. The average fertilization rate was 52%, and the average egg-hatching rate was 37%. The total number of fry hatched out was 6,900. Their body shape is similar to that of Grass Carp fry.
6. Grass Carp (♀) x Kan Yü (♂). Both the average fertilization rate and egg-hatching rate were 80%. Some 1,300 fry were yielded. Their body shape is very similar to that of Grass Carp fry. They grew faster than Grass Carp fry.
7. Silver Carp (♀) x Bian Yü (♂). The fertilization rate was 50%, and the egg-hatching rate was 75%. 380 fry were hatched out.
8. Bian Yü (♀) x Grass Carp (♂). Two experiments were carried out. The average fertilization rate was 57%, and the average egg-hatching rate was 40%. The total number of fry hatched out was 1,150.

9. Bian Yü (♀) x Snail Carp (♂). The fertilization rate was 80%, and the egg-hatching rate was 70%. 560 fry were hatched out.

Through short periods of observation and experimentation (the longest was 3 months), the above 9 artificial hybrid species proved, preliminarily, that they could adapt to pond culture, especially the Grass Carp x Kan Yü hybrid, which grew rapidly. Their common characteristics were largely similar and many of the hybrids' behavioural patterns were closer to the mothers' side.

The above hybridization experiments were, regretably, not followed up by systematic observations, and so no conclusive results were achieved.

After Liberation, especially since 1958, after the success in pond propagation of farm fish, fish hybridization work in our country followed the vigorous development of fisheries science, and it has been progressing broadly and quickly and has achieved some results.

During the period from Liberation to the year 1958, work on artificial hybridization of freshwater fish in our country was chiefly limited to cross-breeding the Common Carp with Goldfish and various varieties of Common Carp with one another. This resulted in some success.

After 1958, many fisheries research organizations and production units conducted extensive fish hybridization work. Chekiang Freshwater Fisheries Research Institute carried out five cross breeding trials: Silver Carp (♀) x Common Carp, Silver Carp (♀) x Bighead, Silver Carp (♀) x Snail Carp, Bian Yü (♀) x Grass Carp, and Bighead (♀) x Silver Carp. The Fisheries Research Institute of Heilungchiang Province tried Silver Carp (♀) x Bian Yü; the Freshwater Culture Research Institute of Shantung Province, Grass Carp (♀) x Common Carp and Common Carp (♀) x Grass Carp; the Southsea Fisheries Research Institute, Bighead (♀) x Silver Carp, Silver Carp (♀) x Bighead, Common Carp (♀) x Silver Carp, Grass Carp (♀) x Common Carp, Bighead (♀) x Common Carp, Bighead (♀) x Tilapia (Tilapia mossambica), Grass Carp (♀) x Silver Carp, Grass Carp (♀) x Red-eye Chuan (Squaliobarbus curriculus), Grass Carp (♀) x Bighead, and Silver Carp (♀) x Red-eye Chuan. Various fry farms and people's communes in Kwangtung also carried out large-scale artificial hybridization work. For example, Nantao Fry Farm in Chungshan District conducted hybridization experiments on Common Carp (♀) x Mud Carp, Common Carp (♀) x Grass Carp, Common Carp (♀) x Bighead, Bighead (♀) x Mud Carp, and Bighead (♀) x Silver Carp.

The above hybridization experiments, on the whole, can be summarized by listing several common prominent points.

1. Almost all the above Cyprinid fish (except Tilapia) used for hybridization experiments are able to be fertilized, and the fertilization rates are not low (generally 40-90%). The rates are only slightly lower than those of pure species. The nearer the blood relationship, the higher the fertilization rate.

2. During the embryonic development process, the mortality rate of hybrids is distinctly higher than that of pure species. In the fry stage, it is exceptionally high. Almost all hybrid species, such as Bighead x Silver Carp and Grass Carp x Red-eye Chuan, survive. In the experiments referred to above, therefore, only a very few hybrid descendants could pass through the fry stage and continue normal growth and development.

3. The living behaviour and prominent characteristics of the existing normal-growing hybrid species appear mostly like the median type, but occasionally an individual may appear more like the father or the mother.

4. Generally, in fish hybridization work, the nearer the blood relation, the higher the success rate. This is true in cases such as Bighead x Silver Carp (both species belong to Sub-family Hypophthalmichthyinae) and Grass Carp x Red-eye Chuan (both species belong to Sub-family Leuciscinae). If the species used for hybridization are not members of the same sub-family, the success rate is very low. For example, we tried Bighead (♀) x Common Carp and Grass Carp (♀) x Common Carp, and although the fertilization rate was very high, a great many deformed embryos appeared (see Plate VII). Even though the cross breeding is successful, the variability of the hybrid descendants is rather high, e.g., the Common Carp (♀) x Bighead hybrid.

Two Normal-Growing Hybrid Species

Bighead x Silver Carp Hybrid

The Rearing Procedure of Hybrid Species: Taxonomically, both Silver Carp and Bighead belong to the Family Cyprinidae, Sub-family Hypophthalmichthyinae, Genus Hypophthalmichthys. Their natural hybrid species appear occasionally in natural rivers. Because the hybrid species possess a certain behaviour pattern and the prominent characteristics of the parents, some fish farmers (such as those in the Nanhai Chinchiang area in Kwangtung Province) call it "Pseudo-husband". This has hitherto not been recorded in the literature. Very few fish farmers have cultured the fish, let alone carried out systematic observations of it.

On June 2, 1958, we used 15 Common Carp pituitary glands to estrualize an 82 cm long, 9,650 g female Bighead. On June 3 we used a similar dose for the second injection; 9 hours later, the fish began to lay eggs. Because of an insufficient milt supply from the male Bighead, we took the testes of a male Silver Carp, cut them into thin slices, used 0.7% physiological salt solution to concoct a sperm-containing fluid, and carried out artificial hybridization of Bighead (♀) x Silver Carp (♂). Under an average water temperature condition of 29.5°C, it took 17 hours and 10 minutes to hatch about 20,000 hybrid fry. The fertilization rate was 95%, and the successful hatching rate was 35%. After 3 days of temporary rearing in the hatching box, the fry were released into a fry pond specially prepared for the rearing of these hybrid fry. The stocking density was 20,000 fry per mu, and the rearing method used was the ordinary "Big-grass" method. The fry grew rapidly, and their body quality was strong. After 10 days their body length reached 2 cm; the survival rate attained was 80%. In the adult rearing stage, they were mixed with other farm fish. Because of the fairly high stocking density and not under-refined rearing conditions, six fish were examined in October 1959. Their average total length was 39.3 cm; and body weight, 625 g. Five more specimens were examined in December of the same year. Their average total length was 40.3 cm; and body weight, 659.25 g. In April 1960, the fish were transferred to a brood fish rearing pond. Because of a lower stocking density after the transfer, the growth rate increased faster than before. In July, six fish were examined. Their average total length reached 54.6 cm; body weight, 1,775 g (generally, the body weight was about 1,500 g). The male fish were mostly mature; milt could be squeezed out. Some of the female fish appeared to have swollen bellies and good gonadal development. We selected 6 female fish with good gonadal development for artificial estrualization. All the fish laid eggs, which were hatched into fry. In the summer of 1961, this batch of brood fish had mostly developed to maturity, and were fit for use in large-scale artificial propagation. The production result was excellent.

Morphological Variation of Bighead x Silver Carp Hybrid: In morphological structure, the hybrid is generally about midway between its parents, but closer to its mother's side (Bighead). See Figure 48.

The morphological structures of Bighead, Silver Carp and their hybrid are compared in Table 82.

Table 82 shows that the hybrid's most important characteristics, such as relative head length, relative intestine length, ventral keel and gill-rakers structure, appear to be of the middle type.

General Habit: Bighead are gentle and tame. They are not active swimmers and do not leap.

The hybrid, however, is a fairly active swimmer and leaps occasionally when frightened.

Silver Carp are quick-tempered, active swimmers and always leap when frightened.

Food Habit: According to Ni Da Shu and others, Bighead feed principally on zooplankton. The average ratio of zooplankton and phytoplankton in its diet is 1:4.5. Silver Carp, however, feed mainly on phytoplankton; the average ratio of zooplankton and phytoplankton in its diet is 1:248. We examined the digestive tracts of 4 hybrid species. Its food habit is also between those of Bighead and Silver Carp. The average ratio of zooplankton and phytoplankton in its diet is 1:33. Among the zooplankton groups eaten, Rotifers and Cladocereans are more numerous. Among the phytoplankton groups, *Microcystis*, *Merismopedia* and *Coelosphaerium* of the Cyanophyte, and the *Scenedesmus*, *Pediastrum*, *Pleodorina* and *Asterococcus* of the Chlorophyte are more numerous; Diatoms and Euglenoids are less numerous. The structure of the food-filtering organ (the gill-rakers) of the hybrid species indicates that it, too, is between those of the parents. Therefore, according to the food habits of hybrid species, these fish should be able to utilize more fully the planktonic food resources in the water.

Growth: Our observations, under similar pond environment and rearing method conditions indicate that with a body length within 10 cm, Silver Carp fry grow faster than Bighead fry; but when the fry are over 10 cm in body length, Bighead fry grow faster than Silver Carp fry, probably because the Silver Carp have basically changed their food habit to feed principally on phytoplankton. Probably because of its broad food range, the hybrid species in the fry stage grows faster than Silver Carp and Bighead. In 1961 the Sinfui Lilok Farm did comparative studies on fry growth of similar-sized Silver Carp, Bighead and their hybrid species reared together in one pond. Observations showed that the hybrid fry have a faster growth rate. Our own observations show that the hybrid hatchlings reached 2 cm in body length after 10 days of rearing and grew to 12 cm in 30 days. Although we have not done a comparitive study, the hybrid species also shows a good growth rate in the adult stage. For example, on December 12, 1959, their average body length measured

33.05 cm, and their average body weight was 659.25 g. In the summer of 1960 (only half a year later), their average body weight increased to 1,500 g. The measurements for 6 of the larger male fish showed an average body length of 44.1 cm and body weight of 1,775 g. Owing to its early maturing characteristics, mature individuals basically stop growing at 2 full-years of age; therefore, they are a relatively smaller fish. These growth characteristics should be taken advantage of in the practice of aquaculture.

Reproduction: It was pointed out in Chapter I that in Kwangtung the maturity age of pond-reared Bighead is generally 4 years, though some individuals may mature at 3 years. The maturity age of Silver Carp is generally earlier than that of Bighead by one year. Male fish generally mature earlier than female fish by one year. The Bighead x Silver Carp hybrid develops sexual maturity characteristics earlier than the parents. We examined hybrid males aged one full-year with a body length of 32.6 cm and a body weight of 26.56 g (TN: this must be a misprint) and found that they had active spermatozoa in their testes. Male fish aged 2 full-years were all mature. Some female fish ovaries had developed to Stage IV. On July 20, 1960, we carried out artificial propagation with 6 two-full-year old females. All the fish laid eggs, which were hatched into normal, second-generation fish. Female fish aged 3 full-years all matured. In 1961 the Aquaculture Experimental Station of the Southsea Fisheries Research Institute carried out artificial propagation with these hybrid brood fish and obtained more than 2,000,000 fry, which was 30% of the total artificial fry production at the Station.

From the production figures of the Aquaculture Experimental Station of the Southsea Fisheries Research Institute in 1961 on artificial propagation of various species of farm fish, it is established, preliminarily, that the Bighead x Silver Carp hybrid possesses the following superior characteristics:

1. High egg-laying rate, as shown in Table 83.
2. Slightly higher egg-hatching rate, as shown in Table 84.
3. Slightly higher reproductive power, as shown in Table 85.

Has the relatively higher reproductive power of the hybrid species any relationship to the smaller size of brood fish individuals? On this question, we would like to cite some comparative figures obtained in the same year at the Sinfui District Lilok Farm, for they can provide an explanation. The brood Silver Carp used for fry production in the Farm were rather small individuals. Their average body weight was 1.88 kg, but on an annual basis the brood fish laid an average of only 59,890 eggs per kg of body weight. Therefore, we recognize that the hybrid species possesses higher relative reproductive power, but it is not related to the size of the brood fish.

4. Stronger endurance power. After the Silver Carp went through the artificial propagation process, a considerable number of deaths usually occurred due to the fish's short temper and fondness of leaping. Generally, the mortality rate reaches 30-40%, sometimes even higher than this figure. Bighead, on the other hand, seldom died after artificial propagation. The hybrid species possesses the specific endurance powers of the mother (Bighead), and the brood fish seldom die after the artificial propagation treatment.

Grass Carp x Red-eye Chuan (Squaliobarbus curriculus) Hybrid

Grass Carp, because of their grass-eating habit, grow fast and provide delicious meat; they are an excellent fish for culture. It is a pity that because of their low resistance to disease, their disease rate and mortality rate are fairly high during culture.

In 1953 the Southsea Fisheries Research Institute planned to develop a new species of grass-eating fish with a high resistance to disease and a fast rate of growth. It carried out Grass Carp (♀) x Kan Yü (Elopichthys bambusa) hybridization experiments. The hybrid fry were able to hatch out, but in the end the experiment failed.

On May 20, 1961, the Nantao Fry Farm in Chungshan District carried out Grass Carp (♀) x Red-eye Chuan hybridization experiments. The hybrid offspring grew normally, and were able to live through the winter safely.

On May 1, 1962, we cooperated with the Sinti Fry Farm in Shuntak District in repeating the same hybridization experiment carried out by the Nantao Fry Farm the year before and decided to create, through the above route, a new grass-eating fish. First, we used 10,000 units of veterinary gonadotropin for the initial injection to estrualize an 8 kg female Grass Carp. After 12 hours, we injected her with 18 Common Carp pituitary glands. Seven hours later, the brood fish laid about 500,000 eggs. About 7,000 eggs were taken out at random from this batch of eggs to cross-breed with the Red-eye Chuan. During the incubation process, the water temperature was 28°C. The embryos developed rapidly. The fertilization rate and egg-hatching rate were largely similar to that of the pure species (Grass Carp). Over 2,000 hybrid fry were hatched out, and the hatching rate was about 30%. On June 1, the hybrid fry were released into a specially prepared pond for culture observation.

The growth situations of the hybrid species are shown in Tables 86-88. Tables 86-88 indicate, preliminarily, that the growth rate of the hybrid species is far slower than that of the mother (Grass Carp) but slightly faster than that of the father (Red-eye Chuan). After two winter-years of age, the fish's growth rate becomes notably slower. This specific growth trait clearly follows the father's side.

Table 89 shows clearly that under similar culture conditions, the growth rate of Grass Carp is much superior to that of the hybrid species.

The specific characteristics and age variations of Grass Carp, Red-eye Chuan and their hybrids are compared in Table 90.

Table 90 indicates that some of the specific characteristics of the hybrid species display the father's traits, some reflect the mother's traits, and some are between the two. For example, in head length, the maternal side increases proportionately more with the increase of body length. The paternal side is reflected in just the opposite way, and the hybrid species appears to have no regularity in this aspect. Another example is the snout length, which varies with age, distinctly following the maternal line. The intestinal development pattern in the early stage is maternal; later it becomes paternal. The lateral line scales are paternal. The pharyngeal teeth formula is basically paternal, but their shape and colour are maternal (Figure 49).

Apart from the above, we would also like to provide a brief introduction to another hybrid species - Common Carp x Bighead hybrid.

This hybrid species was developed in Kwangtung, Chungshan District, Nantao Fry Farm. On April 22, 1960, the Farm used a Kwangtung Pond Common Carp (commonly called "Purse Common Carp" or "Big-belly Common Carp") for the mother and a Bighead for the father and successfully carried out the cross-breeding. Regrettably, only 3 fish grew to adulthood (only one was left when we examined the fish). After 17 months of rearing, this hybrid fish, at the last examination on October 17, 1961, had grown to 4.875 kg in body weight, 73.6 cm in total length, 66.6 cm in body length, 23 cm in head length, and 21 cm in body height (Figure 50). These figures show that the growth rate of the hybrid species has surpassed that of the paternal Bighead and particularly that of the maternal Common Carp. (In Kwangtung, a 17-month old Bighead is generally 1.5-2.5 kg in body weight; the Common Carp, generally 0.5-1.0 kg).

The principal morphological characteristics of the hybrid species and its parents are compared in Table 91.

The above preliminary results of experiments on hybridization show that through hybridization there is a great future in the development of superior quality farm fish.

Since Liberation, considerable rapid progress in seed production has been achieved in the fields of agriculture, forestry and animal husbandry in our country, and those developments have made their rightful contribution to productivity. But in the field of fish seed production, the record is still a blank. In recent years, though, many scientific research organizations have started moving forward. However, the majority of them lack clear objectives and long-term systematic research programmes. Therefore, the results are not distinct. It is hoped that from now on, special fish-breeding stations will be established in suitable regions and given clear objectives and long-term systematic research plans to carry out the identification of existing species, to do selective breeding and cross-breeding, and to induce new species for domestication. All these works should fulfill the function of promoting the vigorous development of aquaculture productivity.

FIGURES, TABLES, AND PLATES

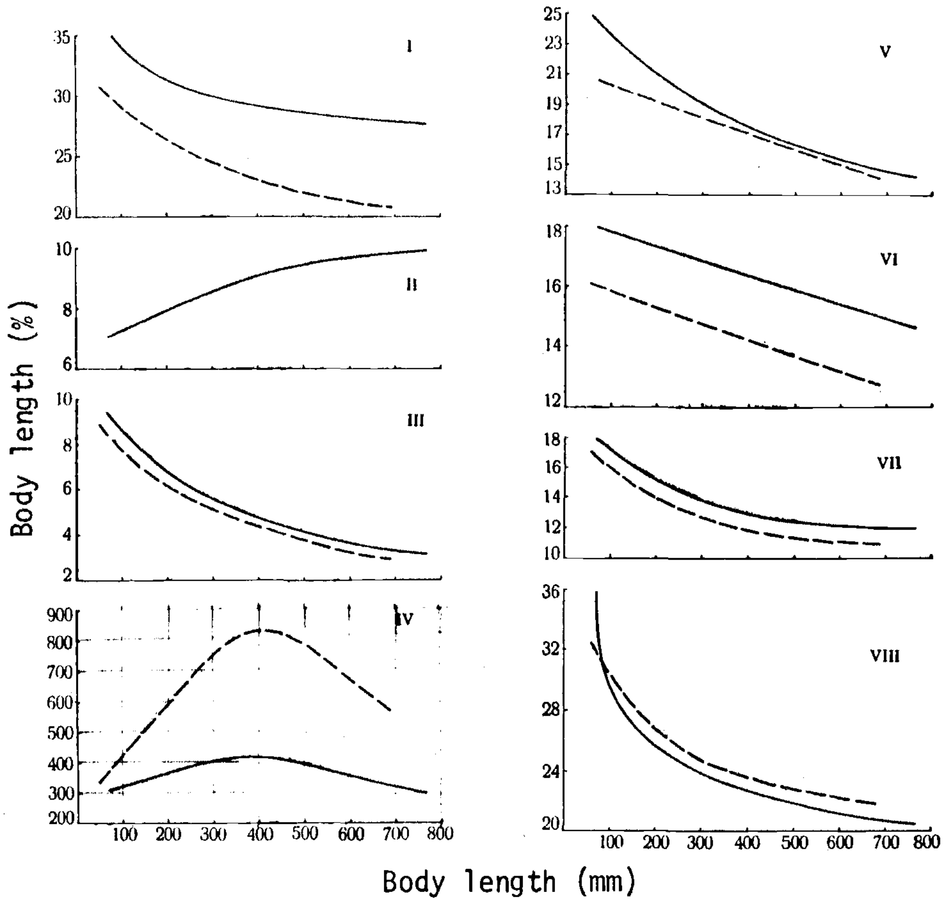
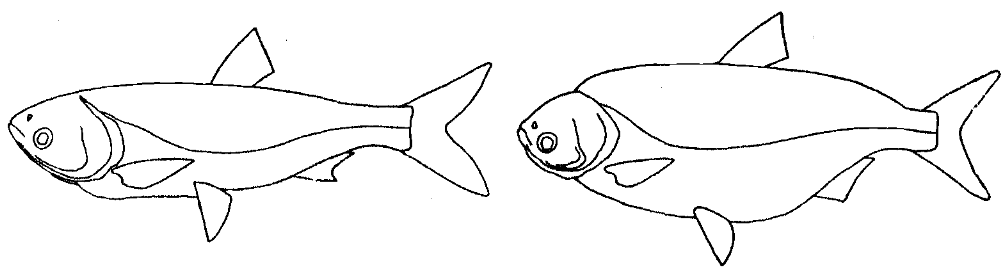


Fig. 1. Variations in the morphological characteristics of Silver Carp and Bighead in relation to age (solid line: Bighead; dotted line: Silver Carp).

I Head length II Snout length III Eye diameter IV Length of intestine V Length of dorsal VI Length of ventral VII Length of anal VIII Length of caudal.



1. Pearl River Silver Carp 2. Hainan Island Silver Carp

Fig. 2. A comparison of the morphology of Pearl River Silver Carp and Hainan Island Silver Carp.

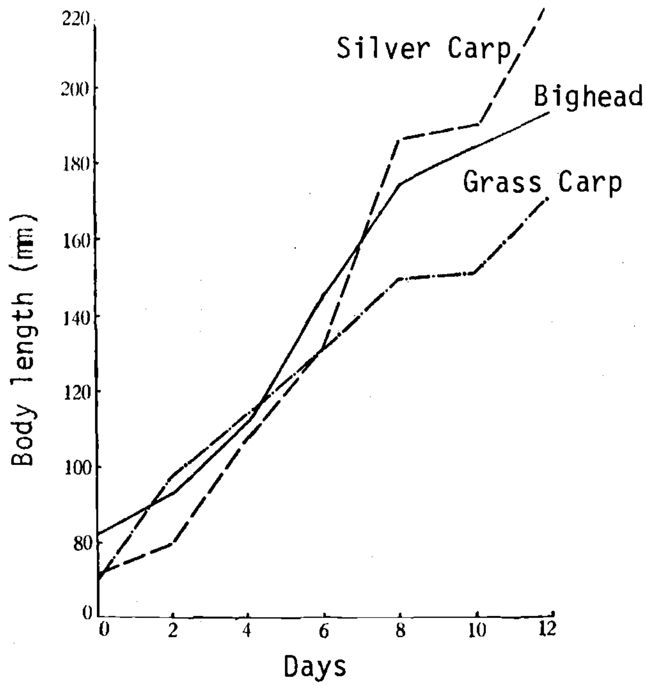


Fig. 3. A comparison of growth of Silver Carp, Bighead and Grass Carp.

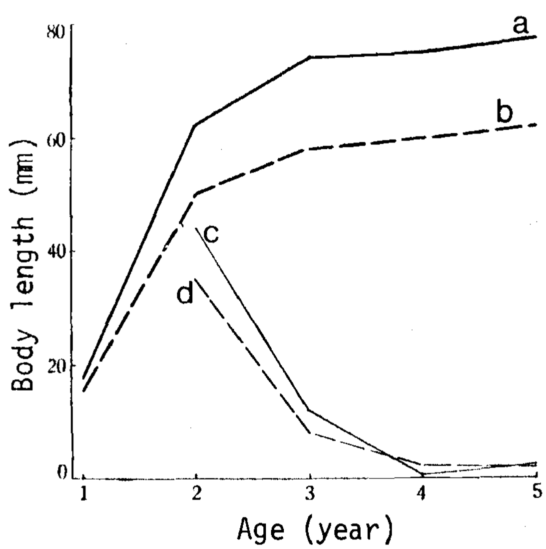


Fig. 4. Comparison of annual growth of body length of pond-reared Silver Carp and Bighead.

a. Silver Carp absolute growth b. Bighead absolute growth
c. Bighead yearly growth d. Silver Carp yearly growth

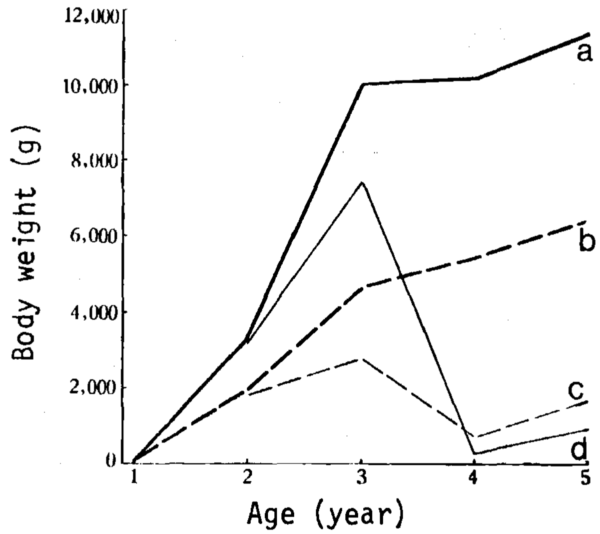


Fig. 5. Comparison of annual growth of body weight of pond-reared Silver Carp and Bighead.

a. Silver Carp absolute growth b. Bighead absolute growth
c. Bighead yearly growth d. Silver Carp yearly growth

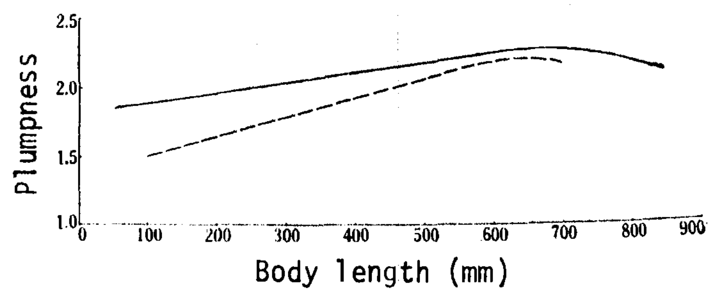


Fig. 6. Relationship between body length and plumpness of pond reared Silver Carp and Bighead (solid line: Bighead; dotted line: Silver Carp).

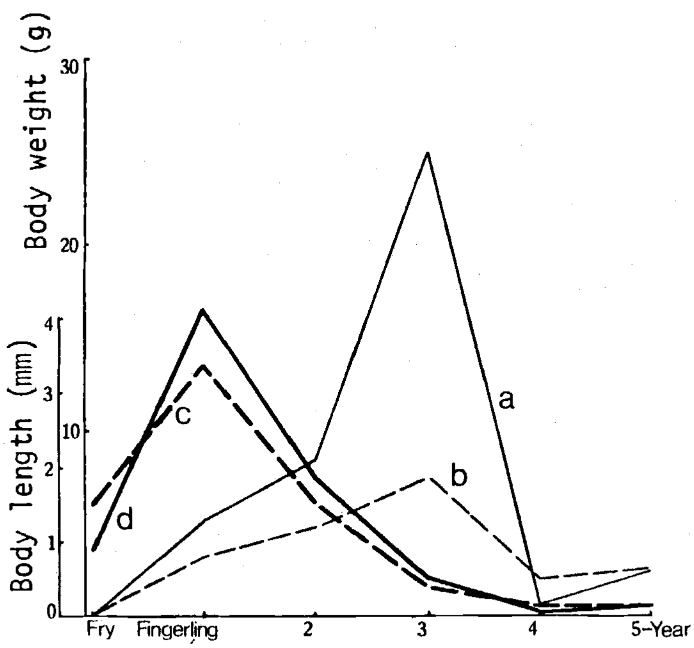


Fig. 7. Average daily growth curves for body length and body weight of Silver Carp and Bighead in all stages of growth development.

a. Bighead body weight b. Silver Carp body weight c. Silver Carp body length d. Bighead body length

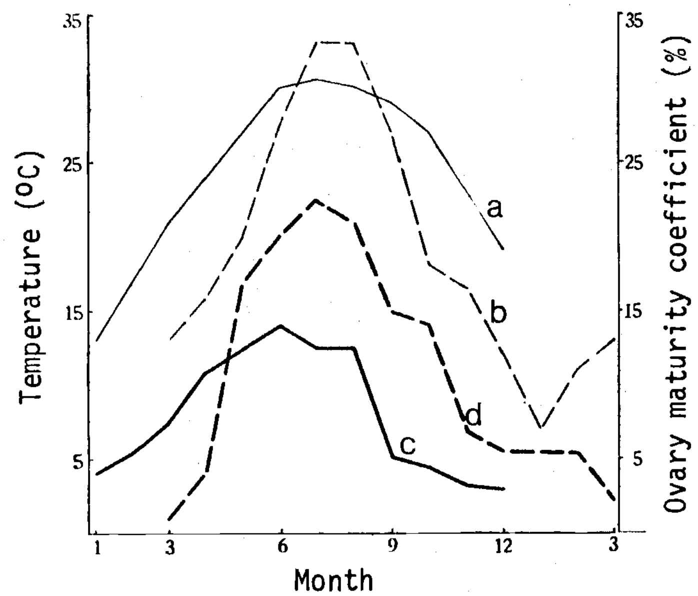


Fig. 8. Annual variation of gonadal development in pond-reared Silver Carp, Kwangtung and Chekiang regions.

a. Kwangtung water temperature b. Chekiang water temperature c. Kwangtung d. Chekiang

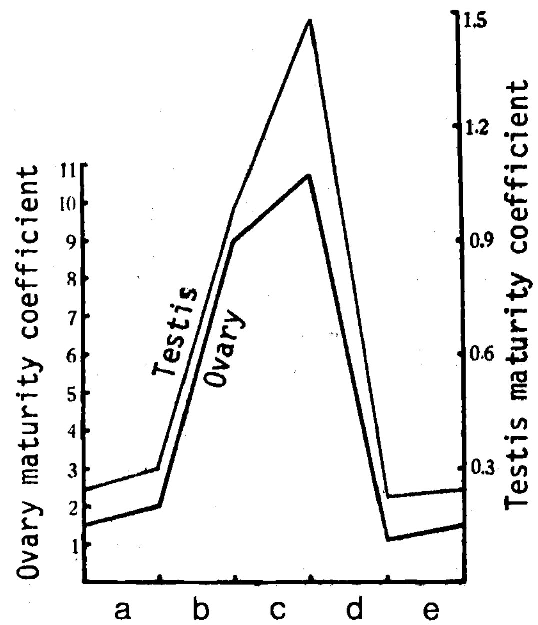


Fig. 9. Annual variation of gonadal development in Grass Carp in Hunan region.
a. winter b. spring c. summer d. autumn e. winter

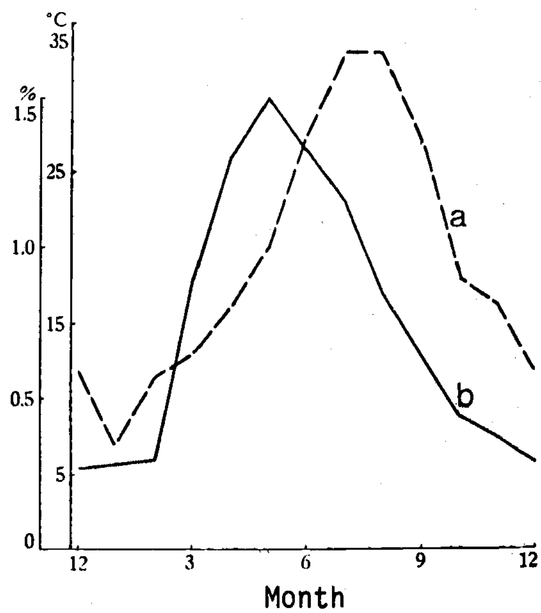


Fig. 10. Annual maturity coefficient curve of male pond-reared Silver Carp in Chekiang region.
a. Water temperature b. Testis maturity coefficient

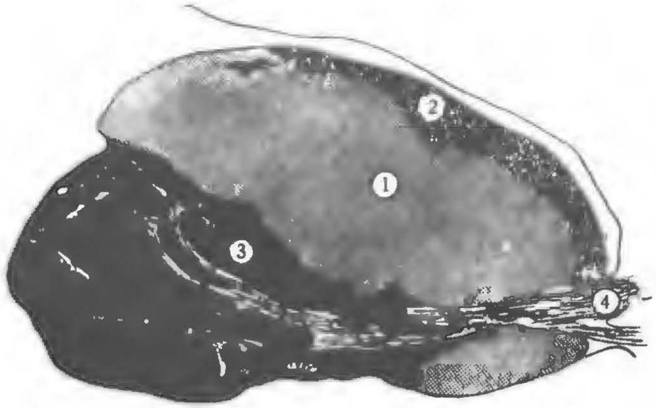


Fig. 11. Cross-section of the pituitary gland of Common Carp (Source: Walter M. Scruggs).

1. Meso-adenohypophysis 2. Pro-adenohypophysis 3. Meta-adenohypophysis 4. Neurohypophysis

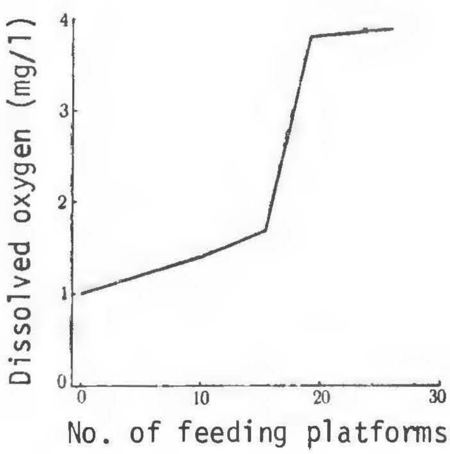


Fig. 12. The relationship between dissolved oxygen and the feeding intensity of fish.

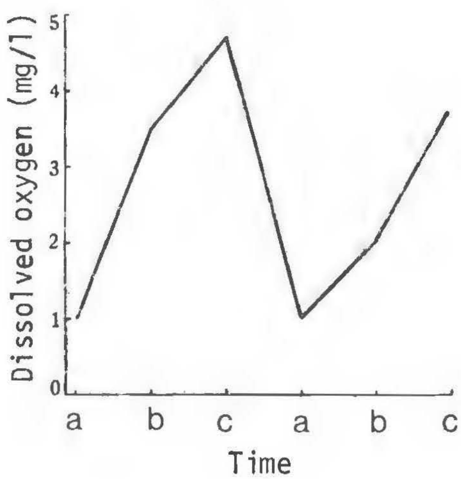


Fig. 13. The daily fluctuation of dissolved oxygen in the fry pond.

a. Morning b. Noon c. Evening

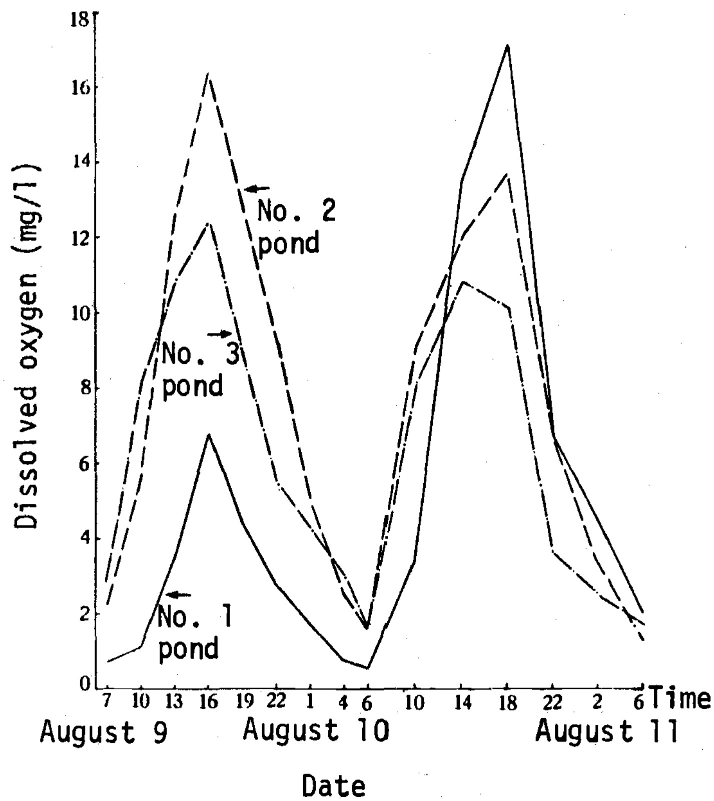


Fig. 14. Daily fluctuation of dissolved oxygen in the sewage water fish pond.

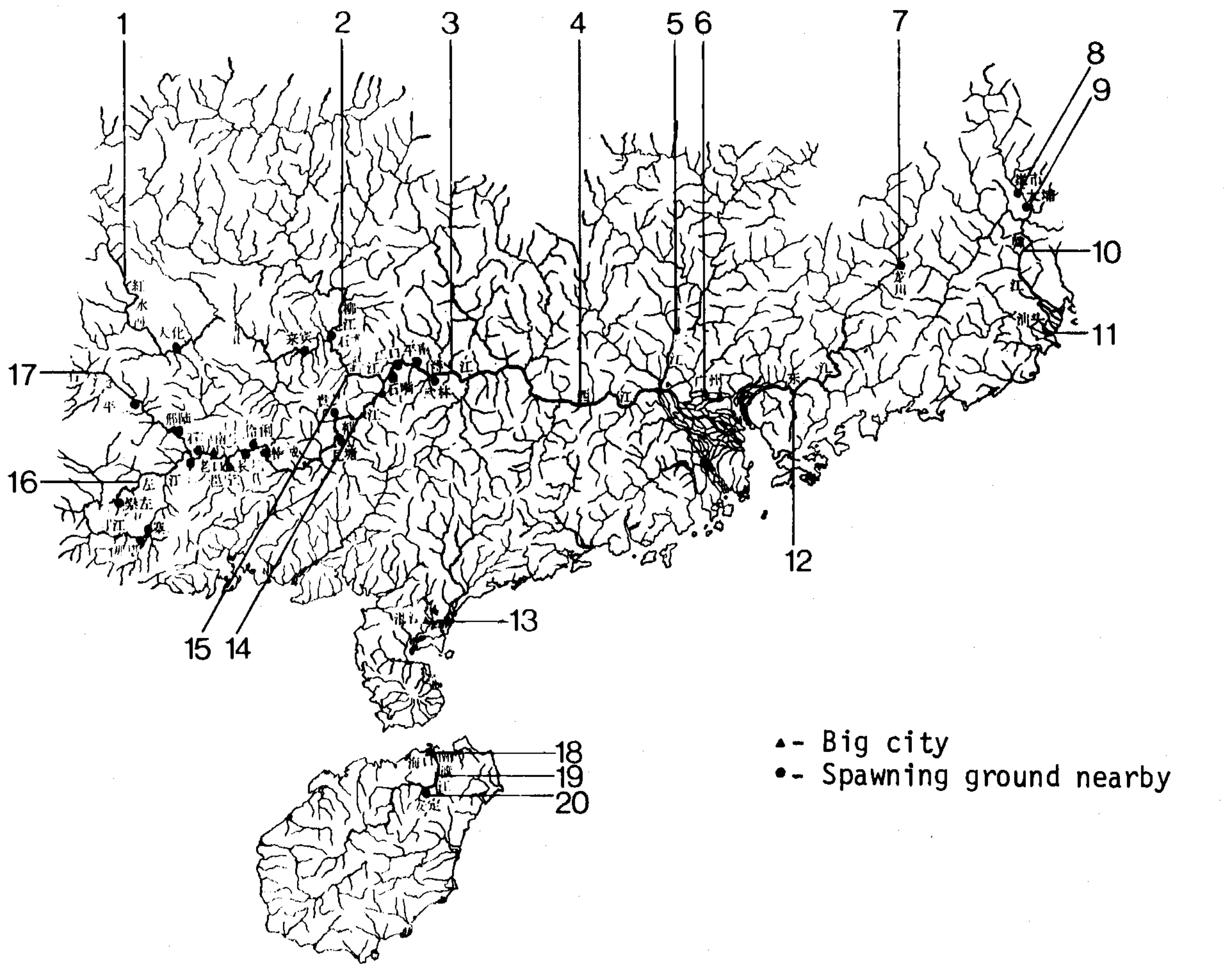


Fig. 15. Map showing the distribution of farm fish spawning grounds in the rivers of Kwangtung and Kwangsi.

1. Haungshui River 2. Liu River 3. Chum River 4. West River 5. North River 6. Kwangchow (Canton) 7. Lungchuan 8. Fungshih 9. Datang 10. Han River 11. Swatow 12. East River 13. Shamkiang 14. Yu River 15. Chien River 16. Tso River (left) 17. Yu River (right) 18. Haikao 19. Nandu River 20. Anting

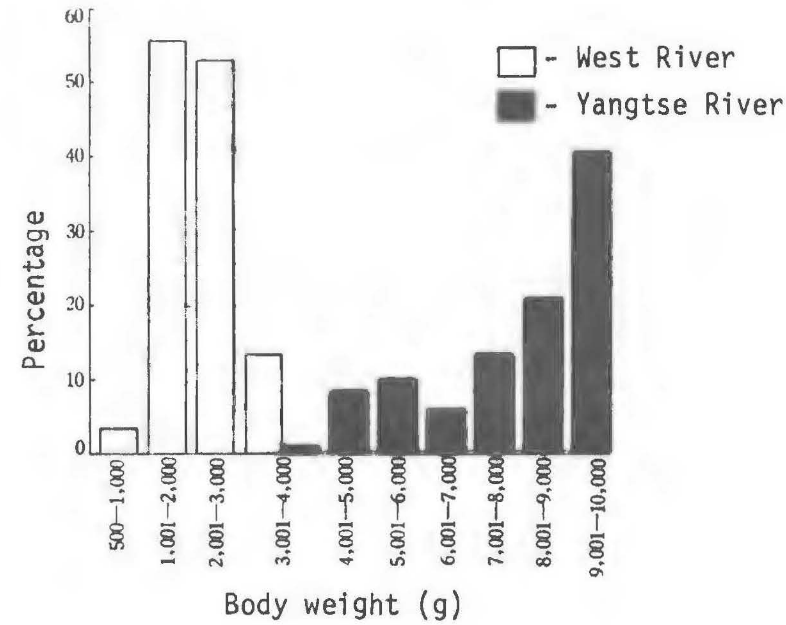


Fig. 16. Composition of body weight of Silver Carp spawning schools in Yangtse River and West River.

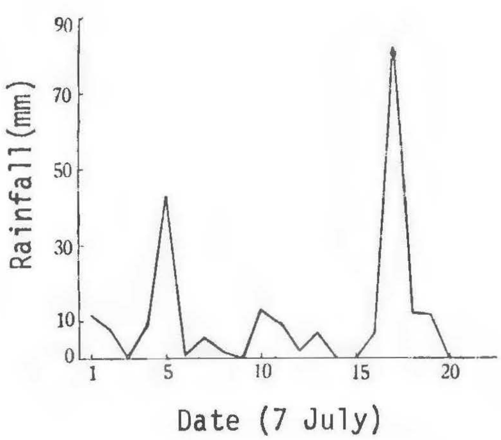


Fig. 17. Amount of precipitation - Zhaoqing Prefecture (1957).

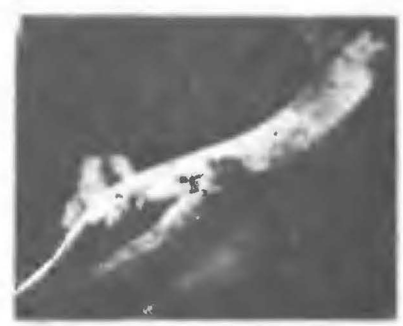


Fig. 18. Carp ovulation - ventral view.

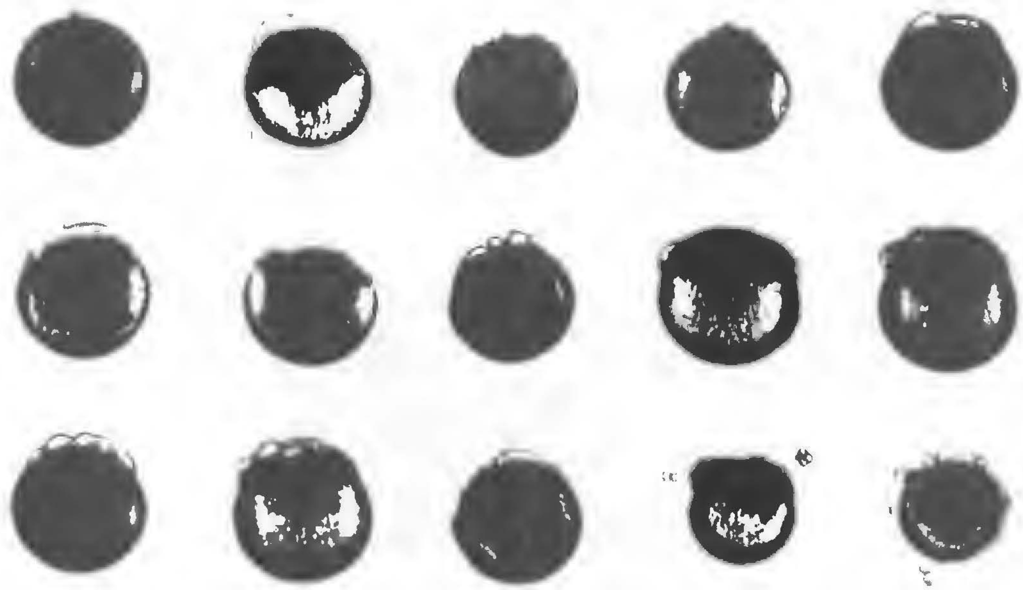


Fig. 19. Silver Carp larval development.

Fig. 20. Impregnation of single carp egg.

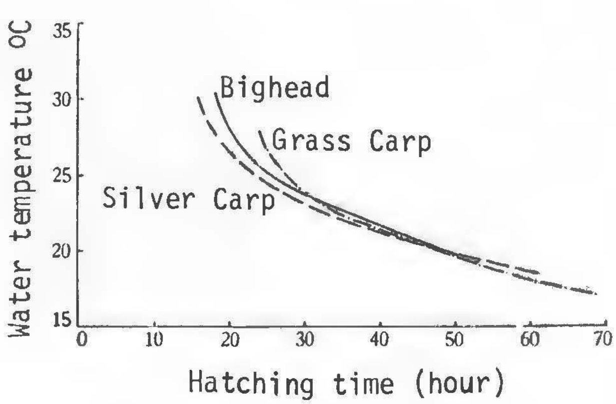


Fig. 21. The relationship between water temperature and hatching period of Silver Carp, Bighead and Grass Carp.

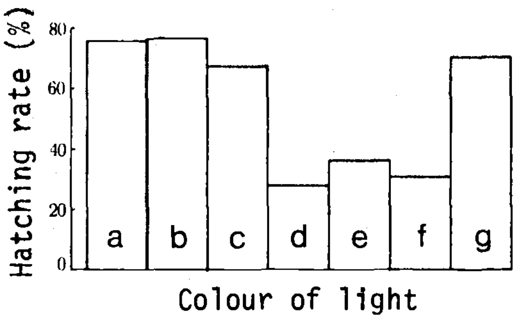


Fig. 22. Effects of different colours of light on egg-hatching rate of Silver Carp (source: Shanghai Fisheries Institute, 1961).

a. White b. Pale-Yellow c. Pale-Red d. Green e. Blue
f. Red g. Control (natural light)

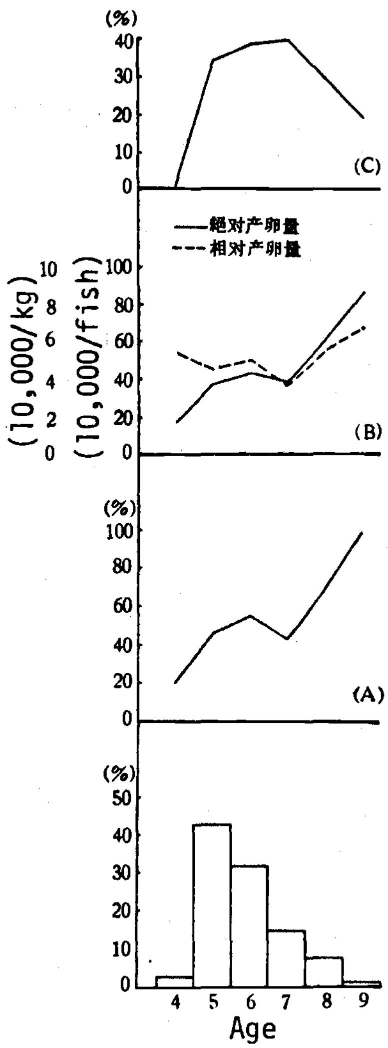


Fig. 23. Age groups and their relations to (A) egg-laying rate, (B) egg-laying quantity and (C) egg-hatching rate.

____ Absolute egg-laying quantity

---- Relative egg-laying quantity

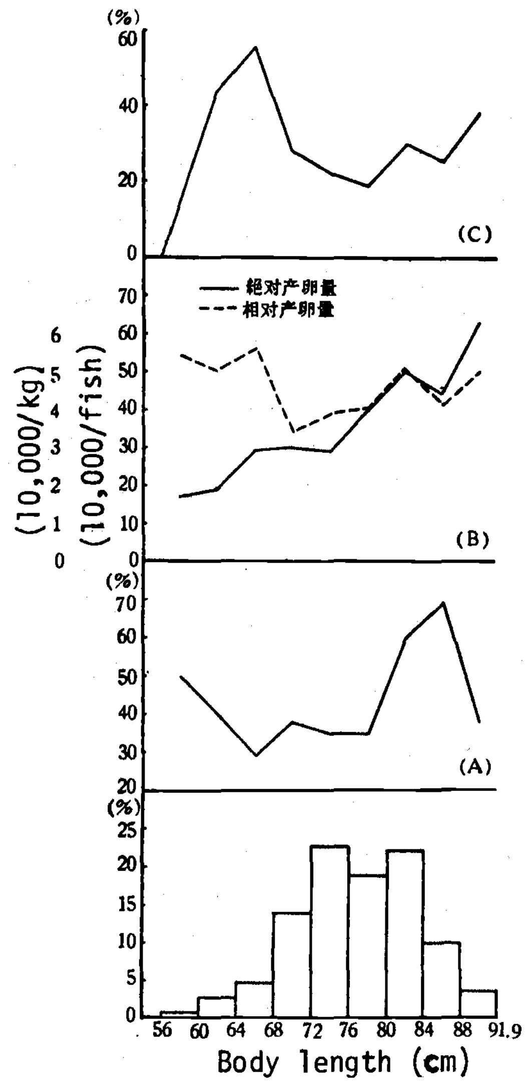


Fig. 24. Body length groups and their relation to (A) egg-laying rate, (B) egg-laying quantity and (C) egg-hatching rate.

____ Absolute egg-laying quantity

---- Relative egg-laying quantity

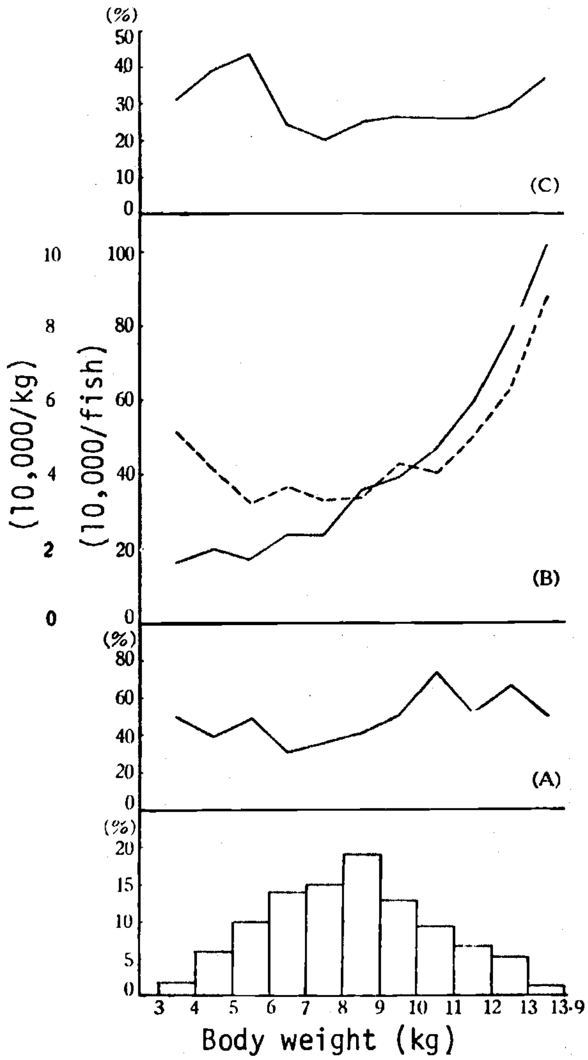


Fig. 25. Body weight groups and their relation to (A) egg-laying rate, (B) egg-laying quantity and (C) egg-hatching rate.

____ Absolute egg-laying quantity

---- Relative egg-laying quantity

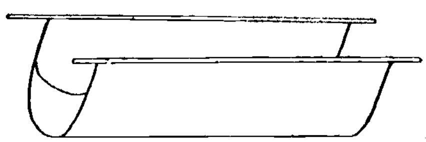


Fig. 26. Cloth clamp.

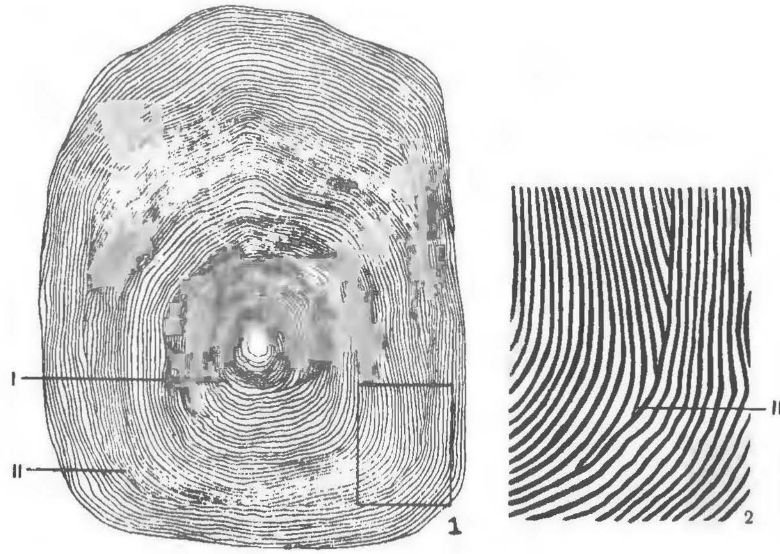


Fig. 27. 1. Two-year-old fish scale of Silver Carp. 2. Section of scale enlarged. (Institute of Experimental Zoology, Chinese Academy of Sciences.)

I First-year ring II Second-year ring

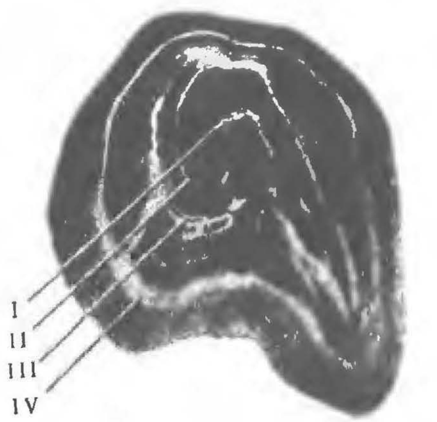


Fig. 28. Cross-section of pectoral fin of 4-year-old Silver Carp.

I First-year ring II Second-year ring III Third-year ring IV Fourth-year ring

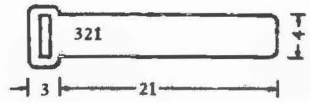


Fig. 30. Silver tag (unit: mm).

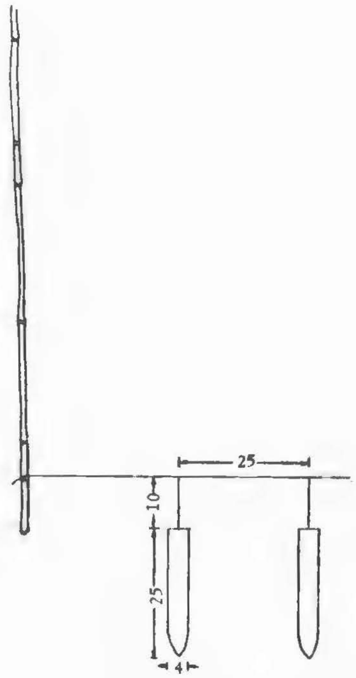


Fig. 29. Fish breeding gauge
(unit of measurement: cm).

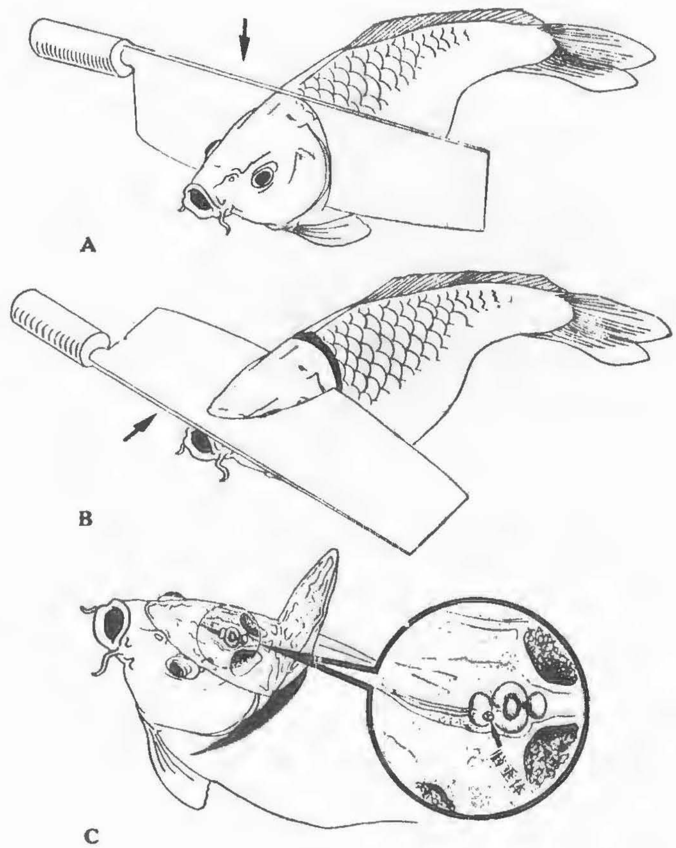


Fig. 31. Method for displaying carp's pituitary gland.

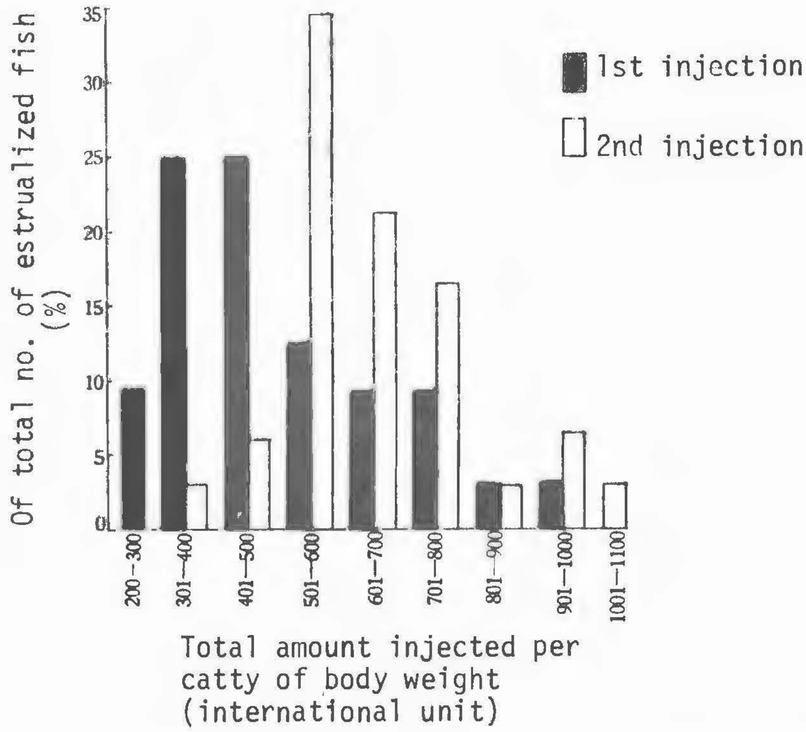


Fig. 32. Number of injections in relation to dosage (source: Fushan Division, Fisheries Research Station, Datung Group, Silver Carp, 1961).

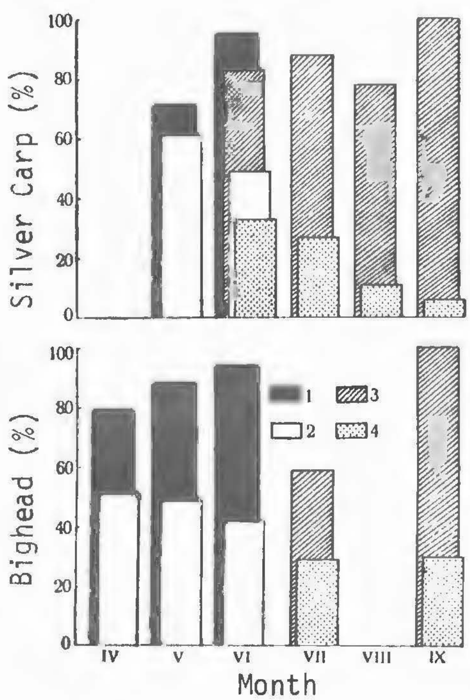


Fig. 33. Relationship between effectiveness of two estrualizing agents and seasons (Kwangtung, Sinfui District, Lilok Farm, 1961).

1. Egg-laying rate using pituitary gland 2. Egg-hatching rate using pituitary gland 3. Egg-laying rate using gonadotropin 4. Egg-hatching rate using gonadotropin.

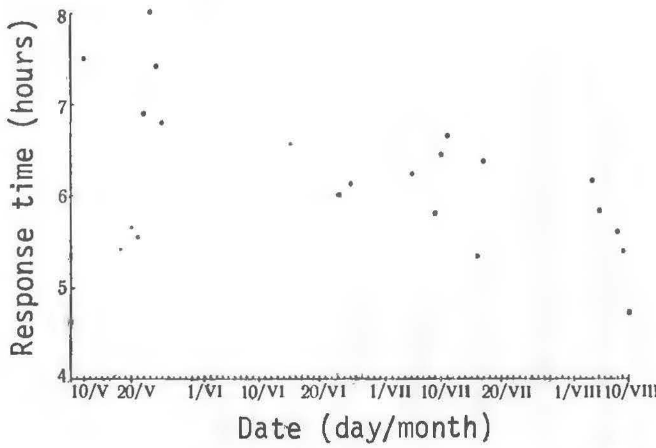


Fig. 34. Relationship between different seasons and response time (Shuntak District, Shakao Fry Farm, 1961).

Note: Hormone injected into Silver Carp, dual-injection, response time calculated from the second injection.

Fig. 35. Grass Carp swimming.

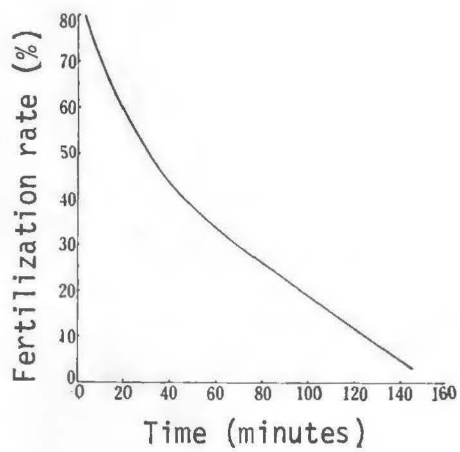


Fig. 36. Fertilization rate and time required for ovulating carps.

Fig. 37. Milt-collecting operation.

Fig. 38. Egg-collecting operation.

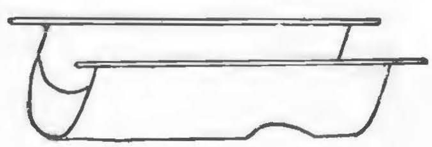


Fig. 39. Egg-collection clamps.

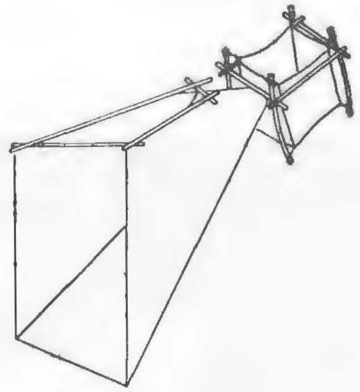


Fig. 40. Egg-collection trap net.

Fig. 41. Hatching box.

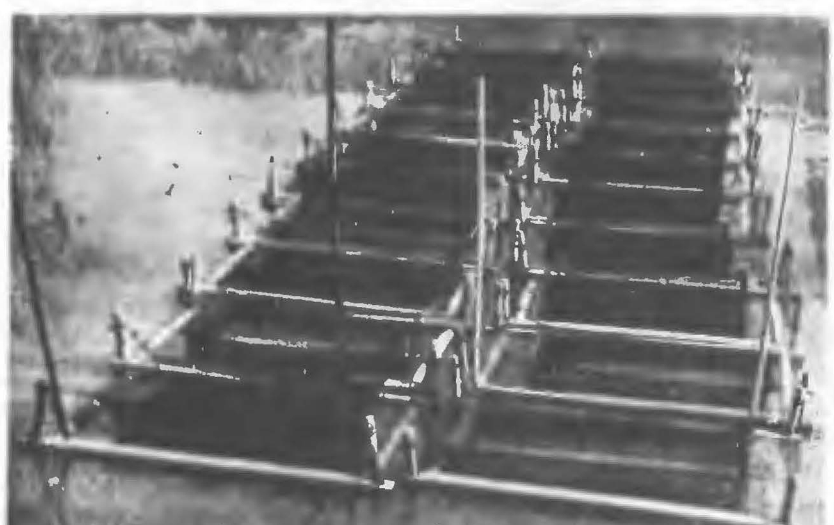


Fig. 42. Hatching boxes set in series in water.

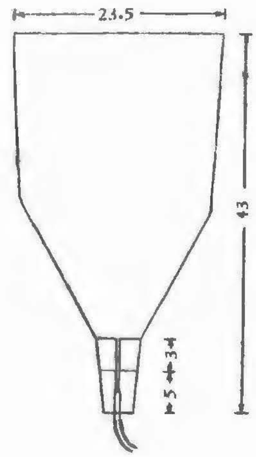


Fig. 43. Flowing-water type of hatching jar (unit: cm).

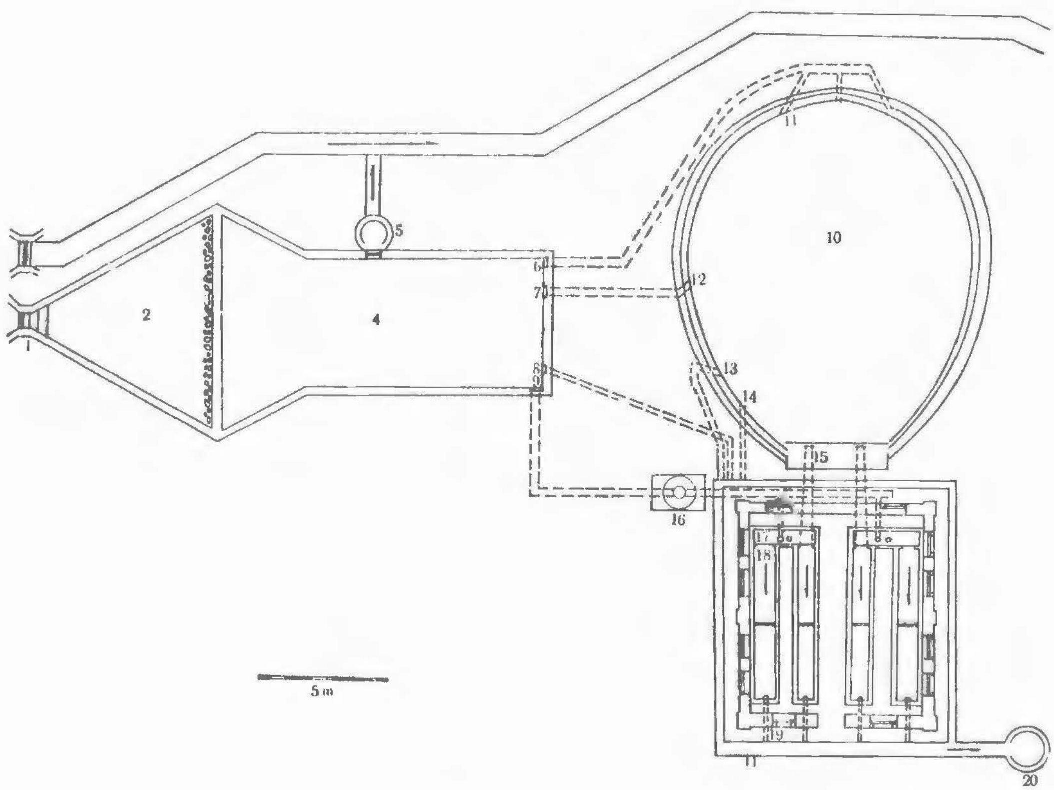


Fig. 44. Ground plan of hatching room at Shinnin Fry Farm, Kwangtung Province.

1. Filtering pond water inlet gate; 2. Filtering pond; 3. Stone filter layer; 4. Water storage pond; 5. Water level adjustment outlet of storage pond; 6. Water pipe leading to eggs drifting pipe and gate; 7. Water pipe leading to spawning pond and gate; 8. Water outlet; 9. Outlet water pipe leading to hatching room; 10. Spawning pond; 11. Egg drifting pipe water inlet; 12. Water inlet; 13. Water outlet; 14. Water outlet for lowering water level; 15. Egg-conveying pipe; 16. Sedimentation pond; 17. Water storage tank; 18. Hatching trough; 19. Hatching trough draining pipe; 20. Stone filtering layer of water outlet drain.

Fig. 45. Concrete spawning pond.

Fig. 46. Hatching trough.

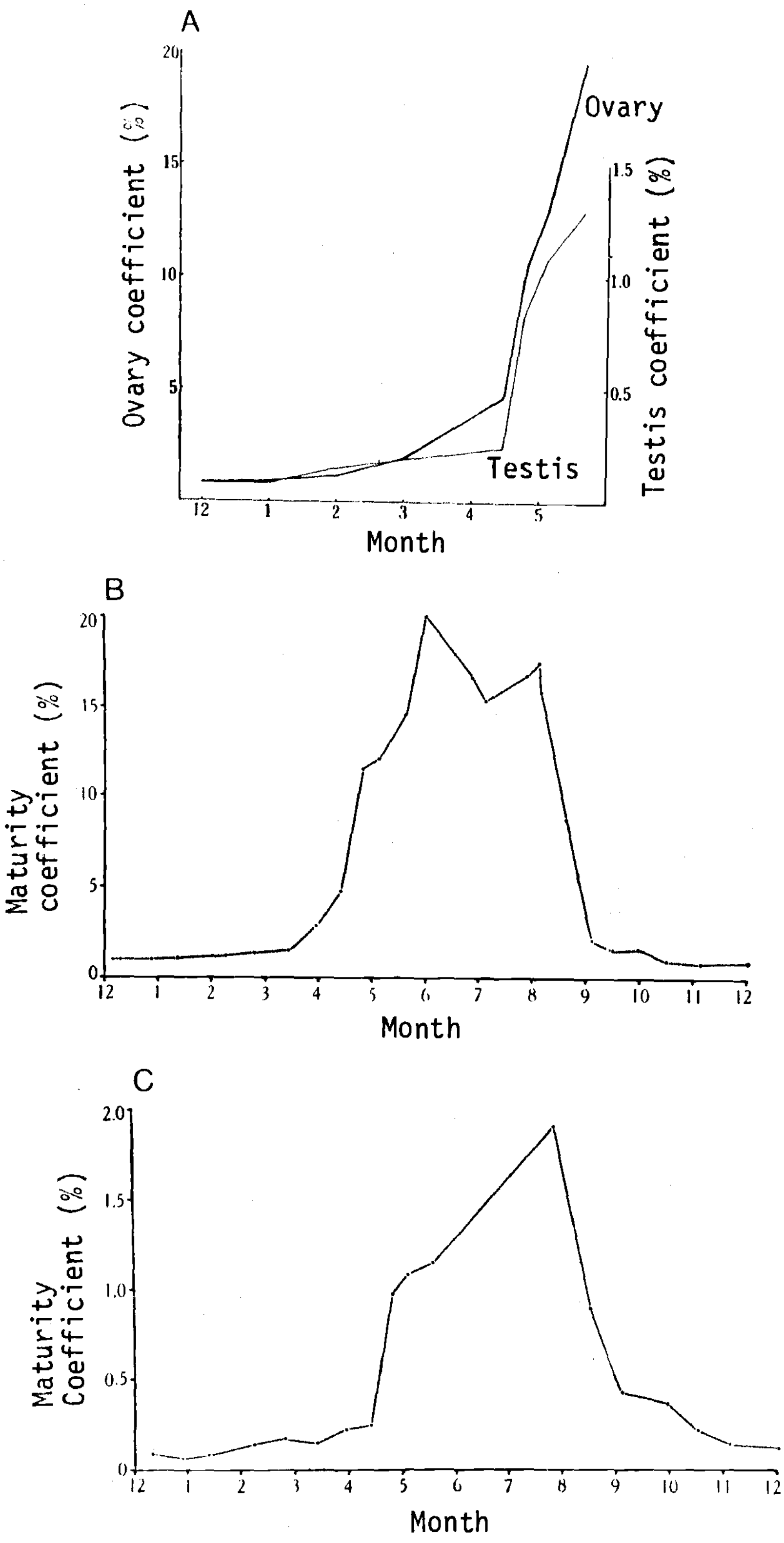


Fig. 47. Gonadal development and maturity coefficient of Mud Carp.

A. Comparison of gonadal development of both sexes before spawning.
B. Annual fluctuation of ovary maturity coefficient in pond-reared Mud Carp.
C. Annual fluctuation of testis maturity coefficient in pond-reared Mud Carp.

Fig. 48. Bighead x Silver Carp hybrid.

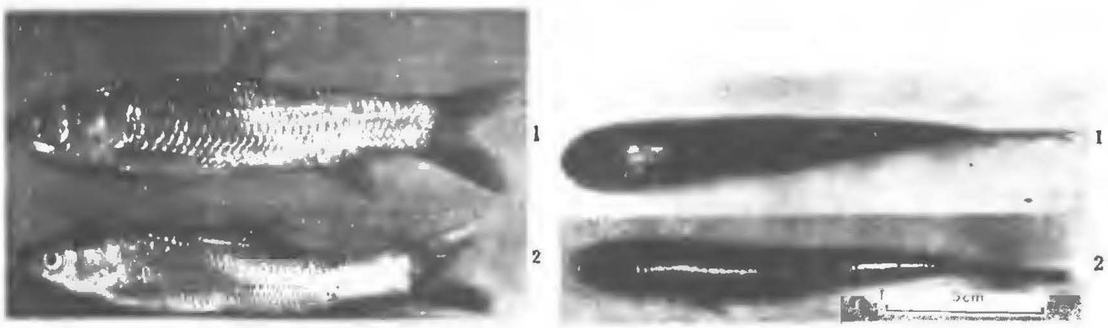


Fig. 49. Morphology of Grass Carp and Grass Carp (♀) x Red-Eye Chuan.
1. Grass Carp, 2. Grass Carp (♀) x Red-Eye Chuan

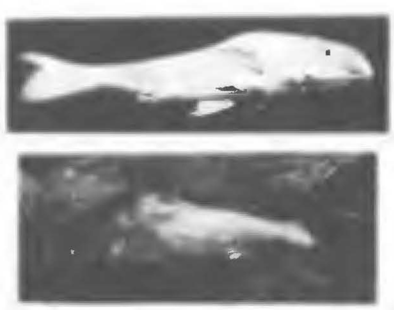


Fig. 50. Common Carp (♀) x Bighead hybrid.

Table 1: The variations in morphological characteristics of Grass Carp in relation to age (ratio to body length expressed in terms of %).

Characteristics	Body length (mm)				
	63	121	230	340	690
1. Head length	26.98	26.44	26.08	23.23	21.74
2. Snout length	6.35	7.44	6.96	5.12	6.81
3. Eye diameter	8.73	7.02	5.65	5.12	3.19
4. Length of caudal peduncle	10.32	12.8	13.04	13.35	16.23
5. Length of dorsal	20.63	20.66	19.56	17.09	16.67
6. Length of anal	19.04	16.53	16.08	15.29	13.04
7. Length of intestine	214.29	292.56	295.65	323.53	-

Table 2: A comparison of the characteristics of Nandu River Silver Carp and Pearl River Silver Carp (units: mm, g)

Characteristics	Nandu River Silver Carp	Pearl River Silver Carp
Dorsal	3.7	3.7
Anal	3.14-16	3.12-14
Pectorals	1.18	1.17-18
Ventrals	1.8	1.8
Lateral line	$80\text{-}88\frac{19\frac{1}{2}}{11\frac{1}{2}}$	$110\text{-}123\frac{26\frac{1}{2}}{17\frac{1}{2}}$
Body length	415	412
Head length (ratio to body length in %)	94(22.65)	107(25.97)
Snout (ratio to head length in %)	22(23.4)	26(24.3)
Eye diameter	15.5(16.47)	14(13.08)
Interorbital space	57(60.6)	53(49.53)
Space between corners of mouth	40(42.55)	39(36.44)
Body height	161(38.8)	116(28.16)
Body width	38(20.24)	60(12.14)
Body circumference at posterior edge of gill cover	337(81.57)	283(68.93)
Body circumference at anterior of dorsal	381(91.81)	289(70.14)
Trunk length	220(53)	166(40.29)
Tail length	114(27.47)	139(33.74)
Caudal peduncle length	62(14.94)	80(19.42)
Caudal peduncle height	46(11.08)	44(10.68)
Base of dorsal	40(9.64)	40(9.71)
Dorsal	-	71(17.23)
Base of pectorals	22(5.3)	25(6.07)
Pectorals	76(18.31)	84(20.39)
Base of ventrals	125(3)	14(3.4)
Ventrals	57.5(13.86)	60(14.56)
Base of anal	66(15.9)	64(15.53)
Anal	-	44(10.68)
Predorsal length	220	210
Base of pectorals to tip of snout	99	111
Base of ventrals to tip of snout	203	195
Anterior base of anal to tip of snout	303	289
Scales on back, length x width	6.8x7.5(1.639x1.807)	4.85x5(1.213x1.165)
Scales in mid-portion of lateral line, length x width	7.1x8.6(1.711x2.072)	5.1x6.9(1.238x1.675)

(continued)

Table 2. (concluded)

Characteristics	Nandu River Silver Carp	Pearl River Silver Carp
Body weight	2180	1400
Plumpness	3.085	2.001
Pharyngeal teeth	4-4, upper surface flat, with fine lines and small grooves	Same as left
Gill rakers	Forming sponge-like membraneous sieve	Same as left
Gill membrane	Not connected with isthmus	Same as left
Ventral keel	Ventral keel present anterior and posterior to ventral fins	Same as left
Body colour	Deeper, light dark gray	Lighter, grayish white
Fat content (%)	13-15% of body weight	4-8% of body weight

Table 3: The distribution of Silver Carp, Bighead, Grass Carp and Mud Carp fry in Rivers in Kwangtung

Name of river	Distance (km)	Silver Carp	Bighead	Grass Carp	Mud Carp
West River	2129	+	+	+	+
East River	460	+	+	+	+
North River	462	–	–	+	+
Han River	403	+	+	+	+
Kam River	215	(+)–	(+)–	+	+
Nanliu River	313	+	+	+	+
Nandu River	251	+	–	+	+
Mokyong River	150	–	–	–	+

Note: "+" present; "–" absent; "(+)–" said to be present but has not been encountered in recent years.

Table 4: The growth of Silver Carp and Bighead fry

Age (days)	Bighead		Silver Carp	
	Body length (mm)	Body weight (g)	Body length (mm)	Body weight (g)
2	8.1	0.004	7.2	0.003
4	8.5	0.012	8.1	0.010
6	11.6	0.027	10.7	0.021
8	11.8	0.054	13.3	0.040
10	13.0	0.090	18.8	0.094
12	15.2	0.134	19.2	0.188

Note: Data used in this table were obtained by the "Big Grass" fry rearing method; stocking density, 140,000/mu.

Table 5: Silver Carp and Bighead fry growth in relation to stocking density (units: mm, g).

Stocking density (fry/mu)	No. of days reared	Bighead fry		Silver Carp fry	
		Body length	Body weight	Body length	Body weight
209440	10	15.2	0.05	14.5	0.086
135770	10	18.6	0.134	19.2	0.198
102220	10	19.1	0.176	21.2	0.200

Table 6: Comparison of growth expressed as total length (TL) and body weight (BW) of Silver Carp, Bighead and Grass Carp (units: mm and g).

Age (days)	Silver Carp				Bighead				Grass Carp				
	TL	BW	Average for one day TL	Average for one day BW	TL	BW	Average for one day TL	Average for one day BW	Age (days)	TL	BW	Average for one day TL	Average for one day BW
20	4.7	1.08			4.35	0.9			27	5.7	1.48		
			0.31	1.4			0.40	5.16				0.34	2.04
60	17.3	55.3			24.2	207.5			74	21.6	157		
			0.24	6.78			0.23	7.1				0.26	8.04
120	31.8	420			37.6	633			134	37.2	661		

Table 7: Age and growth development of pond-reared Silver Carp and Bighead (units: mm and g).

Age (years)	Bighead				Silver Carp			
	Body length	Growth in 1 year	Body weight	Growth in 1 year	Body length	Growth in 1 year	Body weight	Growth in 1 year
1	170	stocking	120	-	150	stocking	67	-
2	630	460	3250	3130	500	350	1870	1803
3	746	116	10700	7450	576	76	4650	2780
4	751	55	10900	200	603	27	5340	690
5	778	27	11800	900	630	27	6400	1060

Table 8: The nutritive elements (%) of Silver Carp and Bighead (whole fish) in relation to different body lengths (mm).

Nutritive elements	Silver Carp			Bighead		
	170-197	360	510	207-209	428	595
Moisture	78.13	77.71	74.47	80.12	79.10	79.90
Crude ash	4.44	2.02	1.95	4.56	2.390	2.12
Crude protein	12.27	13.37	16.99	11.75	12.27	13.01
Crude fat	1.30	4.39	6.38	1.15	3.60	4.76

Note: 1. Whole fish (including viscera) are used in the determination of nutritive elements. The fish are oven-dried and crushed into powder form, from which samples are taken.

2. In determining the amount of moisture, fresh specimens (before oven-dried) are used.

3. The results of the analysis are shown as "amount contained in the specimens", that is, on a "wind-dried basis".

Table 9: Comparison of growth of 4-year old males and females of Silver Carp and Bighead (units: mm, g).

Species	Sex	No. of fish used	Maximum		Minimum		Average	
			Body length	Body weight	Body length	Body weight	Body length	Body weight
Silver Carp	♂	16	652	6500	554	4100	622	5550
	♀	13	640	7750	531	4250	614	5980
Bighead	♂	13	760	11250	728	9380	746	10300
	♀	14	784	13000	741	11100	781	12600

Table 10: Comparison of maturing age of farm fish in our country.

Species	Southern China (Kwangtung, Kwangsi)	Central China (Hunan, Chekiang)	Northeastern China (Heilungchiang)
Silver Carp	2-3	3-4	5-6
Bighead	3-4	5	6-7
Grass Carp	4-5	5-6	6-7

Table 11: A comparison of growth of body weight of Silver Carp and Bighead of various ages from Tungdapao and Pohaipao, Heilungchiang Province (unit: g).

Name of lake	Quantity of planktons (no./l)	Silver Carp			Bighead		
		2-year	3-year	4-year	2-year	3-year	4-year
Tungdapao	635000	1500	3700	5650	3000	5000	11500
Pohaipao	198000	550	1775	2050	1200	4500	6000

Table 12: Gonadal development of Grass Carp under bad cultural management conditions.

Body length (mm)	Body weight (kg)	Ovaries weight (g)	Maturity coefficient(%)	Ovary maturity stage
63.2	5.25	120	2.2	Stage II+
65.5	5.25	60	1.1	Stage II
66	6.25	400	6.4	Stage III-IV
70	6.5	230	3.5	Stage III
73	6.5	350	5.4	Stage III-IV

Table 13: The relationship between feeds and fecundity of Grass Carp.

Fine feeding materials: Categories	Fine feeding materials: g/day/fish	Green feeding materials	No. of fish examined	No. of eggs laid per kg of body weight	Locality
Dried silkworm pupae.	42	447	76	47663	Kwangtung Liklau Fry Station
Paddy sprout, wheat sprout, soy bean, ground-nut cake.	45	800	22	57500	Kwangtung Shinglin Fry Station
Paddy, crushed rice, tares.	57	260	52	20446	Kwangtung Siulam Fry Station
Crushed rice, tares, rice bran, paddy.	105	240	65	27236	Kwangtung Chungsan Agriculture Station

Table 14: A comparison of growth (expressed as body weight in grams) of Silver Carp and Bighead in areas of different latitudes.

Region	Species	Growth rate: 2-year	Growth rate: 3-year	Growth rate: 4-year	Amount of feed: Zooplanktons (No./l)	Amount of feed: Phytoplanktons No.(10000/l) / Species digestible%	O_2 consumed by organic matter (mg/l)	Growth period: Months	Growth period: Total heat (degree-day)
Southsea Fisheries Research Institute, No.4 experimental pond (Kwangchow or Canton)	Silver Carp	1870	4650	5340	21729	399.75 / 59	8.62	11	8250
	Bighead	3250	10700	10900					
Heilungchiang Province Tungdapao	Silver Carp	1500	3750	5650	36800	59.82 / 61	5.45	5.5	3240
	Bighead	3000	5000	11500					

Table 15: Silver Carp maturing period in relation to total quantity of heat.

	Kwangsi	Kwangtung	Kiangsu	Heilungchiang	Notes
Growth period (months)	12	11	8	5.5	Growth period is calculated when monthly average water temperature is above 15^{0}C,
Average water temperature in growth period (^{0}C)	27.2	25	24.1	20.2	because that is when Silver Carp start normal feeding activity and thus normal embryonic development.
Total heat quantity for growth period (degree-day)	9792	8250	5780	3333	Total heat quantity for growth period is calculated by multiplying average
Maturing age (years)	2	2-3	3-4	5-6	water temperature in the growth period by the number of days.
Total heat quantity for sexual maturation (degree-day)	19584	16500-24750	17340-23120	16665-19998	Total heat quantity for sexual maturation is calculated by multiplying the
Average total heat quantity for sexual maturation (degree-day)	19584	20625	20230	18315	total heat quantity for the growth period by the maturing age.

Table 16: Effects of estrualization on farm fish after the flowing water treatment.

		04 Bighead	06 Bighead	06 Grass Carp
No. of days in flowing water treatment		40	40	46
Body weight at the beginning of trial (kg)		6.95	5.85	10.0
Body weight at end of trial (kg)		6.4	5.6	9.88
Effects of estrualization	No. of eggs laid	500000	500000	550000
	No. of fry hatched	420000	300000	400000

Note: Intermittent flowing water was used, speed of flow was 0.6-1.5 m per second, every 2-3 days, for 3-6 hours per day.

Table 17: Growth and development situations of Silver Carp and Bighead at the Shangwen Reservoir, Kwangtung (summer 1962).

Species	Sex	Age	Body length (mm)	Body weight (g)	Gonads weight(g)	Gonadal coefficient
Silver Carp	♀	5	80	7500	437.5	5.83
	♀	5	80	7000	421.9	6.03
	♂	4	75	7250	31.3	0.6
	♂	4	75	5000	31.3	0.63
Bighead	♀	5	95	12500	312.5	2.5
	♀	5	93	15000	375	2.5
	♂	5	97	10500	46.9	0.45
	♂	5	98	13000	56.3	0.43

Table 18: Sex composition of spawning schools of Silver Carp and Grass Carp

	Yangtse River (1953)			West River (1940)			Songari River (1956)			Average	
	No.of fish examined	Male %	Female %	No.of fish examined	Male %	Female %	No.of fish examined	Male %	Female %	Male %	Female %
Silver Carp	149	97.2	2.8	33	88	12	172	96	4	93.7	6.3
Grass Carp	112	77.7	23.3	40	75	25	Estimated	80	20	77.5	22.4

Table 19: The spawning of farm fish and some of its relationships to hydrography and meteorology.

	1953					1954				
Rainy days and date in Ichang	-	3-V	20-V	21-V	-	26-IV	5-V	8-V	-	19-V
Farm fish spawning date	26-IV	4-V	20-V	21-V	26-V	27-IV	6-V	9-V	15-V	20-V
Difference of water level with the previous day(m)	+0.66	+0.35	-0.32	-0.25	+1.41	+0.31	+0.93	+0.55	+0.49	+0.15
Surface current speed (m/sec)	1.13	0.94	0.94	0.78	1.20	1.93	1.86	2.05	2.26	2.23

Table 20: The test fish in the ecological experiments.

Species	Number	Male fish Number	Male fish Average body weight (kg)	Male fish Age	Female fish Number	Female fish Average body weight (kg)	Female fish Age
Silver Carp	6	3	5.54	5	3	6.04	5
Bighead	8	4	10.31	5	4	12.5	5

Table 21: The changes in body condition of Silver Carp before and after "laying eggs".

Time	Total length (cm)	Body weight (kg)	Abdominal circumference(cm)
Before spawning	71.5	5.75	47.5
After spawning	71.5	4.0	37.5

Table 22: Egg-bearing situations of Silver Carp.

Locality and type of water	Body weight(g)	Ovaries weight(g)	Absolute no. of eggs(pieces)	Relative no. of eggs(pieces)	Ovary coefficient(%)
Kwangtung Province (pond culture)	1375	246	172200	125	17.89
	3300	488	241600	76	14.8
	4530	839	587300	129	18.5
	6100	1220	854000	140	20
	7000	1608	1125600	161	24
Chekiang Province Tsientang River	6560	938	656600	100	14.3
	8000	1500	1050000	131	18.75
	10880	2750	1925000	177	25.27
Chekiang Province Chuchi (pond culture)	6000	1586	1110200	185	26.05
	7130	1438	1006600	141	20.18
	8000	1938	1356600	170	24.22
Liaonin Province (pond culture)	3562	506	354200	100	14.2
	4900	914	639800	131	18.6
	5750	1395	976500	170	27.2
Amur River	4800	735	514500	107	15.3
	4870	668	467600	96	13.7
	5000	704	492800	99	14.1
Szechwan Province, Chongsheu Lake Reservoir	6500	1100	770000	118	16.9
	8150	1625	1137500	140	20.2
	7780	1783	1248100	160	22.5
	6800	1183	828100	122	17.4
	6850	1216	851200	124	17.8
	6850	1221	854700	125	17.9
	6600	1300	910000	141	19.6
	6300	1425	997500	158	22.5

Table 23: Egg-bearing situations of Grass Carp.

Locality and type of water	Body weight(g)	Ovaries weight(g)	Absolute no. of eggs(pieces)	Relative no. of eggs(pieces)	Ovary coefficient(%)
Kwangtung Province (pond culture)	7460	1523	1066100	143	20.4
	5060	624	436800	86	12.3
	6410	1090	763000	113	17
Honan Province, Shinshiang (pond culture)	4700	450	315000	67	9.6
	6500	617	431900	67	9.5
	7000	1243	870100	124	17.7
Hopeh Province Weiyuen River	5000	1050	735000	147	11.7
	5500	1666	1166200	212	29.2
	9000	1050	735000	82	21
West River (Pearl River)	15000	1760	1232000	82	11.74
	5250	702	491400	94	13.36
	9900	710	497000	50	7.18
Szechwan Province, Chongsheu Lake Reservoir	8500	1500	1050000	124	17.6
	9250	3000	2100000	227	32.4

Table 24: Egg-bearing situations of Bighead.

Locality and type of water	Body weight(g)	Ovaries weight(g)	Absolute no. of eggs(pieces)	Relative no. of eggs(pieces)	Ovary coefficient(%)
Kwangtung Province (pond culture)	6400	980	686000	107	15.3
	8020	1310	917000	113	16.3
	11500	2330	1631000	142	20.2

Table 25: Egg production of farm fish under artificial propagation.

Species	No. examined	Maximum no. of eggs laid per gram of body weight	Average no. of eggs laid per gram of body weight	Institute
Silver Carp	50	75.4	51.8	Southsea Fisheries Research Institute (1962)
Bighead	29	77.6	58.8	
Grass Carp	76	103	47.66	Data obtained from Latliu Fry Station, Shuntak District, Kwangtung Province.

Table 26: A comparison of mature-egg releasing rates of pond reared farm fish under artificial propagation.

Species	Average no. of eggs conceived per gram of body weight	Average no. of eggs laid per gram of body weight	Average discharge rate (%)	Maximum discharge rate (%)
Silver Carp	124	57.8	41.77	61.1
Bighead	108.3	58.8	54.4	71.8
Grass Carp	107.3	47.66	44.6	96

Table 27: Dissolved oxygen consumption of Silver Carp in embryonic stage.

Oxygen consumption	2-8 cell stage	Blastula	Gastrula	Appearance of tail	Heart beating	Just hatched out	Water temperature
mg/1000 egg/hour	0.272	0.319	0.318	0.657	0.846	0.853	25-27°C
mg/g/hour	0.19	0.223	0.223	0.46	0.59	0.597	25-27°C

Table 28: Dissolved oxygen consumption of Silver Carp in fry stage.

Oxygen consumption	Beginning of blood circulation	24 hours after hatching	47 hours after hatching	68 hours after hatching	Water temperature
mg/1000 fry/hour	0.983	1.64	3.41	3.983	25-27°C
mg/g/hour	0.59	0.82	1.71	1.99	25-27°C

Tables 27 and 28 are taken from the Shanghai Fisheries Institute "Preliminary research into the environmental conditions pertaining to White and Silver Carp development.

Table 29: Dissolved oxygen consumption of Silver Carp in fingerling and sub-adult stages.

Body weight of fry or fingerlings(g)	0.77	1.7	118	130.7	301	284
Dissolved oxygen consumption (mg/g/hour)	0.632	0.483	0.264	0.21	0.216	0.178
Water temperature (°C)	28.5-29.6	28.8-29.9	28.2-28.7	27.3-28.2	23.5	17

Table 30: Suffocation of Silver Carp at various development stages in connection with dissolved oxygen content in water.

	Embryonic stage	Fry stage (TL 11.7 cm)	Adult stage (TL 40-50 cm)
Dissolved oxygen content at suffocation (mg/l)	1.6	0.79	0.3-0.4

TL = Total Length

Table 31: Results of hatching of Bighead embryos at different depths of water (average of two hatching boxes).

Time examined	26.5 mm	16.7 mm
10:00	100	99
12:00	98.5	95
16:00	88	79.5
20:00	86.2	66.7(hatching period)

Table 32: Predation of _Thermocyclops oithonoides_ on blastula embryos.

No. of embryos	No. of water fleas	Result (7 hours duration)		
		No. of dead embryos	Deformed embryos	Perfect embryos
10	0	0	0	10
10	50	0	0	10
10	100	1	0	9
10	150	2	2	6
10	200	1	3	6
10	250	8	2	0
10	300	7	3	0

Table 33: Predation of <u>Thermocyclops oithonoides</u> on day-old fry.

No. of fry	No. of water fleas	Result (960 minutes duration)	
		No. of dead fry	Perfect fry
10	0	0	10
10	5	6	4
10	15	9	1
10	30	10	0
10	50	10	0
10	100	10	0

Tables 32 and 33 refer to experiments carried out in 20 millilitres of fresh water.

Table 34: Fry production in Yangtse and Pearl River Systems (unit: billion fry).

Year	Total	Yangtse River System						Pearl River System		
		Hupeh	Hunan	Kiangsi	Anhwei	Kiangsu	Total	Kwangtung	Kwangsi	Total
1936	454.15	100.15	29.86	23.95	55.66	32.95	242.57	88.89	122.68	211.57
	58.06	21.06	5	7	-	-	33.06	16	9	25
1951	40.21	13.16	2.06	2.55	4.35	-	22.12	11.59	6.5	18.09
1954	121.82	20.82	7.8	4.7	7.64	13.95	54.91	23.3	43.61	66.91
1957	234.05	45.11	15	9.7	43.67	19	132.48	38	63.57	101.57

Table 35: Total production of farm fish fry in Kwangsi and species ratio, 1957 (unit: 10,000 fry).

Species	Total	Silver Carp, Bighead Fry	Grass Carp Fry	Mud Carp Fry
Production	195692	5571	25211	164910
%	100	2.85	12.89	84.27

Table 36: Total production of farm fish fry in Kwangtung Province, Shaoching Division and species ratio, 1957 (unit: 10,000 fry).

Species	Total	Silver Carp	Bighead	Grass Carp	Mud Carp
Production	194157	12621	4541	38249	138748
%	100	6.5	2.34	19.69	71.46

Table 37: Production of farm fish fry in Kwangtung Province, Shaoching Division and species ratio, 1950-1957.

Species	Silver Carp	Bighead	Grass Carp	Mud Carp
%	7.2	3.6	26.98	62.22

Table 38: Production of farm fish fry in Kwangtung Province (except West River), 1938 (unit: 10,000 fry).

River	No. of baskets	Total	Silver Carp	Bighead	Grass Carp	Mud Carp
Total	5795	63734.012	1255	29	1247.012	61203
East River	2996	21922	42	29	191	21660
North River	12	5.012	-	-	0.012	5
Hau River	1619	36588	115	-	53	36420
Nanliu River	1050	3993	930	-	1003	2060
Nandu River	118	1226	168	-	-	1058

Table 39: Kwangtung, Hupsui Reservoir fish production, 1957-1961 (unit: kg).

	Total	Silver Carp	Bighead	Grass Carp	Mud Carp	Common Carp	Bream	Tilapia	Others
Total production	157142	20000	31500	19000	56500	14500	7306.5	66	8269.5
%	100	12.73	20.04	12.09	35.95	9.35	4.65	-	5.26

Table 40: Effects of using fertilizers in rearing ponds of Silver Carp and Bighead.

No.	Research Unit and pond no.	Water type	Area (mu)	No. of fish per mu: Silver Carp	No. of fish per mu: Bighead	No. of fish per mu: Total	Fertilizer applied	Growth rate	Maturity rate: Silver Carp	Maturity rate: Bighead	Remarks
1	Southsea Fisheries Research Institute No. 4 pond	About 14 days in a month tidal water was let in, at the rate of 1/4-1/7 pond capacity, good water quality, suitable fertility.	3	6	4	10	No fertilizer applied. There There is a latrine on the pond. 460 Grass Carp are mixed among other species per mu.	Fast growing, full 3-year old Silver Carp average 4.65 kg in body weight; Bighead average 10.7 kg.	100	100	
2	Southsea Fisheries Research Institute No. 1 pond	Still-water pond, near river, some seepage, good water quality, suitable fertility.	3	8.6	8.6	17.2	From January to August an average of 2545 kg of manure, 206 kg of dairy cow dung and 426 kg of wine residue is applied each month. 500 kg of human night-soil is applied only once.	Four-year-old Silver Carp generally average 3 kg in body weight; Bighead, 6-7 kg.	80	80	Estimated maturity rate
3	Southsea Fisheries Research Institute No. 2 pond	Still-water pond, good water quality, suitable fertility.	14	9.6	9.3	19	From April to December an average of 1366 kg of green manure, 1052 kg of dairy cow dung is applied monthly. There are two latrines on the pond, 1500 kg of human night-soil is applied once.	Four-year-old Silver Carp body weight generally average 3-4 kg; Bighead, 9-10 kg.	80	90	Estimated maturity rate
4	Experimental Biological Research Institute Shangyuen Small River	Constructed from an enlarged small river bed, some river water let in every month, fertile	3.2	25	-	25	No fertilizer applied. There are pig-sties and duck pens at the river edge. There is a constant flow of fertile water	Moderate growth rate, full 3-year old Silver Carp body weight average 3-3.5 kg	95		
5	Chekiang Fisheries Research Institute No. 11 pond	Still-water pond, from March to July river water was let in once a month, good water quality, fertile	3.5	19.8	-	19.8	From February to July an average of 1915 kg of human night soil, 1880 kg of pig dung, 11.57 kg of superphosphate are applied per mu per month.		100		
6	Chekiang Fisheries Research Institute No. 12 pond	Still-water pond, water fertile, no changing of water, slightly smelly.	4	13	-	13	From February to July an average of 2050 kg of human night soil, 888 kg of animal dung, and 10.75 kg of superphosphate are applied per mu.		No mature individual found.		Pond 5 and 6 were used for comparitive analyses, and the conditions were basically the same, although the water was changed periodically in them.
7	Shanghai Chingpu Fish Farm No. 1-13 ponds	Still-water pond, fertile.	Avg. 6.4	-		Avg. 9.5	An average of 1450 kg of human night-soil per mu is applied each month.		55	32	
8	Chekiang Tekching United Fry Farm	Water slightly flowing, good water quality, fertile.	40	4.7	8.5	13.2	Apart from the continuous application of animal dung and silk-worm pupae water, large quantities of sewage water and waste water from a silk factory flow into the pond.		68.5		Average maturity rate.

Table 41: Water quality and phytoplankton levels at various research units.

No.	Research unit and pond no.	Organic matter oxygen consumption	Nitrate	Phosphate	Silicate	Total ferrous	Chlorinity	Total hardness	Dissolved oxygen	pH	Transparency	Phytoplankton Total number 10000/l	Phytoplankton Utilization species %	Zooplankton Total Number 10000/l	Remarks
1	Southsea Fisheries Research Institute, No. 4 pond	8.622	0.0999	0.198	4.919	0.0886	7.725	3.404	4.892	7.5	42.1	399.75	59	21729	Annual average
2.	Southsea Fisheries Research Institute, No. 1 pond	10.988	0.137	0.0396	7.224	0.1194	8.433	5.875	3.955	7.8	21.9	314.7	58	53314	April-December monthly average
3.	Southsea Fisheries Research Institute, No. 2 pond	10.671	0.0904	0.0277	4.606	0.0852	8.938	5.876	4.002	7.8	26.9	282	64	17629	April-December monthly average
4.	Experimental Biological Research Institute Shangyuen, Small River	26.525	0.398	0.627	3.1	-	128.45	20.26	-	-	-	1855.4	-	182925	April-May two times average
5.	Chekiang Fisheries Research Institute, No. 11 pond	10.53	-	1.02	-	0.44	24.5	3.69	-	6.1	35	304.7	75	25000 50000	
6.	Chekiang Fisheries Research Institute No. 12 pond	12.37	-	1.57	-	0.44	26.4	4.56	-	8.3	25	456.6	25	25000	
7.	Shanghai Chingpu Fish Farm No. 1-13 ponds											1077.81	-	27612	March-June 10 times average
8.	Chekiang Tekching United Fry Farm														Rich in plankton, transparency lower than 40 cm.

Note: Utilizable phytoplankton species see feeding habits of Silver Carp and Bighead. Methods of calculation for phytoplankton may vary slightly as to place.

Table 42: A comparison of growth and maturity of Silver Carp in ponds of different fertility.

	Growth situation: Body weight at stocking (mg)	Body weight at 2 years old (kg)	Body weight at 3 years old (kg)	Body weight at 4 years old (kg)	Maturity rate (%)
Southsea Fisheries Research Institute, No. 4 experimental pond.	200-300	1.87	4.65	5.34	100
Experimental Biological Research Institute, experimental pond.	10-20	1.5-2	3.3-3.35	3.35-4.125	95

Table 43: Relationship between plankton and water fertility.

Water type	Organic matters oxygen consumption (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Phytoplankton No. (10000/l)	Phytoplankton Digestible species(%)	No. of zooplankton (No./l)
Lower reaches of Pearl River (within Canton area)	7.69	0.187	0.061	40.5	82	5851
Yangtse River (Ichang section)	8.05	0.064	0.021	30.4	94	-
Kwanting Reservoir	11.35	0.0338	0.356	75.49	85	1492
Liangtse Lake	7.05	0.0387	0.0024	4.72	78.6	1683
Southsea Fisheries Research Institute, No. 4 pond (intermittent letting-in of water, good water quality)	8.62	0.0999	0.198	399.75	59	21729
Southsea Fisheries Research Institute, No. 2 pond (still-water pond, good water quality).	10.67	0.091	0.028	282	64	17629
Chekiang Fisheries Research Institute (still-water pond, fertile)	12.37	-	1.57	456.6	25	25000

Table 44: Various rearing methods used in Kwangtung.

Pond and water type	Area (mu)	Stocking: Total no. of Grass Carp	Stocking: No. of fish per mu	Stocking: Age	Stocking: Body weight per fish(kg)	Mixed culture	Feeding	Situation of gonadal development	Experimental unit
No. 4 East Pond. Tidal water was let in about 14 days in every month, good water quality.	1.5	9	6	4-5	5-7	With small number of other farm fish	Refined rearing began in the spring of 1960. From February to May a total of 454 kg of grass fodder, 762 kg of rice bran and oat meal, and 280 kg of dung was given each month.	Female fish well developed, abdomen full, maturity rate 60-70%, good result of estrualization (immaturity may be due to age); male fish full of milt, all mature.	
No. 4 West Pond. Same as above (the above two ponds are in fact the same pond divided in two by a bamboo fence).	1.5	10	6.6	4-5	5-10	With small number of other farm fish	From February to May 1960, monthly total grass fodder given 591 kg; grain meal 125 kg; paddy sprouts and wheat sprouts 220 kg; dungs 280 kg.	(Same as above) plumpness of fish in this pond higher than the above.	Southsea Fisheries Research Institute (1959-60)
Pond No. 13. Still water, fertile.	9	45	5	4-5	5-6	Mainly Bighead and Silver Carp	From February to May,1960. Monthly total grass fodder given 990 kg; grain meal 1064 kg; wheat 125 kg; there was a latrine on the pond.	Female reached maturity, maturity rate 40-50% (immatured ones may be due to age), amount of milt in the males is slightly less than that in the above two ponds.	
Pond No. 1. Still water, some seepage, good water quality, suitable fertility.	3	38	12.7	4-5	5-6	Mainly Bighead with other farm fish	From February to May 1960, monthly total grass fodder given 718 kg; grain meal 366 kg; dungs 65 kg (table salt added in the food).	Sexual maturation slightly earlier, first time successful artificial propagation (April 20), the two Grass Carp used were selected from this pond. Maturity rate 60-70%, good response to estrualization.	

(continued)

Table 44. (concluded)

Pond and water type	Area	Stocking					Feeding	Situation of gonadal development	Experimental unit
		Total no. of Grass Carp	No. of fish per mu	Age	Body weight per fish(kg)	Mixed culture			
Pond No. 1. Still water, fertile.	5.5	70	12.7	6	6-8	Mainly Bighead with other farm fish	From July to December, 1961, daily given silk-worm pupae at 4.5% of total body weight of Grass Carp, green fodder 3%; beginning from spring silk-worm pupae reduced to 0.6%, green fodder increased to 9%.	Maturity rate about 80%, good response to estrualization.	Shuntak District, Sinti Fry Farm (1961-62)
Pond No. 6. Still water, new water constantly let in two months before propagation, good water quality.	4	70	17.5	6	6-8	Mainly Bighead with other farm fish	From July to December, 1961, daily given silk-worm pupae at 4.5% of total body weight of Grass Carp, green fodder 3%; beginning from spring silk-worm pupae reduced to 0.6%, green fodder increased to 9%.	Sexual maturation slightly earlier than the above pond, maturity rate 90%, response to estrualization better than that of the above pond.	
Pond No. 1. Still water water, rather fertile.	1.8	12 (♀10)	6.6	n.a.	5-7	Mainly Bighead with other farm fish	One year before propagation feeding not sufficient and not even; beginning from spring fermented corn flour or crushed rice 2-3 kg given daily, about 2.4% of total body weight of Grass Carp; green fodder 15-20 kg, about 15-30% of total body weight.	Maturity rate reached 90%, egg-laying rate 80%, good response to estrualization.	Chungshan District, Nantao Fry Farm (1960-61)
Pond No. 6. Still water, rather fertile.	0.75	10 (♀2)	13.3	n.a.	5-7	Mainly Bighead with other farm fish	One year before propagation feeding not sufficient and not even; beginning from spring fermented corn flour or crushed rice 2-3 kg given daily, about 2.4% of total body weight of Grass Carp; green fodder 15-20 kg, about 15-30% of total body weight.	Male fish generally produced milt in the beginning of April.	

Table 45: Relationship between brood fish ovary development and feeding.

Fine food: Kinds	Fine food: g/day/fish	Green fodder (g/day/fish)	Fine food/ green fodder	No. of fish	Egg-laying rate(%)	Egg-laying quantity per kg of body weight (No.)	Egg-hatching rate (%)	Locality
Dried silk-worm pupae	42	447	1/10.6	76	63.2	47663	31.8	Latliu farm
Silk-worm pupae Corn	57 14 (71)	109	1/1.54	32	28.1	42730	16.2	Chiunan farm
Corn and rice bran	125	577	1/4.6	51	70.2	38214	22.9	Lilok farm
Crushed rice, bran and tares	57	260	1/4.6	52	44.4	20446	43.2	Siolam farm
Crushed rice and tares	105	240	1/2.3	65	30.5	27236	22.0	Chungshan farm
Paddy sprouts, wheat, soy-bean and ground-nut cake	45	800	1/17.0	24	83.3	57500	87.5	Shinnin farm

Table 46: Grass Carp ovary development and its relation to pond environment.

	Pond environment			Water chemistry (mg/l)							No. of estrualized fish	No. of fish that laid eggs	Egg-laying rate (%)	Insemination rate (%)	Egg-hatching rate (%)	Remarks
	Area (m^2)	Water depth (m)	Silt depth (m)	pH	O_2	Organic matter	PO_4	NH_3	NO_2	Cl						
Huishin big pond	5994	1.5-2.0	0.3	7.7	4.7	16.4	0.068	0.13	0.137	25.7	13	8	61.5	56.5	22.1	
Lilok No. 3	2331	0.8-1.0	0.15	7.7	4.8	17.4	0.167	0.087	0.213	11.39	22	21	95.5	62.7	21.0	Intermittent changing of water
Lilok No. 6	2331	1.0-1.3	0.15	7.9	4.6	24.8	0.287	0.105	0.167	20.73	16	12	75	51.9	31.5	Still water
Nantao No. 1	1200	1.0-1.2	-	-	-	-	-	-	-	-	10	8	80	-	-	Insemination rate and egg-hatching rate not counted.

Table 47: Brood fish development in relation to polyculture and stocking density.

Pond	Area m^2	No.of brood fish stocked (fish/mu)				Results of propagation		
		Grass Carp	Bighead	Silver Carp	Mud Carp	No.of fish estrualized	Egg-laying rate (%)	Egg-hatching rate (%)
Huishin small pond	4089	6	3	2	110	6	33.3	20.3
Huishin big pond	5994	16	1	9	-	13	61.5	22.1
Lilok No. 6	2331	10	-	17	-	16	75	30.5
Siolam No. 2	3863	10	7	10	-	14	50	55.2

Table 48: Measurements of the chemical and physical characteristics of the water during transportation on the first occasion (units: ^oC, mg/l).

Date (1958)	Air temperature			Water temperature			pH			O_2			Chlorides		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
September 8	32.9	23.0	28.9	30.0	25.0	27.3	6.9	6.8	6.8	2.541	1.334	2.311	36.48	19.15	27.81
September 9	27.8	21.0	24.6	25.2	21.0	23.8	7.3	7.0	7.1	6.501	2.166	3.492	28.72	14.84	21.78
September 10	29.5	19.5	20.8	22.0	18.5	20.2	7.4	7.3	7.3	3.366	3.035	-	-	-	12.16

Table 49: Measurements of the chemical and physical characteristics of the water when the brood fish died (units: ^{o}C, mg/l).

Date	Time	Air temperature	Water temperature	pH	O_2	Remarks
September 8	18:00	29.0	28.0	6.9	1.3336	Two female and one male Silver Carp died (death occurred 10 hours after journey started)
September 9	1:00	24.1	25.2		6.4320	One female Bighead died
September 9	2:00	23.0	25.0	7.0	2.6896	One female Silver Carp died
September 9	6:00	21.0	24.5	7.2	2.8688	One female Silver Carp died
September 9	8:00	22.8	24.5	7.0	3.0784	One male Silver Carp died
September 9	14:00	27.0	23.5	7.2	4.2592	One male Silver Carp died
September 9	24:00	21.0	21.8	7.3	3.9584	Two female Silver Carp and one male Bighead died

Table 50: Measurements of the chemical and physical characteristics of the water during transportation on the second occasion (units: °C, mg/l (average value)).

Fish vat No.		1			2			3		
No.of fish/amount of water contained		4 Grass Carp and 1 Bighead/ 2.5 m^3			5 Grass Carp/2.5 m^3			3 Grass Carp, 1 Silver Carp and 2 Bighead/2.5 m^3		
Date	Air temp.	Water temp.	pH	Dissolved oxygen	Water temp.	pH	Dissolved oxygen	Water temp.	pH	Dissolved oxygen
November 27	14.7	19.2	-	3.6392	19.0	-	2.6471	19.1	-	3.6392
November 28	12.1	15.6	7.0	3.0866	15.6	7.2	2.7237	15.2	7.1	3.4014
November 29	10.2	12.4	7.7	6.6560	12.1	7.7	5.1119	11.8	7.6	6.6066
November 30	9.0	12.6	7.7	5.6699	10.6	7.7	5.7369	11.3	7.7	7.2859
December 1	8.7	9.7	-	5.9273	9.2	-	5.3630	8.7	-	7.2799
December 2		9.0	-	4.9636	9.0	-	7.7756	7.8	-	7.4448

Fish vat No.		4			5			6		
No.of fish/amount of water contained		3 Silver Carp, 2 Bighead/ 2.5 m^3			5 Bighead/2.5 m^3			2 Silver Carp, 4 Bighead/ 2.5 m^3		
Date	Air temp.	Water temp.	pH	Dissolved oxygen	Water temp.	pH	Dissolved oxygen	Water temp.	pH	Dissolved oxygen
November 27	14.7	19.3	-	4.0634	19.4	-	3.9705	19.1	-	4.2181
November 28	12.1	15.4	7.1	2.9500	15.4	7.2	2.9944	14.8	7.2	3.6396
November 29	10.2	11.6	7.7	5.6465	11.8	7.7	4.2435	12.0	7.7	5.6828
November 30	9.0	11.4	7.7	6.1941	11.7	7.7	4.8893	11.8	7.7	6.5174
December 1	8.7	9.2	-	5.9970	10.1	-	6.4236	10.4	-	5.6334
December 2		8.0	-	7.1084	9.0	-	6.1212	9.0	-	5.1286

Note: Death of fish occurred not long after journey started, between Canton and Hungyang.
November 27-21:00 Vat No. 4 one Silver Carp died, O_2 4.0634
November 28- 4:00 Vat No. 3 one Silver Carp died, O_2 1.4889
November 28- 5:00 Vat No. 4 one Silver Carp died, O_2 2.31616
November 28- 5:00 Vat No. 1 one Bighead died, O_2 2.9879.

Table 51: Live-water boat transportation of brood fish.

Starting point-terminating point	Duration (hours)	No. of fish transported	Average body weight (kg)	No.of fish per hull	Average air temperature (oC)	Average water temperature (oC)	Survival rate (%)
Kwangli-Canton	29	6 Bighead 4 Grass Carp	6.5, 3.5	3, 4	26.8	26.2	100
Latliu-Canton	18	6 Bighead 10 Silver Carp	6.5, 3.5	6, 5	-	-	100
Yungchi-Canton	17	3 Mud Carp 12 Grass Carp	5.0, 5.0	5, 5	-	-	100

Table 52: The changing of the ovary coefficient of Silver Carp after estrualization (no spawning).

	Body length (cm)	Body weight (kg)	Weight of ovaries (kg)	Ovary coefficient (%)	Remarks
	68	8.25	2.25	27.3	According to data provided in Table 22, the average ovary coefficient of pond-reared Silver Carp in Kwangtung is 20.1%.
	63	7.25	1.90	26.2	
	57	3.3	0.92	28.0	
Average	62.67	6.27	1.69	27.16	

Table 53: Comparison of male and female characteristics of Bighead, Silver Carp and Grass Carp.

	Male characteristics	Female characteristics
Silver Carp	1. A distinctive row of bony serratures, which gives a distinctive "cut" feeling when touched by hand, appear on the first few pectoral rays, especially on the first one. Once the serratures are formed they will not disappear.	1. Some serratures occur at the distal part of pectoral rays; the other part is rather smooth.
	2. Small belly, when mature fish are pressed lightly by hand at the testes position, the milky seminal fluid (or milt) will flow out.	2. Big and soft belly, cloacal opening often slightly protruding, sometimes slightly pink in colour.
Bighead	1. Upper edge of the first few pectoral rays serrated, with posteriorly-inclined serratures, which give very distinctive "cut" feeling when touched by hand. Once these serratures are formed, they will not disappear.	1. Pectoral fins smooth, easy to distinguish.
	2. Sexually well developed individuals often have Pearl organs on their back and operculum, which gives a slight "coarse" feeling when touched by hand.	2. Back, head and operculum often smooth.
	3. Small belly. When mature fish are pressed lightly by hand at the testes position, the milky seminal fluid will flow out.	3. Big, soft belly; cloacal opening often slightly protruding, sometimes pale pink in colour.
Grass Carp	1. Dorsal surface of pectoral rays scattered with pale gray colour horry tubercles - Pearl organs, especially on the first and third rays, which are the most distinguishable; coarse to the touch; some Pearl organs appear only in the propagation season, and disappear when the season is over.	1. Only the upper part of pectoral rays has some Pearl organs, but their rows and numbers are few.
	2. Pectoral rays slightly thin and short, fan-shaped.	2. Pectoral rays slightly thick and slender.
	3. Pearl organs often appear on back of head and operculum of sexually well matured individuals.	3. No Pearl organs on back of head and operculum.
	4. When the belly is pressed lightly at the testes position, the milky seminal fluid will flow out.	4. Belly bigger than that of the male and soft, but generally smaller than that of the female Silver Carp and Bighead.

Table 54: Comparison of effective dosages of Common Carp pituitary gland (unit: no.of glands/kg).

Name of organization	Silver Carp				Bighead				Grass Carp			
	No.of fish	Max.	Min.	Avg.	No.of fish	Max.	Min.	Avg.	No.of fish	Max.	Min.	Avg.
Southsea Fisheries Research Institute	29	9.75	1.29	3.56	29	4.56	2	3.04	16	5	2.8	3.8
Lile Farm, Xinfui District, Guangdong Province	61	6.66	3.5	4.7	78	9.0	2.2	3.84	51	3.8	2.5	3.2

Note: Body weight of Common Carp generally 0.4-1 kg.

Table 55: Comparison of chorionic gonadotropin dosages (unit: international units/kg).

Name of organization	Silver Carp				Bighead			
	No.of fish	Maximum	Minimum	Average	No.of fish	Maximum	Minimum	Average
Southsea Fisheries Research Institute	19	1076	778	990	34	2180	728	988
Kwangtung, Sinfui District Lilok Farm	163	1600	800	1196				
Kwangtung, Shuntak Shakao Fry Farm	85	1384	428	680	67	2560	676	888
Hunan Chitung Fisheries Experimental Station	20	4666	890	1900	9	2600	1735	2200
Yangtse River Fisheries Research Institute(1961)				500-800				500-800

Note: Dosage used for Grass Carp is generally larger than that for Silver Carp and Bighead; generally use 1500-2500 units/kg.

Table 56: Pituitary gland dosage in relation to egg-laying quantity (Bighead).

Dosage(no./kg)	Average no.of eggs laid per kg	No.of fish	Dosage(no./kg)	Average no.of eggs laid per kg	No.of fish
1 -1.19	54200	2	2.0-2.09	54800	20
1.2-1.29	59400	2	2.1-2.19	54000	4
1.3-1.39	61200	6	2.2-2.29	76400	3
1.4-1.49	49800	7	2.3-2.39	-	-
1.5-1.59	53800	20	2.4-2.49	85600	1
1.6-1.69	52800	15	2.5-2.59	30000	1
1.7-1.79	57000	9	2.6-2.99	-	-
1.8-1.89	50600	12	3.0-3.99	40000	1
1.9-1.99	50800	2	4.0-4.99	59000	2

Note: Data for the above table was obtained from the Southsea Fisheries Research Institute, Freshwater Culture Farm and Sinfui District, Lilok Farm (1961).

Table 57: Chorionic gonadotropin dosage in relation to egg-laying quantity (Silver Carp).

Dosage (unit)	Average no.of eggs laid per kg	No.of fish	Dosage (unit)	Average no.of eggs laid per kg	No.of fish
350-399	58200	6	700-749	70000	1
400-449	70200	8	750-799	46600	3
450-499	57800	8	800-849	64000	2
500-549	50800	76	850-899	-	-
550-599	48800	5	900-949	-	-
600-649	47400	46	950-999	-	-
650-699	52400	57	1000-1100	20800	1

Note: Data for the above table were obtained from the Southsea Fisheries Research Institute, Freshwater Culture Farm and Sinfui District, Lilok Farm (1961).

Table 58: Relationship between estrualizing agents and egg-laying rate.

Experiment unit	Species	Pituitary			Gonadotropin		
		No.of fish injected	No.of fish spawned	Egg-laying (or spawning) rate (%)	No.of fish injected	No.of fish spawned	Egg-laying (or spawning) rate (%)
Southsea Fisheries Research Institute	Bighead	52	34	65.38	79	57	72.15
	Silver Carp	-	-	-	41	19	46.34
Kwangtung, Sinfui Lilok Farm	Bighead	92	78	84.78	12	7	58.33
	Silver Carp	98	71	72.45	199	166	83.42
	Total	242	183	75.62	331	249	75.32

Table 59: Relationship between estrualizing agents and egg-hatching rate.

Experiment Unit	Species	Pituitary				Gonadotropin			
		No.of fish injected	No.of eggs	No.of eggs hatched	Egg-hatching rate(%)	No.of fish injected	No.of eggs	No.of eggs hatched	Egg-hatching rate(%)
Kwangtung, Sinfui Lilok Farm	Bighead	92	16670000	7961416	47.75	12	870000	287716	33.08
	Silver Carp	98	7980000	3402554	42.63	199	10890000	2320182	21.31

Table 60: Relationship between estrualizing agents and egg-laying quantity.

	Pituitary gland		Gonadotropin	
	No. of fish spawned	Average no. of eggs laid per kg of body weight	No. of fish spawned	Average no. of eggs laid per kg of body weight
Silver Carp	77	77498	270	62662
Bighead	108	47364	127	41656

Note: Source of data from 1961 statistics of Southsea Fisheries Research Institute, Sinfui District, Lilok Farm and Shuntak District Shakao Fry Farm.

Table 61: Relationship between effectiveness of two estrualizing agents and seasons.

Original no. of experiments	Time	Water temp. (°C)	Gonadotropin				Pituitary gland			
			0	+	++	+++	0	+	++	+++
1-6	17/IV-5/VI	19-25	5	1	3	0	2	0	0	7
7-13	6/VI-28/VI	23-33	7	2	3	4	8	2	2	0
14-15	4/VII-6/VII	29-36	2	11	0	0	1	0	0	0

Notes: "0" - no spawning after estrualization
"+" - spawning occurred after estrualization, but no fry hatched out
"++" - spawning occurred after estrualization, but egg-hatching rate low
"+++" - results very distinguishable after estrualization, egg-hatching rate above 50-60%.

Table 62: Results of estrualization by separate injections.

Experiment unit	Species	No.of fish estrualized	No.of fish spawned	Egg-laying rate (%)	Total no. of eggs laid	No.of fry released in pond	Egg-hatching rate (%)
Sinfui District, Lilok Farm	Silver Carp	285	220	77.19	24780000	8846234	35.7
	Bighead	113	95	84.07	19750000	9050727	45.82
	Total	398	315	79.15	44530000	17896961	42.66
Shuntak District, Shakao Fry Farm	Silver Carp	109	100	91.74	28950000	11829570	40.84
	Bighead	90	81	90	26917500	11765924	43.75
	Total	199	181	90.95	55867600	23595494	42.31

Table 63: The influence of different environments on propagation results (Silver Carp and Bighead).

Experiment unit	Ecological environment of spawning pond	No.of fish	Average no. of eggs laid per kg of body weight	Average hatching rate (%)
Southsea Fisheries Research Institute (1961)	Fish basket (90 cm in diameter, 50 cm high)	4	only a few	17.24
Kwangtung, Sinfui, Lilok Farm (1961)	Still-water spawning pond	315	55072	42.66
Kwangtung, Shuntak, Shakao Fry Farm (1961)	Still-water spawning pond	181	54818	43.75
Kwangtung, Shinnin District Fry Farm (1961)	Flowing-water spawning pond	25	62689	75.65
Shanghai, Chingpu Fish Farm (1961)	Flowing-water spawning pond	169		64.33

Table 64: Comparison of area and flowing speed of spawning ponds in various regions.

Unit	Area(m^2)	Speed of flow(m/sec)
Chekiang Freshwater Fisheries Research Institute	100-130	-
Kiangsu Taichew Fry Farm	100	0.2-0.5
Shanghai Chingpu Fish Farm	150	0.3-0.66
Hopeh Provincial Fisheries Bureau	66	0.25-0.4
Kwangtung Shinnin Fry Farm	110	0.1-0.3
Southsea Fisheries Research Institute	178	0.3-0.6

Table 65: Number of injections in relation to response time.

1st injection			2nd injection	
Average response time (hour:min.)	No. of fish	Average duration from 1st response time (hour:min.)	Average duration from 2nd response time (hour:min.)	No. of fish
11:47	11	15:18	6:38	43

Note: Average water temperature 26-30°C.

Table 66: Comparison of response time of various species of farm fish (May-June, 1962).

Place	Species	No. of fish	Average response time	Remarks
Shuntak District, Sinti Fry Farm	Grass Carp	17	8:20	Dual injections, response time counted from the 2nd injection.
Shuntak District, Shakao Fry Farm	Bighead	43	6:33	
Shuntak District, Shakao Fry Farm	Silver Carp	23	6:03	

Table 67: Situation of Grass Carp with two propagations per year.

Date estrualized		Body weight (g)			Egg-laying quantity				Fertilization rate (%)		Hatching amount			
					First time		Second time				First time		Second time	
First time	Second time	First time	Second time	Weight reduced	Total	No. of eggs laid per kg of body weight	Total	No. of eggs laid per kg of body weight	First	Second	No. of fry	Egg-hatching rate (%)	No. of fry	Egg-hatching rate (%)
April 26	July 19	10625	9000	1625	1063095	100056	242000	26889	87	28.9	1440000	66.6	100000	41.3
April 26	July 10	12750	11000	1750	1099560	96240	555500	50500	78	70.3				
April 28	July 10	11900	10800	1100	792225	66572	418000	38730		75.5	500000	63.1	500000	51.4
May 5	July 9	12125	10625	1500	1207900	99620	550000	5176	77.9	80.0	150000	12.4	10000	1.8
June 29	October 3	9625	9500	125	242000	25142	150000	15790	90.5	61.0	200000	82.6	40000	26.7

Table 68: Situation of Bighead with two propagations per year.

Body length	Body weight	Egg-laying date		No. of eggs laid (per fish)	
		First time (Month-Day)	Second time (Month-Day)	First time	Second time
48	5	5-10	7-21	500000	200000
75	8.5	3-31	5-30	150000	150000
50	6	4-1	6-6	150000	120000

Table 69: Delay of insemination time in relation to fertilization rate of Bighead mature eggs in freshwater.

Time between eggs in water and beginning of insemination	Dry method	30"	45"	1'	1'15"	1'30"
Average fertilization rate	60.5	30.4	23.7	11.5	14.2	6.4

Note: Average of 4 experiments.

Table 70: Use of low temperature to prolong the life-span of farm fish's sperms.

Species from which sperm came	No. of days alive	Survival rate (days) (%)	Remarks
Grass Carp	4	Not examined	Low temperature range -2 to +4°C, mostly at -1 to 0°C; room temperature 25°C (±2°C); 1963.
Grass Carp	8	26(5), 15(7)	
Silver Carp	4	15(3)	
Silver Carp	8	20(5)	
Bighead	4	25(3)	
Bighead x Silver Carp hybrid	8	30(3), 15(7)	
Bighead x Silver Carp hybrid	5	20(5)	

Table 71: Production results from flowing water type hatching jars at the Shanghai Chingpu Freshwater Culture Farm (1961).

No. of eggs laid	Average fertilization rate (%)	No. of fry released in pond	Fry released rate (%)	Hatching rate (%)
26991500	80.4	17362600	80.01	64.33

Note: 1. Fry released rate is calculated from the number of fertilized eggs.
2. Hatching rate is calculated from the number of eggs laid.

Table 72: Comparison of the results of two methods of insemination (1962).

	Artificial insemination						Natural fertilization					
	No.of fish injected	No.of fish that laid eggs	Egg-laying rate (%)	No.of eggs laid (10000)	No.of fry yielded	Fry yielding rate (%)	No.of fish injected	No.of fish that laid eggs	Egg-laying rate (%)	No.of eggs laid (10000)	No.of fry yielded	Fry yielding rate (%)
Silver Carp	7	7	100	131	555760	42.42	24	21	87.5	920	6884278	74.82
Bighead	5	3	60	79	299947	37.97	4	4	100	180	1011900	56.22

Table 73: Comparison of the results of natural fertilization and artificial insemination of Grass Carp (1963).

Method of fertilization	No. of fish estrualized	No. of fish that laid eggs	Egg-laying rate (%)	Average egg-hatching rate (%)	Locality
Natural fertilization	24	20	83.33	87.5	Shinnin Fry Farm
Artificial insemination	84	52	61.9	31.8	Latliu Fry Farm

Table 74: Comparison of indoor and outdoor hatching efficiencies.

Hatching method	Fertilized eggs (pieces)	No. of fry released in pond	Fry release rate (%)	Experimental station
Outdoor hatching	38128300	24103000	63.22	Shanghai Chingpu Freshwater
Indoor hatching	21702200	17362600	80.01	Culture Experimental Station (1961).

Table 75: Stocking density for the first stage rearing of fingerlings (unit: fish/mu).

Principal Species	Bighead	Silver Carp	Grass Carp	Total	Survival Rate(%)
Bighead	5000	20000	10000	35000	85
Silver Carp	18000	4000	8000	30000	90
Grass Carp	1500	3000	25000	29500	80

Note: Data in the above table were taken from the report Pond Fish Culture in Kwangtung, Kwangtung Fisheries Bureau, 1960.

Table 76: Stocking density for the second stage rearing of fingerlings (unit: fish/mu).

Principal species	Bighead	Silver Carp	Grass Carp	Total	Survival rate(%)
Bighead	450	6000	350	6800	90
Silver Carp	600	9000	3000	12600	90
Grass Carp	450	3500	6000	6800	85

Note: Data in the above table were taken from the report Pond Fish Culture in Kwangtung, Kwangtung Fisheries Bureau (1960).

Table 77: Polyculture of Grass Carp and Silver Carp.

	Grass Carp		Bighead	
	Stocking rate	Length of fish when fished from pond	Stocking rate	Length of fish when fished from pond
Chewchiang	3600-5000	3-5 Ts'un	3000-25000	2-5 Ts'un
Linhu	2000-25000	2.5-6 Ts'un	4000-25000	2.5-4 Ts'un

Table 78: Polyculture of Grass Carp and Bighead.

	Grass Carp		Bighead	
	Stocking rate	Length of fish when fished from pond	Stocking rate	Length of fish when fished from pond
Chewchaing	3000-3600	3-5 Ts'un	2000-15000	2.2-5 Ts'un
Linhu	2000-25000	2.5-6 Ts'un	4000-12000	2.5-4 Ts'un

Table 79: Comparison of principal indicators of fecundity for various farm fish in Kwangtung.

Species	Average number of eggs formed per g of body weight	Average number of eggs laid per g of body weight	Average laying rate of mature eggs
Mud Carp	184	130	70.6
Silver Carp	124	51.8	41.8
Bighead	108.3	58.8	54.4
Grass Carp	107.3	47.7	54.6

Table 80: Comparison of results of artificial insemination and natural fertilization of Mud Carp.

Method of insemination	No. of fish tested	Brood fish body weight (g)	Egg-laying rate (%)	Average no. of eggs laid per fish	Fertilization rate (%)	Average no. of fry yielded per fish	Egg-hatching rate (%)
Artificial insemination	58	450-700	39	50300	88.8	36000	81
Natural fertilization	105	500-750	79.5	66000	88.3	52000	89.3

Table 81: Embryonic development of Mud Carp (water temperature - 26.8 - 29.2°C).

Time after fertilization hr.	min.	Development stages
0	0	Egg fertilized.
0	20	Blastodisc upheave.
0	30	1st mitotic division, 2-cell stage.
0	38	2nd mitotic division, 4-cell stage.
0	47	3rd mitotic division, 8-cell stage.
0	55	4th mitotic division, 16-cell stage.
1	02	5th mitotic division, 32-cell stage.
1	07	6th mitotic division, 64-cell stage.
1	27	Morula stage.
2	00	High blastula stage.
2	40	Low blastula stage.
3	55	Gastrula stage (blastodisc wrapping downward ½).
4	30	Late gastrula stage (blastodisc wrapping downward ¾).
5	02	Neurula stage.
5	25	Small yolk plug stage.
5	47	Blastopore closed.
6	30	Embryo formed.
7	10	Appearance of optic vesicles, 8 pairs of somites.
7	30	Optic vesicles distinguishable, 11 pairs of somites.
7	55	Appearance of olfactory plate, 13 pairs of somites.
8	40	Eighteen pairs of somites.
9	30	Appearance of tail bud.
10	16	Appearance of auditory vesicles, 22 pairs of somites; body lengthened; embryo moves 16 times per minute.
11	05	Embryo moves 44 times per minute.
11	35	Embryo moves 67 times per minute.
14	00	Heart beat begins.
16	10	Embryo hatches out.
19	10	Appearance of cloacal opening.
20	50	Heart beats 148 times per minute; caudal fin radial shape.
22	40	Swims vertically.
27	10	Spends longer time lying on bottom of container; 39 pairs of somites.
29	10	Five branchial plates; origin of pectoral fins formed.
30	30	Pectoral fin round in shape, often lying on bottom of container; actively swimming.
32	10	Mouth formed; lower jaw movable; mouth in ventral position.
33	10	Lower jaw distinguishable.
39	10	Lower jaw moves forward; air-bladder begins to appear, fry swimming fast at bottom of container.
42	40	Gill-cover formed; fast swimming.
46	30	Blood pale red colour; pectoral fins large; lower jaw moved further forward.
53	0	Air-bladder distinguishable; oval-shaped; black in colour; yolk-sac situated under the air-bladder in concave elongated shape; mouth in terminal position; lower jaw well developed; very fast swimming.

Note: Observations carried out in shallow basin under indoor conditions.

Table 82: Comparison of morphological structures of Bighead, Silver Carp and their hybrid.

Item	Bighead	Hybrid	Silver Carp
Body length (cm)	28.55	28.88	29.42
Weight (g)	423.5	401.35	460.33
Head/Body length	31.5	30.3	27.8
Snout/Head	29.0	28.0	25.4
Height/Body length	27.2	26.3	28.4
Intestine/Body length	5.19	5.36	7.39
Body colour	Dark green head and back, black dots scattered on body, grayish yellow abdomen.	Colour pigments on head same as those of Bighead, some black dots on back, the rest of the body colour is similar to that of Silver Carp.	Pale dark green back; the rest of its body is silvery.
Pharyngeal teeth	4:4, teeth surface is flat and smooth, no grooves.	Teeth formula similar to that of Bighead; teeth are flat and smooth, but with small grooves.	Teeth formula same as that of Bighead; teeth surface has small lines and grooves.
Gill-rakers	Gill-rakers are fine and dense, separated; inter-gill-rakers space is slightly broad.	Gill-rakers are innumerable; the inter-gill-rakers space appears to be a middle type, with some squares formed by connective tissue.	Inter-gill-rakers space is very narrow; inner gill-rakers squares formed by connective tissue; outer gill-rakers squares formed by bone tissue, together forming a sponge-like body.
Pectoral fins	Reaching 2/5 length of ventral fins, 23.5% of body length.	Reaching 1/5 length of ventral fins, 22.54% of body length.	Nearly reaching or only reaching the base of ventral fins, 22.3% of body length.
Ventral keel	From anus to ventral fins only.	From anus to front of ventral fins.	From anus to pectoral fins.

Note: The measurements are the average of six specimens.

Table 83: Comparison of egg-laying rates of Bighead, Silver Carp and their hybrid.

	No. of fish injected	No. of fish that laid eggs	Egg-laying rate (%)	Ratio (hybrid used as 100)
Bighead	137	95	68.47	99.49
Silver Carp	41	19	46.34	67.35
Hybrid	93	64	68.82	100

Table 84: Comparison of egg-hatching rates of Bighead, Silver Carp and their hybrid.

	Total number of eggs laid	No.of fry released in pond	Fry release rate (%)	Ratio (hybrid used as 100)
Bighead	29412500	5526554	18.77	89.85
Silver Carp	4221000	218708	5.18	24.8
Hybrid	11697000	2443259	20.89	100

Table 85: Comparison of reproductive powers of Bighead, Silver Carp and their hybrid.

	Total number of eggs laid	Total body weight of brood fish (kg)	No. of fish that laid eggs	Average body weight of brood fish (kg)	No. of eggs laid per kg of brood fish	Ratio (hybrid used as 100)
Bighead	29412500	560.8	95	5.9	52452	59.35
Silver Carp	4221000	70.5	19	3.71	59872	67.73
Hybrid	11697000	132.4	64	2.07	88380	100

Table 86: Growth situation of same-year fish (unit: mm, g).

Date examined	Age (days)	Total length	Body length	Body weight
June 26, 1962	29	6.6	5.3	2.85
July 2, 1962	35	11.46	9.15	17.84
September 1, 1962	94	16.46	12.95	47.18
October 3, 1962	126	19.15	14.9	67.95

Table 87: Growth situation of the one winter-year old fish (unit: mm, g).

Date examined	Total length	Body length	Body weight
July 30, 1962	27	22.5	245
August 4, 1962	34.7	27.6	450
August 28, 1962	38.7	30.8	550

Table 88: Growth situation of the two winter-year old fish (units: mm and g).

Date examined	Avg. body length	Avg. body weight	No. fish counted
September 1963	43.5	1463	9
October 1963	44.5	1406	4
December 1963	45.9	1607	7

Table 89: Comparison of growth of Grass Carp and the hybrid species (Grass Carp x Red-eye Chuan).

Month	No. of fish examined		Average body length (cm)		Average body weight (g)	
	Grass Carp	Grass Carp x Red-eye Chuan	Grass Carp	Grass Carp x Red-eye Chuan	Grass Carp	Grass Carp x Red-eye Chuan
September	32	31	28.37	29.7	521	518
October	22	23	32.6	31.6	756.5	626
November	20	20	37.8	34	1194.8	817.5
December	18	23	38.2	34.2	1300	830
January	17	20	39.9	34.3	1332.5	807
February	10	15	39.2	35.2	1265	808

Notes: 1. The hybrid was born on June 1, 1962.
2. The experiment was carried out in the same pond.

Table 90: Comparison of some characteristics and age variations of Grass Carp, Red-eye Chuan and their hybrid.

Characteristics	Grass Carp			Hybrid			Red-eye Chuan		
Body length	132	238	240	133	212	230	162	169	179
Head length (body length/ head length)	4.25	4.03	4	4.15	4	4.18	4.26	4.33	4.59
Snout (body length/snout length)	22	17	15	16.6	13.3	12.8	16.2	16.9	16.3
Eye diameter (body length/ eye diameter)	15.5	17	18.5	14.8	19.3	20.9	14.7	15.4	16.3
Intestine length (no. of times greater than body length)	1.78	2.33	2.83	1.71	2.26	1.96	2.4	2.16	1.68
Plumpness	1.78	1.96	1.82	1.49	1.64	1.79	1.99	2.07	1.61
Lateral line scales	38	-	-	47	46	-	46	45	45
Pharyngeal teeth	4,2 - 2,4			5,3,1/1,2,5	5,3,1/1,3,4	5,3,1/2,2,4	5,4,2/2,4,4	4,4,2/2,4,5	4,3,2/2,4,5
	2 rows, comb-like, black in colour.			3 rows, comb-like, black in colour			3 rows, smooth, hook-shape, white in colour.		

Table 91: Comparison of the principal characteristics of Common Carp, Bighead and their hybrid.

	Body length/ Body height	Body length/ Head length	Lateral line scales
Bighead	3.54	2.7	95-105
Hybrid	3.17	2.9	121
Pond Common Carp	2.4	3	34-38

PLATE I

Gonads Sections of Silver Carp

1. Section of Stage II ovary.
2. Section of Stage III ovary.
3. Section of Stage IV (middle stage) ovary.
4. Section of Stage IV (late stage) ovary.
5. Section of Stage VI (after spawning) ovary.
6. Mature spermatozoa.

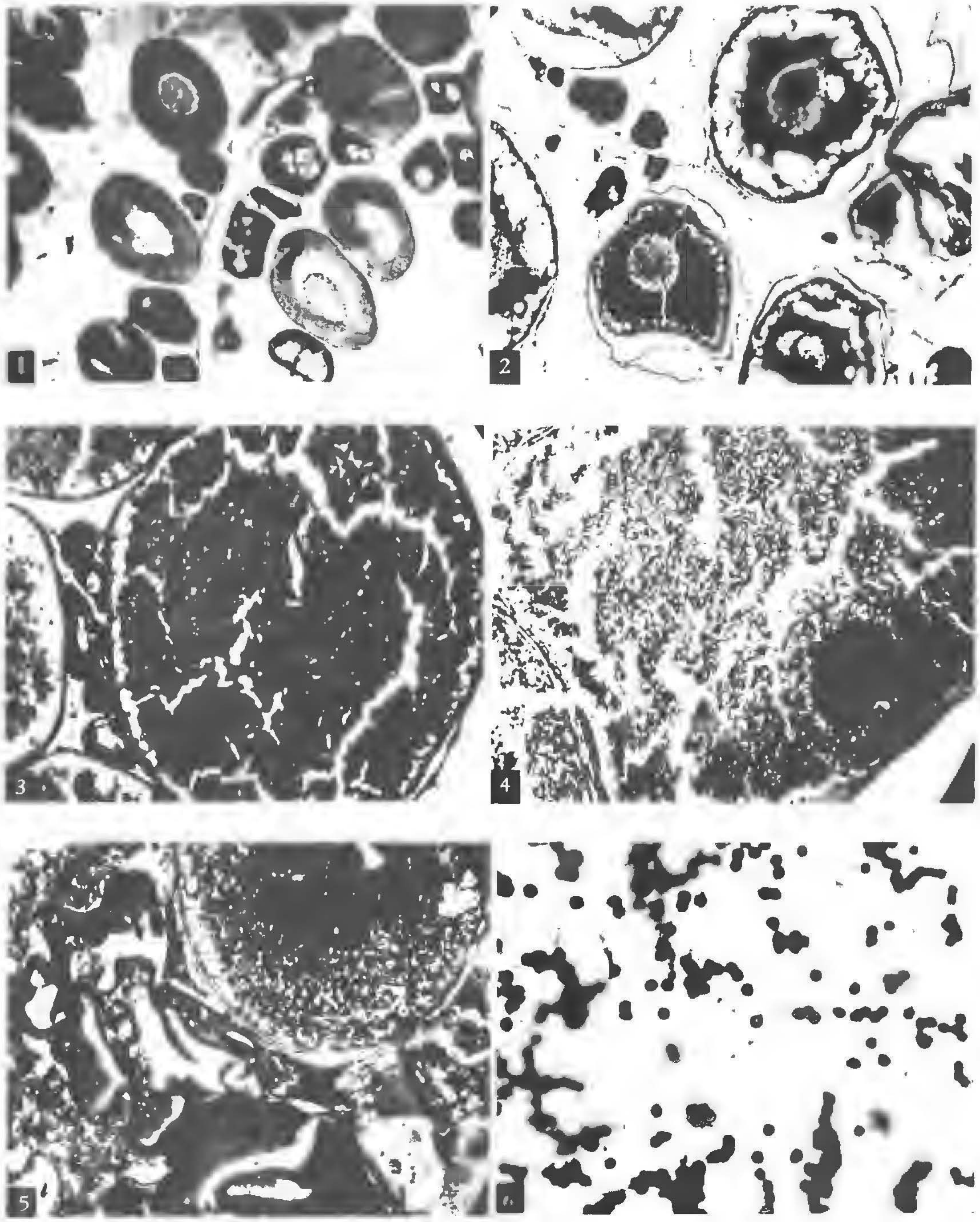


PLATE II

Embryonic Development Process of Silver Carp.

1. Egg membrane begins to absorb water; yolk evenly distributed; poor transparency under microscope.
2. Egg membrane continues to absorb water and expands.
3. Same as 2 above.
4. Same as 2 above.
5. Yolk gradually concentrates toward one side of the egg; blastodisc begins to heave upward; egg transparency increases.
6. Upheaval of blastodisc completed.
7. The first cleft appears along centre of blastodisc; yolk flows towards the animal pole.
8. Two-cell stage begins.
9. Blastodisc divided into 2 equal-sized cells - 2-cell stage.
10. 2nd mitotic division - 4-cell stage.
11. 3rd mitotic division - 8-cell stage.
12. 4th mitotic division - 16-cell stage.
13. 5th mitotic division - 32-cell stage.
14. 6th mitotic division - 64-cell stage.
15. Innumerable cell divisions - multi-cell stage.
16. Morula stage. Under low-power microscope demarcation of cells not distinct; external shape like mulberry.
17. High blastula stage.
18. Low blastula stage; germ layer flattens, wrapping downward toward the yolk portion.
19. Same as 19 above.
20. Same as 19 above.
21. Side view of early gastrula stage, blastodisc wrapping downward 1/2, appearance of germ-ring.
22. Same as 21 above, top view.
23. Early gastrula stage, blastodisc wrapping downward more than 1/2, appearance of germ shield.
24. Middle gastrula stage, blastodisc wrapping downward more than 2/3.
25. Middle gastrula stage, blastodisc wrapping downward more than 3/4.
26. Late gastrula stage, blastodisc wrapping downward more than 4/5.
27. Neurula stage, slightly upheaved neural plate appears on dorsal side of embryo; germ layer covers 4/5 of yolk.
28. Same as 27 above.
29. Large yolk plug stage.
30. Small yolk plug stage.
31. Blastopore closed stage, ventral view.
32. Same as 31 above.
33. Blastopore closed stage, side view.
34. Primitive pattern of embryo formed, head slightly swollen.

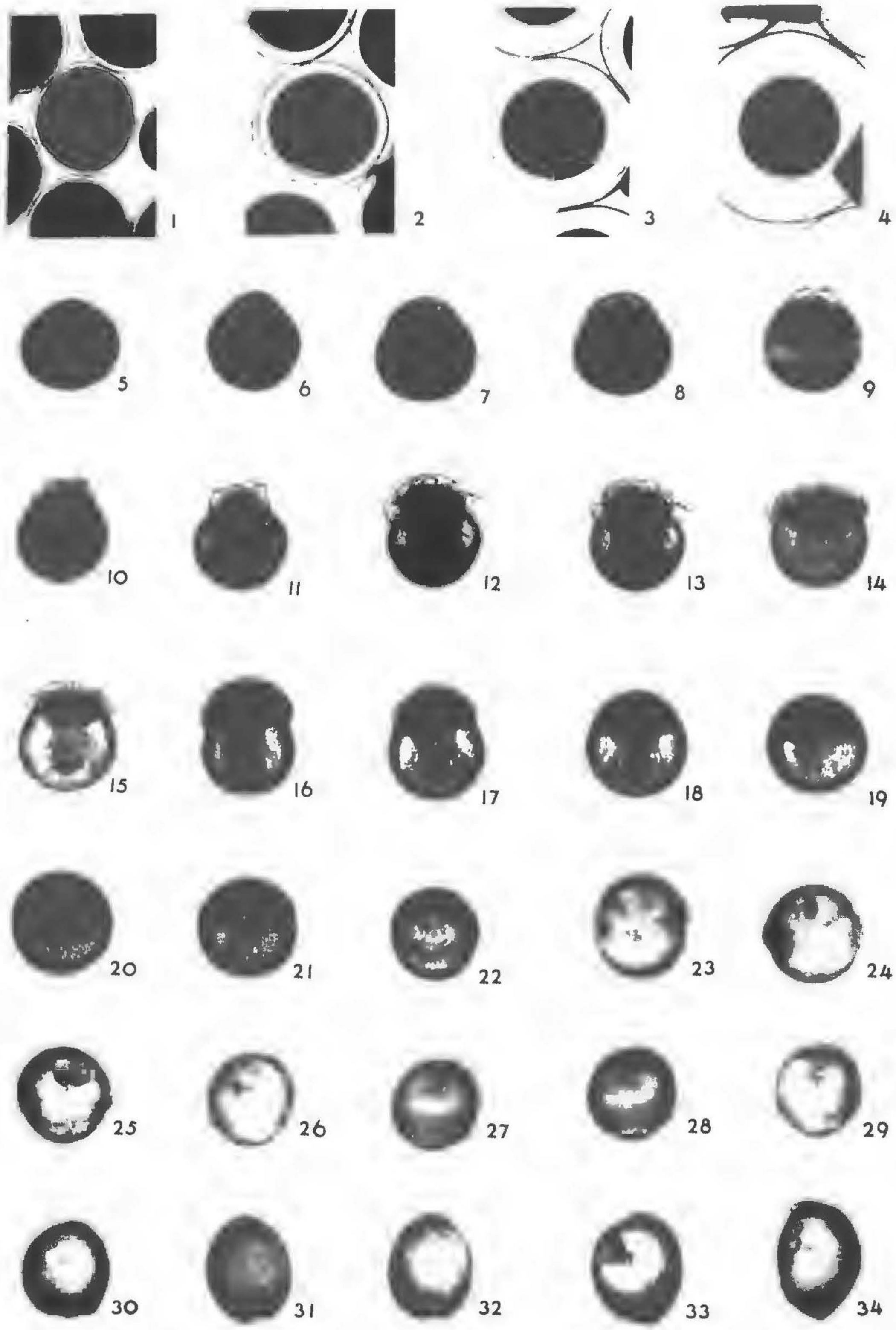

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PLATE III

Embryonic Development Process of Silver Carp

35. Early stage embryo; dorsal-lateral view, 3 pairs of somites.
36. Same as 35 above, ventral view.
37. Origin of optic vesicle appears, side view.
38. Same as 37 above, dorsal view.
39. Optic vesicle clear, 10 pairs of somites.
40. Same as 39 above.
41. Appearance of olfactory plate, side view. A round, thickened olfactory plate appears at lower-anterior part of optic vesicle; 13 pairs of somites.
42. Same as 41 above, side view.
43. Appearance of tail bud, 15 pairs of somites.
44. Apparance of auditory vesicle.
45. Same as 44 above.
46. Appearance of caudal fin; 17 pairs of somites.
47. Embryo lengthened.
48. Appearance of crystal bodies. Somites 19 pairs.
49. Embryo lengthened. Somites 21 pairs.
50. Muscular reaction. Tail lengthened. Somites 23 pairs.
51. Embryo lengthened. Somites 25 pairs.
52. Appearance of heart. Embryo continues to lengthen. Heart situates at front of yolk and below anterior of auditory vesicle. Somites 27 pairs.
53. Olfactory pit appears. A smalll olfactory pit appears in front of eye.
54. Otoliths appear. A pair of small crystalline grains in the auditory vesicle appear; these are otoliths. Side view.
55. Same as 54 above, ventral view.
56. Same as 54 above, ventral view.
57. Same as 54 above, side view.
58. Heart beating.
59. Body lengthened. Brain divides into front, mid and hind portions. Embryo moves unceasingly inside the membrane.
60. Early hatchling. Origin of anus appears at the end of yolk-sac.
61. Same as 60 above.

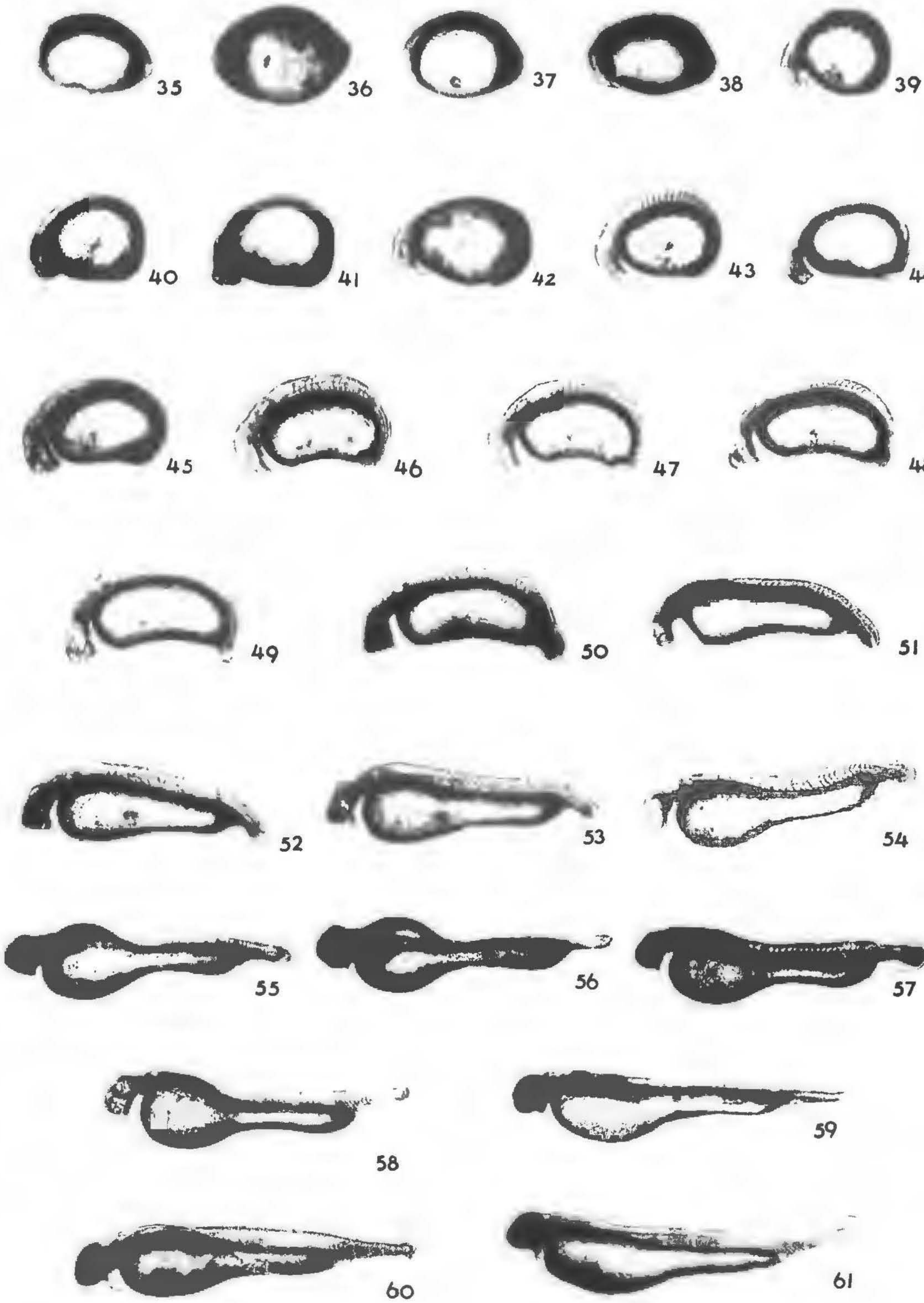
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PLATE IV

Embryonic Development Process of Silver Carp.

62. New hatchling.
63. Eye pigments appear.
64. Heart enlarged and curved; distinct blood circulation, heart beat 108-110 times per min; pectoral fins appear in front of body somites. Oral plate formed.
65. Gill slits formed; five branchial plates.
66. Lower jaw moved forward; movable.
67. Lower jaw moves towards middle position. Intestine formed. A sac-like air bladder appears at posterior of pectoral fins.
68. Side view. Air bladder distinct. Volume of yolk reduced.
69. Dorsal view. Pectoral fins very large. Gill-cover distinct.
70. Dorsal view. Air bladder big, black in colour, oval shaped, filled with gas.
71. Side view. Same as 70 above.
72. Body pigments increased. Intestine completed, with food in it; yolk further reduced. Swims very actively.

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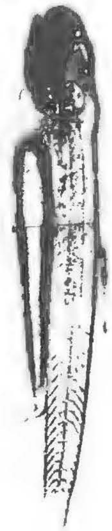

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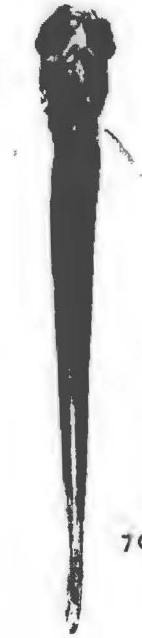

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PLATE V

Embryonic Development Process of Bighead

1. Egg membrane begins to absorb water and swells.
2. Egg membrane continues to absorb water and swells.
3. Blastodisc upheaved.
4. Second division of blastodisc, 4-cell stage.
5. 8-cell stage.
6. 16-cell stage.
7. 32-cell stage.
8. Multi-cell stage.
9. Innumerable cell divisions. Morula stage.
10. Early blastula stage.
11. Low blastula stage. Germ layer flattens, wrapping downward to cover the yolk portion.
12. Early gastrula stage, blastodisc wrapping downward 1/2; germ ring appears.
13. Middle gastrula stage, blastodisc wrapping downward 2/3; germ shield appears.
14. Middle gastrula stage, blastodisc wrapping downward 3/4.
15. Neurola stage. Slightly upheaved neural plate appears on dorsal side of embryo.
16. Early embryo. Appearance of the beginning of the optic vesicles.
17. Optic vesicles clear.
18. Olfactory plate appears. Tail bud appears.
19. Auditory vesicles appear.
20. Caudal fin appears. Body lengthened. Crystal bodies appear.
21. Muscular reaction. Tail lengthened.
22. Embryo lengthened.
23. Just before hatching out.
24. New hatchling.
25. Eye pigments appear.

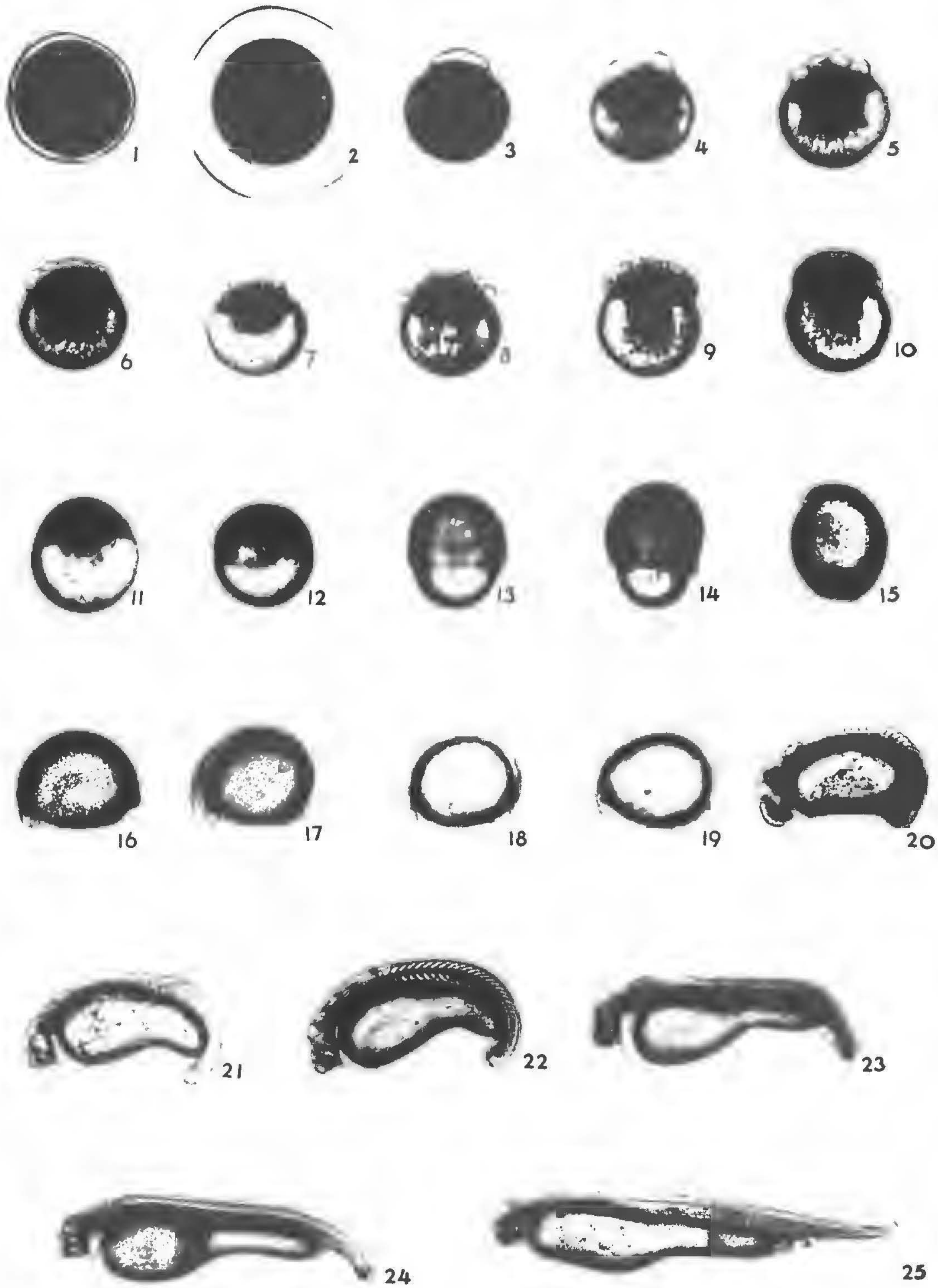
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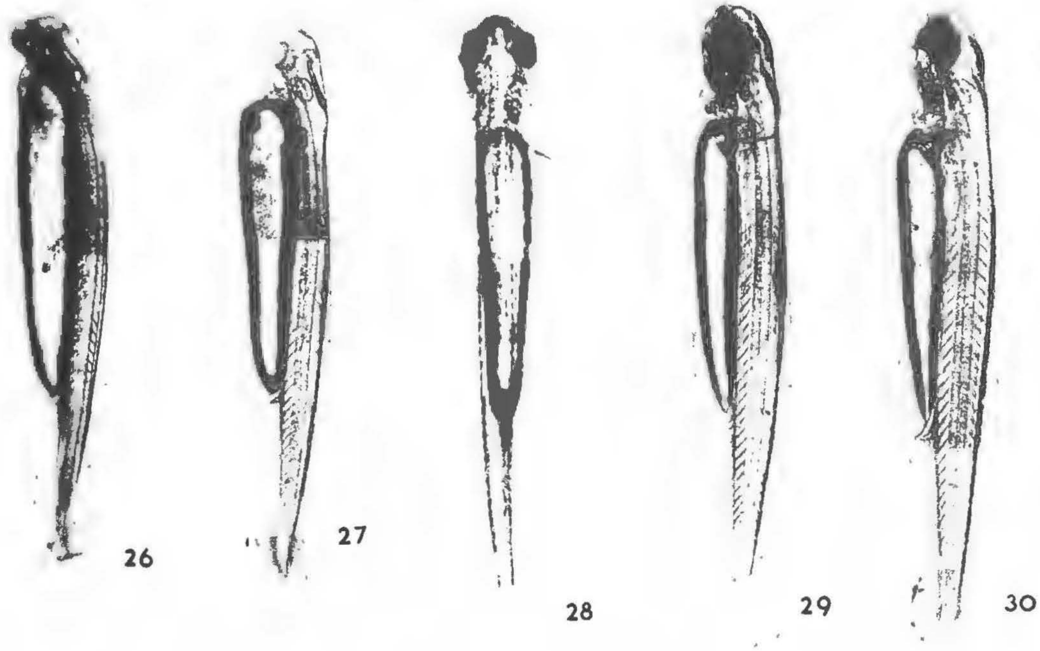
PLATE VI

Embryonic Development Process of Bighead

26. Heart enlarged and curved. Oral plate formed.
27. Side view. Gill slits formed, gill-cover distinct.
28. Dorsal view. Same as 27 above.
29. Lower jaw moved forward, movable.
30. Lower jaw moves towards middle position. Intestine formed, air-bladder formed.

31-41. Deformed Silver Carp hatchlings.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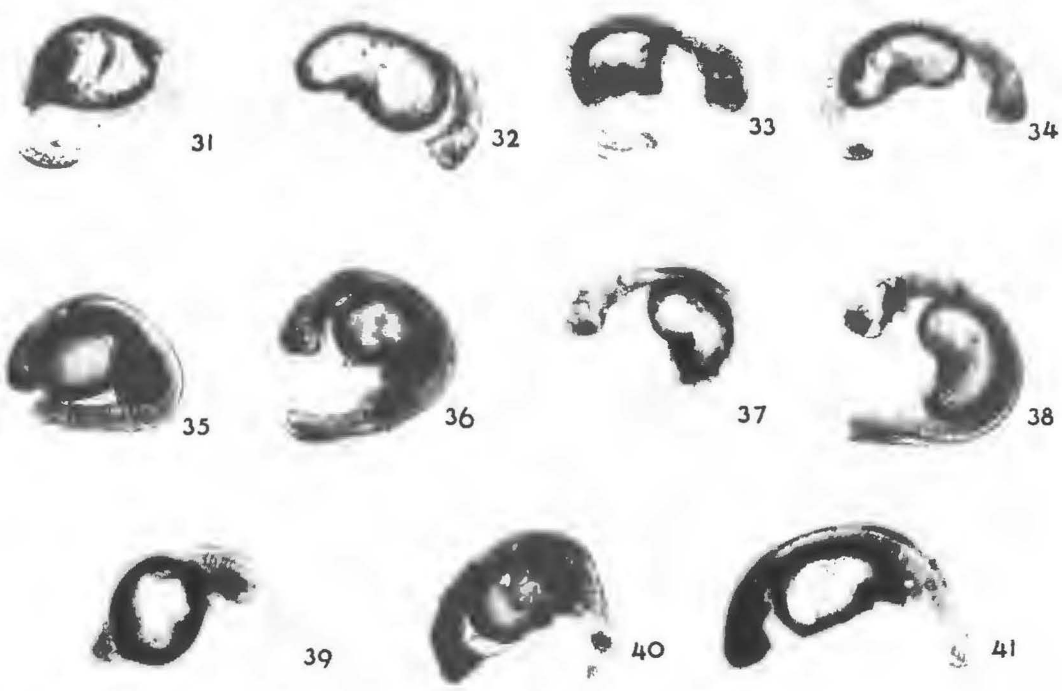
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PLATE VII

Embryonic Development Process of Grass Carp

1. Egg membrane swollen after absorbing water.
2. Blastodisc upheaved.
3. 2-cell stage.
4. 4-cell stage.
5. 8-cell stage.
6. 16-cell stage.
7. 32-cell stage.
8. Multi-cell stage, innumerable cell divisions.
9. Morula stage. Cell demarcation not clear.
10. High blastula stage. Germ layer wrapping downward yolk portion.
11. Low blastula stage.
12. Early gastrula stage. Blastodisc wrapping downward 1/2.
13. Germ ring appears.
14. Germ shield appears.
15. Late gastrula stage. Blastodisc wrapping downward 4/5; yolk plug stage.
16. Blastopore closed.
17. Primitive pattern of embryo formed. Head slightly large.
18. Optic vesicles begin to appear. Somites begin to appear.
19. Optic vesicles clear.
20. Tail bud appears. Auditory vesicles appear.
21. Same as 20 above.
22. Caudal fin appears.
23. Crystal bodies appear.
24. Olfactory vesicles appear.
25. Just before hatching out. Embryo twisting inside the membrane.
26. Origin of anus appears at end of yolk-sac.
27. Air-bladder formed, black in colour, filled with gas.

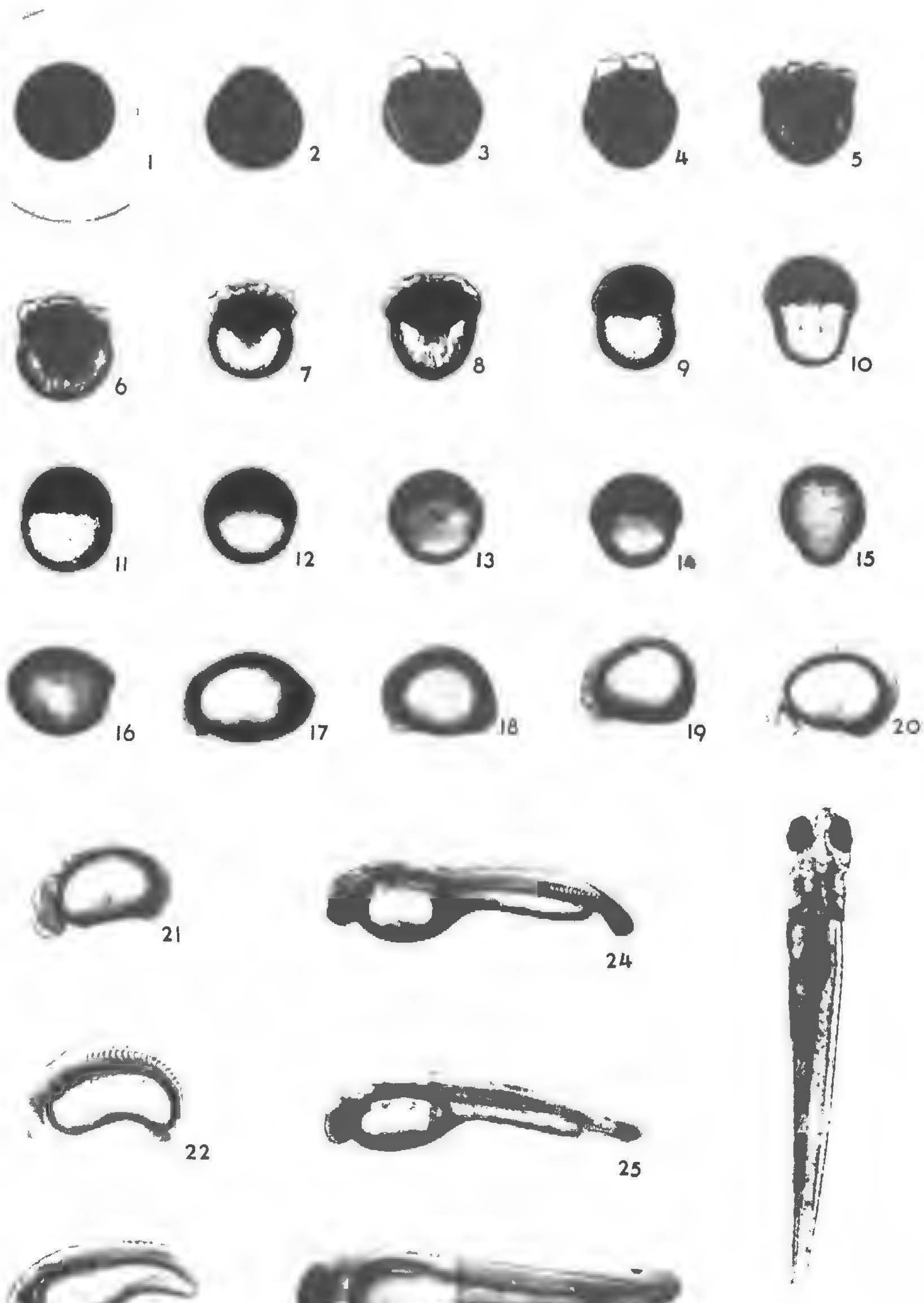
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PLATE VIII

Embryonic Development Process of Grass Carp ( ) x Common Carp

1. Blastodisc upheaved.
2. 2-cell stage.
3. 4-cell stage.
4. 16-cell stage.
5. 32-cell stage.
6. 64-cell stage.
7. High blastula stage.
8. Low blastula stage.
9. Middle gastrula stage.
10. Blastopore closed.

11-23. Embryos. Development gradually abnormal, deformation rate increased distinctly.

24-26. Bighead ( ) x Common Carp Embryos. (Deformation).

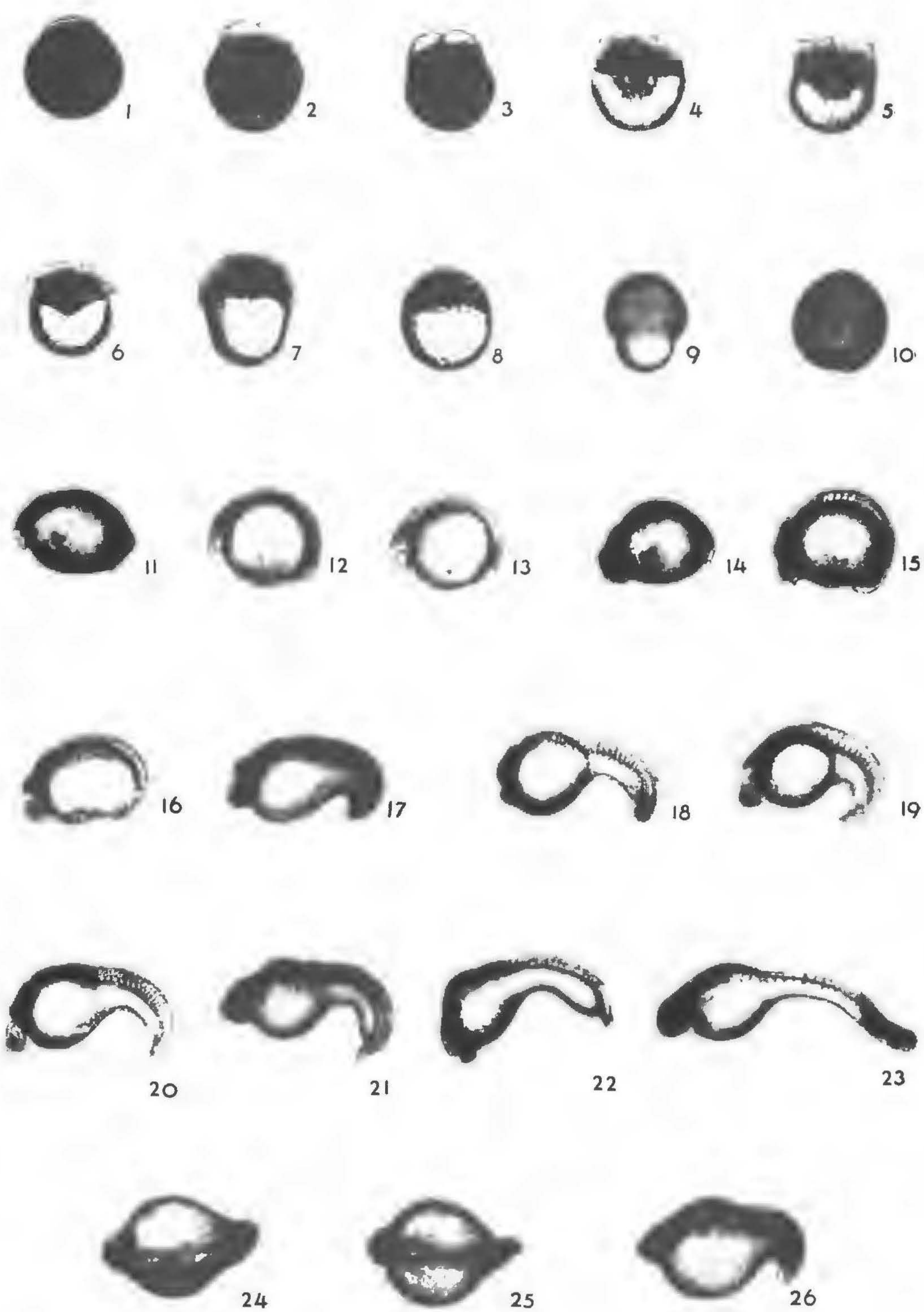
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PLATE IX

Embryonic Development Process of Mud Carp
(water temperature 26.3 - 28.9^{o}c)

1. Blastodisc upheaved.
2. 2-cell stage.
3. 4-cell stage.
4. 8-cell stage.
5. 16-cell stage.
6. 32-cell stage.
7. 64-cell stage.
8. Multi-cell stage.
9. Morula stage.
10. High blastula stage.
11. Middle blastula stage.
12. Low blastula stage.
13. Middle gastrula stage.
14. Late gastrula stage.
15. Blastopore closed.
16. Optic vesicular stage.
17. Tail bud appears.
18. Caudal fin appears.
19. Heart beating.
20. New hatchling.

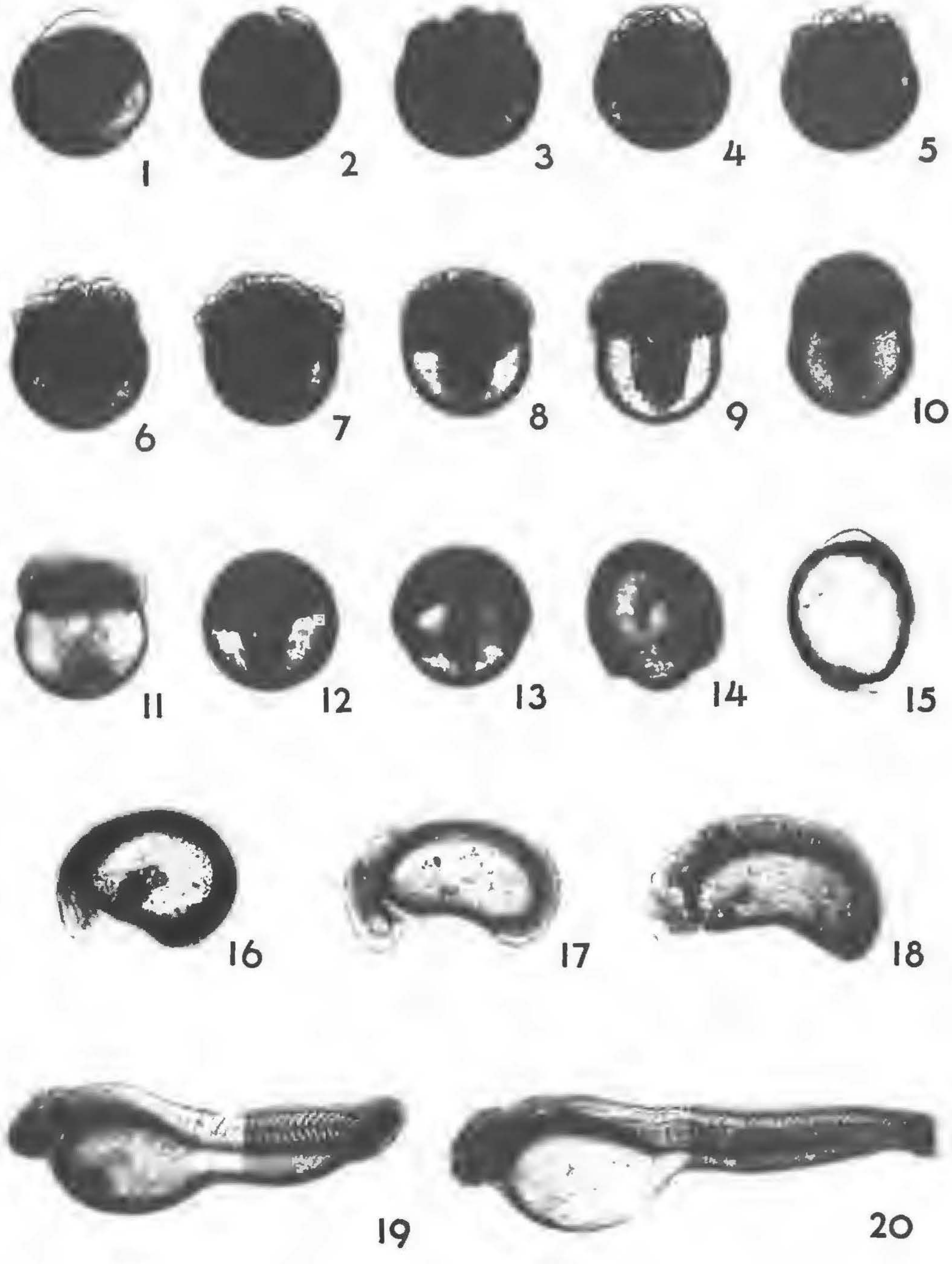
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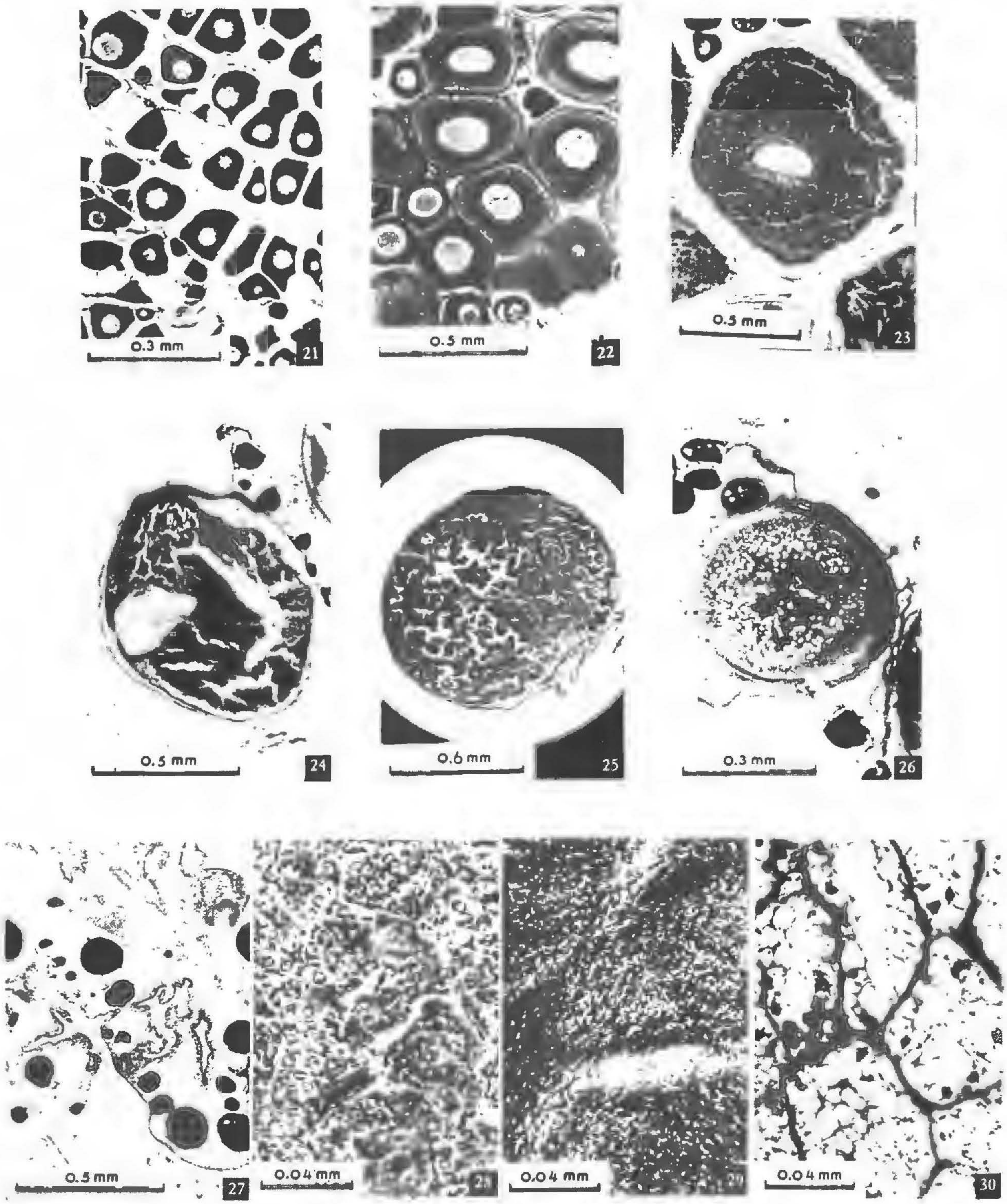
PLATE X

Gonads Sections of Mud Carp

21. Stage II ovary.
22. Stage III ovary.
23. Stage IV (mid-stage) ovary.
24. Late 4th phase oocyte; neucleus moves towards edge.
25. Fifth phase oocyte.
26. Sixth phase oocyte.
27. Ovary after spawning.
28. Stage IV testis.
29. Stage V testis.
30. Stage VI testis.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GRASS CARP AND SILVER CARP: PRODUCTION OF FRY[1]

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Translated from the original Japanese

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Emiritus President

Tokyo University of Fisheries

[1]This article was originally written in Japanese and appeared as part of a chapter in *Lectures on Fish Culutre - No. 2*, which was published in 1967 by Midori Shobo Book Company of Tokyo, Japan. It is a translation of Section 3, entitled *Production of Fry* (pp. 22-55), of the original article, *Grass Carp and Silver Carp* (pp. 13-89).

CONTENTS

FOREWORD

Grass and Silver Carp are two species commonly cultivated in ponds throughout the world, especially in Asia, including Mainland China and India as well as the entire southeast region of the continent. Any information and experience regarding the cultivation of these species is believed to be highly significant for the development of the work and the improvement of the techniques involved.

A number of articles and papers on the cultivation of Chinese carp have been published in various parts of the world, especially in Asian countries. In light of these publications, the present translation was undertaken to introduce readers to how the problems of reproduction and spawning are being handled and tackled in Japan.

The idea for the translation was derived from the exchange of various views among Dr. Takeichiro Kafuku, formerly with the Freshwater Fisheries Research Laboratory, Tokyo, Japan; Dr. Brian Davy, IDRC, Canada; Mr. Minoru Tsuchiya, the author of the article; and the translator.

The translation of the article and its publication were agreed to and permitted by the author, Mr. M. Tsuchiya, and Mr. Yoshio Watanabe, editor-in-chief, Midori Shobo Book Co.

On the actual work of translating the original text from Japanese into English, the following points may be noted: (1) the translation was made so as to convey the real meaning of the author's words, not just to provide a literal translation; (2) several portions in the original text were deleted on request of the author; and (3) a few of the technical words used in the original text were changed at the author's request.

It should also be pointed out that the photographs inserted in the present translation do not necessarily correspond to those in the original. Some of the negatives of the photographs in the original article were not available, so new photographs, prepared by the author were substituted for them. Also, a few new pictures were added to the present English version.

ACKNOWLEDGMENTS

The translator expresses his high gratitude to his colleagues Drs. Takeichiro Kafuku and Brian Davy, Mr. Minoru Tsuchiya and Mr. Yoshio Watanabe for kind cooperation, help and encouragement they gave to the present work. He is also greatly indebted to the IDRC, Ottawa, which financed the translation project (IDRC, Ottawa, 3-P-73-0058; Fisheries Translation, Malaysia, 3-A-77-4045).

EGG COLLECTION

The collection of eggs, the starting point in the rearing of fry, is possible by two methods - collection in natural river water or collection under artificial procedures. The latter method is further classified on the basis of the nature of brood fish; first, fish kept in confinement, and second, fish obtained from river water.

Collection of Eggs in River Water: The eggs that have been discharged and are drifting in river water are collected during the spawning time of the fish. This process is now considered the best and most effective way of collecting the largest number of eggs. By perceiving the spawning activity of fish in the water, a large amount of fertilized eggs can be obtained in the flow-down below the spawning site by doing fairly light work. The work required in hatching the eggs, which is the next step, can be economized if the collection site is properly located.

In the spawning ground, the eggs laid in the water complete the swelling process by absorbing water, usually for one hour after they are discharged, until they measure 4.5-5.5 mm in diameter and the semipelagic eggs flow down in the water. The eggs are then easily collected by using a square net with dimensions 1.5 m x 0.6 m x 0.5 m and with mosquito net of 3 mm mesh size forming its main body (Figs. 1 and 2). The square net is attached to wooden stakes planted on the water bank diagonally to the shoreline, and the gear for egg-collection is operated by two men, who carry out the work on board a small boat or by standing on a jetty constructed along the stakes. The other egg-collecting net is also operated in bank water; it measures 1.0-1.5 m wide and 2.0-2.5 m long. The net is placed in the water with its opening directed against the water flow and the end of the net is laid by hand. The eggs that flow into and accumulate in the net are transferred to a bucket placed in the water or to a small, wooden frame net box attached to the end of the main body of the net. Wing nets are often added and are attached to either side of the net opening to ensure effective collection. Figure 3 shows the net and the egg-collection site on the bank.

The amount of eggs collected depends not only on the density of the flowing eggs but also on the various conditions encountered. The amount of flowing eggs usually increases gradually after the first showing and reaches a maximum level several hours later, then decreases gradually to zero. It is natural to take advantage of this by making the greatest effort to collect the eggs when they are flowing at their maximum level.

The concentration of flowing eggs in the water seems even regardless of their depth or position in the river. It is common practice, therefore, to locate the collection site in shallow water along the bank, preferably where the shoreline of the bank is curved and the water flow is slow. The operation should not be done in the middle of the flow because the faster current there makes the net operation more difficult, and because the pressure of the water flow can sometimes crush the eggs in the net.

The actual site of the egg-collection operation is located in the Edo River, a tributary of the Tone River, where the actual spawning takes place.

Egg-collection is seldom attempted in the main flow of the Tone River because of its stronger flow and water level fluctuations, which badly disturb the net operation. In the Edo River, collection is usually practised at the site near Noda City, Chiba Prefecture, where the current is stable, because the river's flow is regulated at the Sekiyado dam-gate. The other reason for selecting the water near Noda City is that the eggs, if not harvested there, will flow down toward the river's estuary in Tokyo Bay and will thus be exposed to salty water, which kills them. This operation, advocated by conservation-minded people, is based on the idea that the eggs should be utilized to their full advantage. The flowing eggs are observed in the river after each spawning period, but they are found more abundantly after the first spawning period than after the others that follow. In practice, the collection of eggs is attempted in the first or second cycle of spawning activity but seldom in the third.

Artificial Procedure: Egg-collection under artificial procedures is made possible either by using mature parent fish caught in river water or by using fish reared in ponds and induced to spawn by hormone injection.

Of the mature male and female fish which are caught at the spawning site on the day of their reproductive activity, the males are always found to be fully mature, but females with fully mature ovaries usually amount to 30-40% of the total (Table 1). The catching of mature fish in river water is now prohibited by fishery law. But before this law was issued, several million eggs stripped from one female were fertilized successfully by the dry method. It was also observed that the female fish deposited all the eggs she carried at one time, leaving only a few eggs in the ovaries. As shown in Table 2, the number of eggs carried by a female ranges from 1.14 to 2.25 million, depending on the size of the fish.

Induced Spawning by Hormone Injection: The injection of hypophysis hormone can induce the maturation of eggs and their discharge. Hormone injection for this purpose can be applied both to fish caught in river water and to those reared in ponds.

As previously noted, parent fish caught at the spawning site during the season do not show full sexual reproductive functions unless they are exposed to a particular natural condition. In fact, those fish which are caught on days other than their spawning day do not play the role of brood fish unless they are given a hormone injection (Figs. 4 and 5).

Experience shows that fish reared in ponds mature to a certain extent, but never to the point where they will discharge their eggs or sperm if not treated artificially. It is believed that the nature of the fish does not permit the carrying out of the sexual function in captivity.

Brood Stock Fish: These fish are obtained by selecting sexually mature fish from those taken from a river or from the same fish stocked in culture ponds or in farm ponds.

Mature fish caught in river water during the months of June to July can be used for the purpose of spawning. However, it should be recalled that so-called mature brood stock fish, especially large ones, maintain and show their wildness. Due attention, then, must be paid to the handling of these fish whether in catching, transporting, stocking, injecting with a hormone, etc. Quite often these fish, if not handled properly, die after a hormone injection before they reach sexual maturation, and the eggs stripped from them are often abnormal in development.

On the other hand, brood stock fish obtained during the fall or winter, which are non-spawning seasons, can be acclimatized in ponds and tamed through careful feeding and treatment. The so-called wild fish from river water, which weigh 8-15 kg, are easier to handle when anesthetized. Fish reared in ponds can be handled more easily since they not only get mature regardless of their small size but also become tame.

Needless to say, due caution must be paid to the management of pond water and feeding. Otherwise, even though the fish will attain the size and age of maturation, they will not enter the reproductive function and thus the stripping of eggs and sperm from them will end in failure.

Hormones and Their Preparation: The hypophysis of fish is usually adopted as the hormone to induce spawning; a number of fish physiology studies approved of this. It is generally accepted that the gonadal hormone secreted by the hypophysis (anterior lobe) accelerates ovulation. Also, the function of hormones is said to be more effective when the hormones used come from closely related species of fish.

Experiments of hormone injection on Grass Carp have been conducted using the hypophysis of a Japanese frog (Rana n. nigromaculata), Common-Carp (Cyprinus carpio), minnows (Hemibarbus barbus and Tribolodon taczanowskii), Grass Carp (Ctenopharyngodon idella), Silver Carp (Hypophthalmichthys molitrix), etc. The hormone derived from Silver Carp and Grass Carp worked very effectively, and the injection of hormones from the other species listed above resulted in ovulation, though not clearly approved.

The size of the hypophysis, which varied according to the size of the fish, measured about 3-5 mm in the two Chinese carp listed above; they were 8-15 kg in weight. The size of the hypophysis of the Common Carp was 0.6-1.7 mm. It was smaller in the other cyprinid species listed. The hormone extracted from the hypophysis of fish in the prespawning state is said to be the most effective. Moreover, the procedures followed in extraction and the method and duration of preserving a hormone determine its effectiveness. Normally, hormone material transferred into acetone or absolute alcohol will retain its function for 2 years (Fig. 6).

The hormone material, either preserved or fresh, is ground thoroughly in a glass mortar (Fig. 7), with physiological salt solution being added. The material is prepared just before the actual injection. The salt solution should not be kept for a long time.

Dissecting a hypophysis from a fish's brain and preserving it are by no means easy. The work requires techniques of a high standard. Other gonadal hormones available on the market have been tested on Chinese carp. Experiments in the past indicate that the application of such materials singly has never resulted in ovulation, and that the mixture with hypophysis has shown the expected results, but to a low extent only. In contrast, it was found that males treated with medical hormone preparations discharge sperm more vigorously than those untreated. The problems as such suggest the necessity of further investigation.

Method of Injection: The parts of a fish's body where the syringe is inserted are (1) body cavity close to anal fin, (2) muscle around dorsal fin base and (3) muscle at pectoral fin axis. No difference has been found as to the effect of the injection in these three different body parts. However, practice has shown that injection into the body cavity often damages internal organs, and that muscular injection is hindered by scales and a single operation does not allow the injection of a substantial amount of solution. Therefore, injection in the muscle at pectoral axis (Fig. 8) is the procedure commonly practised.

The amount of hormone injected and the interval between injections are determined by the sexual maturity of the fish to be injected. For fairly well matured fish the usual practice is to inject 1.5-3 pieces of hypophysis extracted from fish of a similar size one to three times and in intervals. The proper interval between injections seems to be 6-8 hours, and in most cases the fish are ready to discharge eggs 20 hours after the first injection (temperature of water, 20°C). (Fig. 9).

In case the hypophysis of a smaller cyprinid fish like the Common Carp is used, the quantity injected is determined by the size of fish to be injected. In the Soviet Union, Common Carp were adopted for this purpose. It was reported that for the first injection the hypophyses of Common Carp weighing 4-5 mg (dried weight) were applied to Grass Carp 5 kg or larger, and 2.5-3.0 mg to recipient fish 5 kg or smaller. For the second injection, given 24 hours after the first, the hypophyses applied weighed 3.5-6 mg per kg of the recipient fish. Russian workers reported that the first injection of the hormone in smaller quantities resulted in the ova reaching the preovulation stage, and the second injection in a larger quantity resulted in the effective discharge of the eggs.

Russian sources state that for male recipient fish 9-15 mm of injection per fish are sufficient. The experiments conducted at Saitama Prefecture Fisheries Experiment Station also show that a medical hormone product like synapholin suffices for male fish.

Handling of Fish Following Injection: After injection, the fish are stocked in a rearing pond of moderate size, and are kept in a healthy condition until they reach the stage when they are ready to discharge eggs or sperm. Too narrow a pond tends to hurt the fish, and too wide a pond makes it inconvenient to catch them.

The keeping of brood fish in a cage-net, though formerly practised, is not recommended because of the wild nature of the fish.

The discovery in recent years that moving water is a factor in stimulating egg-discharge made it the actual practice to convert rearing ponds to spawning ponds fed by moving water. It has been observed that when one or two females are placed together with 3-5 males in a concrete pond 2.7 m x 9.0 m and with a water depth of 1.2 m, the fish demonstrate a chasing behaviour followed by the actual discharge of eggs (Fig. 10). The nature of the water fed into the pond, whether muddy river water or clean spring water, makes no difference in spawning activity of the fish as long as the water moves at the rate of 5 litres per second and the temperature of the water is kept preferably over 20°C (the optimum range being 22-27°C).

Collection of Eggs by Stripping: When the brood fish in the pond enter into a vigorous chasing behaviour, which usually takes place 12-24 hours after the first injection, they are taken out of the pond in time for egg-collection. If the fish demonstrating the chasing behaviour were not harvested, the eggs in the ovaries enter into over-maturation and are not fertilized, or if they are fertilized they show high mortality during embryonic development. The key to the satisfactory collection of eggs from the brood fish is the timing of the harvest from the pond and insemination. When checking the brood fish in the pond, due attention should be paid to observing not only their sexual activity but also the number of hours that have elapsed after hormone injection. The reason is that the maturation of the gonad toward the last stage does not necessarily occur simultaneously in the male and female fish which received an injection at the same time and were placed together in the pond. Unparalleled release of sex products between the two sexes often results in the discharge of eggs that are not inseminated.

Gravid female fish weighing over 8 kg are handled by 3 men, and the lighter fish by 2 men. One man holds the head of the fish directly upward and the other one holds the caudal portion of the fish and strips the eggs into a container (Fig. 9), which is clean and carries no moisture. The fully mature female will discharge eggs effectively by pressing lightly on her abdomen. The female which does not discharge her eggs by the same treatment is returned to the pond as quickly as possible. Excess pushing on the abdomen is taboo. In cases where the fish is in over-maturation, the eggs ooze out of the genital opening, and those eggs, even if inseminated, do not generally enter into embryonic development. Normal ripe eggs are bluish-yellow to bluish-gray in colour and have a glittering reflection, but abnormal eggs usually show a dusky colour and are irregular in shape.

The amount of eggs carried in an ovary can number, depending on the size of fish, between 0.1-1.5 million, all of which are discharged at one time, thus allowing complete stripping in a single operation. Because males kept in ponds sometimes have difficulty in ejaculating, they are treated with synapholin for assurance. Male fish that come from river water usually show no problem.

<u>Collection of Eggs Discharged in Pond Water</u>: The spawning behaviour demonstrated by hormone-treated brood fish stocked in ponds will indicate that the eggs laid in the water can be scooped up. The eggs discharged in pond water which may be collected by a net with very small mesh measure about 2 mm in diameter. After the eggs are discharged in the water, they grow bigger with time, up to 4.0-5.5 mm, and can be easily collected with a dip-net made of mosquito screen. The majority of the eggs, depending on the flow of the water in the pond, settle on the bottom and are more easily scooped up with a dip-net. Since the eggs, characterized by their low specific gravity, are easily carried down by the delicate flow of pond water to the outlet opening in the pond, it is advised that an egg-gathering device be built at the outlet (Fig. 11 and 12). It may be further advised that an egg-collecting pool attached to the spawning pond be constructed. The latter is constructed to allow the water-flow in the pond to convey the eggs smoothly to the outlet, which is connected to the egg-collecting pool.

The pond facility as described above is highly advantageous. The brood fish are not bothered by man's hands, and insemination can be accomplished quite effectively.

HATCHING AND EMBRYONIC DEVELOPMENT

<u>Development</u>:

<u>Unfertilized Mature Eggs</u>: Eggs of Grass Carp are spherical in shape,

measure 1.8-2.05 mm in diameter and are coloured greenish-yellow with a grayish tinge, while those of Silver Carp are also spherical in shape, measure 1.56-1.92 mm in size and are greenish-yellow in colour. The colouration of these eggs is so variable, even within the same batch, that the segregation by colour of the two species' eggs is hardly possible. The eggs of Bighead Carp (Aristichthys nobilis) obtained artificially from cultivated brood fish are brownish in colour, differing from those of the two species above, but further observations are needed to confirm definitely the colour pattern of the former. The eggs of Blackhead Carp (Mylopharyngodon piceus), though not yet obtained by artificial insemination, are believed to be quite similar to those of Grass Carp and Silver Carp.

Embryonic Development: The embryonic development of the 4 species of Chinese carp displays a similar pattern. The account below gives the observed development of Grass Carp. (See Table 3 and Fig. 13)

When the fertilized eggs contact water, they start immediately to absorb it. The membrane and cytoplasm depart from each other gradually, and the perivitelline space is filled with water. The eggs swell to about 1.8 times their original size within 30 minutes, and attain their maximum size, 2.5 times their original size, within one hour, while the blastodisc develops and the first cleavage takes place. The cleavages continue and the eggs reach the morula stage within 5 hours. Within 10 hours they move from the blastula stage to the gastrula stage, when embryo covers the yolk dorsally. Within 18 hours the embryo is clearly visible and the optic vesicle appears. In 20 hours the embryo enters the D-shaped stage, with the eye lens and ear vesicle appearing and 7 somites distinguishable. In 28 hours the somites multiply to 14, the otholith appears, and the embryo starts to palpitate.

As time passes, the somites increase in number, and embryonic movement become vigorous. Within 33 hours the embryo starts to rotate within the egg and the membrane grows thinner. Within 37 hours fin folds over the elongated embryo and the brain ventricle begin to show. Within 40 hours the digestive tract reaches the vent, which opens. Within 50 hours the rudimentary heart can be differentiated. Within 52 hours black pigment appears in front of the ventral edge of orbit, and the membrane shrinks partly, while the egg becomes distorted in shape. The eggs hatch in 52 hours and 30 minutes.

The embryonic development described above is based on the observation of eggs placed in water at 17.5-22°C, but there was considerable variation in the time individual eggs kept under the same water took to hatch; some eggs required 12 hours more for hatching than others. However, in general, Grass Carp eggs hatch in two days when they are kept in water with a more or less constant temperature of 21°C.

Prelarvae: The Grass Carp larvae just hatched measure 5.5-5.9 mm in total length and are colourless or transparent except for the black pigment dispersed anteriorly to the ventral edge of the orbit. The larvae usually lie on the bottom of ponds, but at times they swim up by a bending motion of their body to the water surface, returning shortly to the bottom where they continue their previous mode of behaviour. Grass Carp and Silver Carp exhibit a similar mode of living; thus in this respect a specific distinction between the two species is impossible.

One day after hatching the rudiment of the gill arch begins to show, and parts of the mouth begin to form. Within about two days after hatching, starry black pigment appears on the breast and on the ear vesicle, while the body as a whole becomes somewhat darker. The mouth cavity is formed by the growth of a lower jaw. Blood circulation is visible in the gill as well as on the sides of the body posteriorly to the caudal base. The pectoral fins are extended, but the larvae remain still on the pond bed except for some weak swimming in bottom water. The absorption of the yolk continues, and the digestive tract in the form of a simple tube runs over the yolk. The vent opens, but not feeding takes place. At this stage, the larvae attain a total length of about 7 mm.

Three days after hatching the larvae, which now measure 7.6 mm in length and show blackish pigment on their body, reach the so-called floating stage and swim around in surface water. At this stage, the yolk is completely consumed, and the larvae feed on the food supplied.

Post-larvae: About one week after hatching the larvae, 8-9 mm long, grow into the post-larvae stage. By this time it is possible to distinguish between Grass Carp and Silver Carp. Grass Carp are light brown in colour and their body has grown thick, while Silver Carp are darker in colour and their body is slender. The specific characteristic that is especially apparent is the development of pigments on the ventral fin fold of Silver Carp; Grass Carp do not develop this trait. The pattern of swimming also differs between the two species. Grass Carp tend to swim slowly in the middle to bottom layers of the water, while Silver Carp swim fast in a step-by-step manner mostly in surface water. Both species are now vigorous feeders and their digestive tracts are filled with food. Within a week the larvae attain a total length of 18 mm, and the larvae of the two species at this stage are easily distinguishable. The separation of larvae smaller than 18 mm between the two species requires careful and detailed observation. In both species, scales appear on larvae about 18 mm long.

Method of Hatching: The eggs of both Grass Carp and Silver Carp discharged in natural river water hatch while riding the water flow. Accordingly, when placed in standing water and in a high-density condition, their eggs show a very low rate of hatching. Their eggs are characterized by a low specific gravity compared with their size (a feature quite different from that of salmon and trout) and are not managed safely when placed in a container fed by moving water. In designing the hatching apparatus for such eggs, due consideration had to be given to how to prevent the eggs from being carried by moving water and pressed against the screen and damaged. This problem was solved by designing a hatching box as illustrated in Figures 14-16. The screen-cage in which the eggs are placed receives running water from the bottom, and the water, which makes a slow rotating motion within the screen, carries the eggs toward the surface. The eggs that reach the surface are then carried down again by the movement of the water along the surface of screen. Naturally, the eggs flowing up and down also make a continuous rotating motion until they hatch. The hatched fry leave the screen-cage by passing through the mesh and finally are carried into a fry-receiving box.

The wooden hatching box measures 175 cm (length) x 57.5 cm (width) x 37 cm (depth). It is divided into 3 compartments, each of which holds a screen-cage inside it. In each cage 50,000-120,000 (15-30 litres) eggs are stocked; thus, a single hatching-box takes care of 150,000-360,000 eggs (15-30 litres) (Fig. 17). By supplying water at the rate of 20 litres per minute to the hatching-box, the apparatus is capable of hatching 100% of the eggs. The water, whether it comes from a river or spring, must be clean, and its temperature should be kept at 20-25°C.

The hatching of eggs is also possible whether in stagnant pond water, circulating pond water, a circular tank, or in other constructions. Under such conditions, special care must be taken in the actual hatching operation to prevent the growth of fungi and water pollution due to the decay of egg membranes left by the hatched fry.

REARING OF FRY

Habit During Larval Stages: As pointed out previously, fry have a peculiar habit of lying laterally on the bottom of a water body. At times they swim up to the surface, but return to the previous behaviour pattern. When they are kept in a narrow, limited space, such behaviour often causes the death of the fry piled up on the bottom.

This peculiar mode of behaviour of the fry has not been observed in river water. Repeated experiments have shown that when fry are exposed to constantly flowing water, which prevents them from lying on the bottom, no trouble arises. Within 3 days (in water at a temperature of 20°C), they float up to the surface and tend to swim across the water flow. Fry at that stage, when stocked in a standing-water pond, tend to swim in shoals along the pond wall, and normally keep the same mode of swimming except when they rush swiftly toward food thrown into the pond. The dispersal of the fry, if it happens, may be said to be abnormal compared with their usual movement in shoals. When they reach the post-larval stage, Silver Carp swim in surface water, while Grass Carp prefer to stay in the deeper layers.

Rearing Apparatus of Larvae Up To Floating-Up Stage: Since the hatched fry tend to stay lying on the bottom, the rearing of these fry in a pond requires special attention in order to avoid an accumulation of debris on the bottom and to keep the depth of the water below 30 cm so as to allow the fry to move easily in a vertical direction. When fry are stocked in excess density, they lie on one another on the bottom and often choke to death. The problem was solved by moving the water in the container, which, in practice, was actually the same box as used for hatching. For the rearing of fry in the box, the screen-cage, which was used for the hatching of the eggs, was converted to a net-cage with different mesh sizes suited to the size of fry. In practice, the fry collected in the fry receiving-box are moved to the rearing box, and the water is supplied from the bottom, the same way as in the hatching of eggs. It is important to avoid muddy water in the rearing of fry, because such water often clogs the mesh of the cage-net and the eventual overflow of water carries the fry out of the box. The rate of the water supply is kept at 20 litres per minute, the same as in the case of the hatching of eggs. One unit of the box takes care of 300,000 fry without any trouble.

Rearing Apparatus of Post-Larvae: For the rearing of fry from hatching to the post-larvae stage, the usual practice was to use a small concrete pond 30-100 m^2 or a dirt pond of similar size reinforced by wooden walls (Fig. 18). However, the net-cage system used for this purpose and initiated in 1960 by Saitama Prefecture Fisheries Experiment Station has become so popularized today that commercial fish fry dealers everywhere in the country have adopted the system.

It is considered a convenience that the netting material of the net-cage, which is 3.3-5.8 m^2 in area and 0.9-1.2 m deep, can be selected from various synthetic products with accurate and regular mesh formation. The net-cage (Fig. 19) is placed in an ordinary large rearing pond and tied to bamboo or wooden stakes. The mesh size of the netting is determined and adjusted according to the growth of the fry reared. Three different mesh sizes (30-15 mesh per inch) are sufficient for the rearing of Chinese carp fry from the floating-up stage to the fingerling stage. In the initial stocking (3-4 days after hatching or right after floating-up), the mesh size of the netting should be over 30; if not, the fry may escape through the mesh. As the fry grow, larger mesh sizes, which also permit the free passage of water must be adopted.

When setting the cage-net in the pond the following items must be considered. The net-cage should be placed in the pond with its bottom level at least 20 cm above the pond bed and its upper level 30 cm over the water surface. The actual depth of water within the cage, therefore, measures 60-90 cm, which is sufficient for rearing. Needless to say, the cages are operated in a group, and each cage should be 50 cm from the others. Preferably, each cage should be supplemented with a water spray system (Figs. 20 and 21) or an aeration system to save the fish from oxygen deficiency.

Feeding: Timing, Method and Amount: Five-six days after hatching at 20°C, the yolk is absorbed completely, the fry enter the floating-up stage, and they begin in no time to seek food. Therefore, it is logical to start feeding on the same day as stocking or, at the latest, on the following morning.

The initial feeding may consist of zooplankton such as daphnia or rotifer. Since these materials are not easily available due to the low temperature of the water at the time, they are at present generally substituted for by synthetic foods. They include egg-yolk (boiled or half boiled), liver, powdered milk, yeast, soybean milk, fish meat, codfish roe, fermented soybean, roasted wheat meal, daphnia (frozen or dried), synthetic fish food, etc. As the result of a number of experiments, boiled egg-yolk and liver have become the most commonly used items.

The Saitama Prefecture Fisheries Experiment Station found the following preparation for initial feeding highly effective; boiled egg-yolk is strained into small particles through gauze or other fine-meshed cloth and dissolved in water; fresh animal liver is finely ground by a meat chopper and dissolved in water; these two "solvents" are then mixed. The synthetic food thus prepared is spread by sprayer on the pond water. This procedure, which was initiated by the Station, is done for several reasons. The fry, just after being stocked into the water, are not necessarily active swimmers, thus their horizontal and vertical range of movement is limited. The food in the form of tiny particles disperses softly in the water and is eaten by the fry with ease over a number of hours. Recently some synthetic foods such as fish meal and yeast are also showing satisfactory results when sprayed over the water in the same way as noted above. Food in the form of tiny particles is thoroughly eaten by the fish, thus reducing the chance of water pollution, and it can be rationed correctly. Feeding by spray may be used for a period of about 2 weeks after stocking or until the fish attain a total length of 1.5-2.0 cm. Then the food should be fed to the fish in the form of dough.

With the spraying method the daily ration expressed in units of egg-yolk, may be one unit per 10,000 fry per day, which is administered in 4 separate sprayings. The quantity or ration of animal liver is estimated to weigh

3-5 g per 10,000 fry per day. As the fry grow, the ration is increased gradually; the amount of both egg-yolk and liver is increased by 10% every day or every 2 days. In the case of fresh-meal or yeast, the ration will be about 20 g for each 10,000 fry a day.

It may be pointed out that the amount of ration noted above is based on a single standard, but it is by no means a fixed rule.

CAUTIONS TO BE TAKEN IN THE REARING OF FRY

Water Quality of Rearing Pond: Before fry in the floating-up stage are stocked in the rearing pond, the pond water must be carefully checked; otherwise, nearly all the fish stocked sometimes die a few days later. The stocking of fry on summer days is not favourable to their survival because the high temperature of the water often leads to sudden changes in water quality. If the pond water is coloured blue-green due to an excess swarm of planktonic-green algae, it will cause gas-disease in many fish. The same problem is also experienced when the fry are stocked in a pond which is fed by raw, fresh well-water. Newly stocked fry are sometimes killed in mass by a change in water quality due to excess organic matter in the well-water; the fish are unable to adjust their physiology to the change. What is suitable water quality to the fry may not be defined in precise terms, but it may be stated indirectly as follows: if the pond receives a new supply of water 2-3 days before stocking, the water quality of the pond should be adequate for the rearing of fry.

Cautions to be Taken in Stocking: When preparing to stock a pond with fry, the first step is to check the temperature of the water very carefully. The limit of tolerance of fry against a sudden change of temperature is said to be about 10°C, but a difference of temperature of only 5°C will gradually show ill effects. Fry should be stocked in a pond either in the early morning or in the late afternoon, but never during the hot daytime. If the stocking must be done during the daytime because of unavoidable circumstances, the container in which the fry are carried is placed in the pond water for a number of hours until the water temperature both in and outside the container becomes more or less equal.

The oxygenated polyethylene bag is suitable for shipping fry over long distances. It is recommended, though, that the space in the bag be filled with oxygen and air in the ratio of 50:50 rather than filled with 100% oxygen, because after the fry become acclimatized to the high oxygen content in the bag they will have difficulty adjusting physiologically to the low oxygen of pond water. This difficulty, if suspected, may be avoided by pouring pond water little by little into the shipping container so as to equalize the gas content in and out of the container; the fry can then be transferred into pond water.

Cautions to be Taken During Rearing: If properly fed and developing normally, fry stocked in rearing ponds tend to swim along the pond wall in a school in the form of a narrow band. This behaviour indicates that the fish are in good health. If the fry do not form schools, they are not in good shape, and a high mortality rate in later days will not be avoided. Sometimes the fry are distracted from schooling and disperse in a powerless manner in the pond water. When this happens, it is believed to be a bad sign.

To find the fry in pin-head and their body colour turning is also a sign of trouble. Checking the state of their health may also be possible by observing the lower part of the body, which becomes whitish when they are fed egg-yolk. If this whitish colour is not observed, the fish have a problem. All these unfavourable conditions are caused mostly by poor quality pond water and abnormal water temperatures.

When shallow concrete ponds are used for the rearing of fry, there is sometimes a big difference in temperature between daytime and nighttime. This problem may be solved by spreading a screen over the pond during the daytime. When a cage-net is used, the surface of the netting must be brushed every 2 or 3 days so that debris, algae, excrement, dirt, and other particles clogging the mesh are scraped off; this procedure keeps the water running smoothly through the meshes. This maintenance work must be done shortly after stocking the pond and is necessary to help ensure the successful growth of the fish.

REARING OF FINGERLINGS

Size and Definition of Fingerlings or Seedlings: Fingerlings or seedlings are commonly produced according to the size and time-of-delivery demands of culturists. Chinese carp seedlings of various sizes are in demand nearly all year round in Japan. The processes for the production of seedlings in three different sizes - small, medium and large - will be described.

Small seedlings, 2-3 cm long, are requested by fish farms mainly during the summer. Seedlings of this size are suitable for shipping long distances within the country and even for exporting. Small seedlings, which are developed by controlling their growth during the summer, are often delivered in fall or even during the winter.

Medium-size seedlings, 6-12 cm in total length, are suitable for restocking or liberating in natural bodies of water. It is generally felt that seedlings falling into this category are the minimum size for setting free into rivers or lakes.

Large seedlings, 15-20 cm long, are used mainly for pond culture, and are in demand from the fall to the spring.

REARING OF SMALL SEEDLINGS

Facilities: Small seedlings are reared in a pond or cage-net similar to that used for the growing of fry fish. In the interests of efficient management, it is recommended that a moderate-size pond not larger than 100 m^2 in area and 60-80 cm in depth, made preferably of concrete and filled with water 40-60 cm in depth be built. The water to each unit or pond should be supplied by a piping system rather than by a canal system, so that the possibility of fish escaping through intake openings connected to the canal can be avoided. The bottom of the pond should be flat and it should decline slightly toward the outlet opening to promote smooth drainage. Depending on the topography at the pond-site, it is advisable to add a fish-catching basin attached to the pond-outlet, so that fish can be harvested in the basin automatically along with the draining of water. This process will cause no harm to the body of the fish.

The cage-net used in the rearing of small seedlings is built the same as that used for fry rearing. Netting with mesh size larger than 20 (per inch) is applied. The setting and operation of the cages is also the same as in the case of fry rearing (Fig. 19).

Stocking Rate: The number of fish stocked may vary depending on the duration of rearing as well as on the type of feeding, but one standard procedure used for rearing is as follows: 1,500-2,500 fish per m^2 in ponds and 12,000-20,000 fish per m^2 in cage-nets. If the rate of stocking is lower, the water does not have to be renewed except in the case of an emergency.

Food and Feeding: The same food material in the form of a "solvent" that was given to the fish in the fry stage is supplied by spraying, and the feeding lasts until the fish have grown to 1.5 cm. The fish are then given food in the form of dough together with the "solvent" for some time, after which the diet is changed to dough only. The dough is prepared from synthetic fish food (for Common Carp) mixed with wheat bran, and these materials are compounded by boiling them in water; the amount of water is the same or a little larger than the raw materials. The dough is mounted on an earthen or some other dish-shaped container and hung in the pond water.

A number of pans or dishes holding dough food are placed in the pond so that feeding takes place at even distances. Sometimes rice-bran, wheat-bran and synthetic fish food are sprayed on the surface in addition to the dough food, but under the condition that excess feeding does not result. The daily ration of dough food (dry weight) is estimated at 1/20 the weight of the fish. The fish are fed two to four times a day, and are not given their total daily ration in one feeding.

Growth and Survival Rate: Table 5 provides some figures on fish growth and surival rate as observed in both a pond and a cage-net. In general, it takes 20-30 days to grow seedlings 2-3 cm long, and the survival rate over the same time averages 40-80% in the pond and 60-90% in the cage.

Management Required During Rearing: The rearing of seedling fish is conducted in stagnant water, and the renewal of the water, or the addition of fresh water, must be avoided unless there is a danger, such as an excess rise in water temperature or an unfavourable change in water quality. Young fish in the seedling stage have a good appetite in water 25-30°C and grow better in so-called "stable" water, which is coloured moderate-green due to the proper growth of water-bloom. The green algae, Spirogyra and Hydrodiction, which often flourish in concrete ponds, can be controlled by keeping the water temperature stable or by sustaining proper growth of water-bloom. The growth of water-bloom is accelerated by fertilizing the water with urea (5 ppm as nitrogen in pond water).

A dirt-pond carries, or is often invaded by, noxious insects which attack young fish. To control these insects, the following insecticides are recommended: trichrophon, dipterex, or urea at a concentration of 0.5-1.0 ppm, a dosage not harmful to the fish.

The cage-net, when used for the growth of seedlings, can be managed in the same way as that for fry rearing. The mesh size of the netting is changed according to the growth of the fish, and the mesh is cleaned by brushing once or twice a week. Since the stocking rate is high in the net, the fish become easy prey to predator birds such as the kingfisher, night-heron, egret, etc. If these predators abound at the site, the cage is covered by a net.

Toward the completion of the rearing stage, the biomass of seedling fish grows larger and the fish often start gulping in surface water during the night, at dawn or on cloudy days due to a lowering of the oxygen content of the water. When such behaviour is observed, it is necessary to administer a shower over the water surface, to supply new water, or to undertake aeration. If shown in the daytime, the gulping behaviour will not last long. Therefore, the remedial procedures listed above will be taken within a limited time.

Harvesting, Keeping and Selecting: Utmost care must be taken in the handling of small seedlings, 2-3 cm long, so as not to hurt their very delicate bodies. The material recommended for the harvesting, keeping and selecting the fish is a soft, netting-like silk-gauze, so that any damage to the fish is kept to a minimum. In practice, any sort of handling of the fish should be done only in water and the fish should not be left in the air or on the net for an extended period.

The harvesting of the seedlings from a cage-net is easily done (Fig. 22). The bottom of one side of the cage is hauled, thus driving the fish toward the opposite side where they are scooped up with a hand-net. When only a portion of the seedlings is to be harvested, the job can be easily done with a square dip-net with the length of one of its sides the same as the width of the cage.

In contrast, the harvesting of fish from rearing ponds is not an easy job. Harvesting by seine, a common practice, does not collect all the fish in the pond in one operation. In the seining operation, it is usual to experience Grass Carp escaping from the net through the space between the bottom and the sinker-line, while Silver Carp jump over the float-line. When seining is attempted in a dirt-pond, caution must be taken not to stir up too much bottom mud and to prevent the fish from getting muddy. Silver Carp are liable to suffer respiratory difficulty in floating mud and the fish that are harvested must be transferred to clean water in a container as soon as possible; otherwise, return the fish to the pond water and give up the harvest. A safe way to harvest fish is to provide for a collecting pool connected to the outlet opening of the pond; thus the fish carried into the pool with the water are easily scooped up with a net. Before the fish are harvested, they must be starved for a half day to a whole day to strengthen their ability to adjust physiologically, the timing of the harvest being scheduled accordingly.

The seedlings harvested from the pond or cage are transferred quickly to a stocking facility, where they are kept for the required period of time. If the shipping or delivery of the fish is scheduled within a short time, a small pond or cage-net supplied with clean water will suffice for keeping or maintaining the fish. When placed under such environmental conditions, the fish excrete their gut contents and get strength to endure the next step in the transportation process (Fig. 23). However, if the fish are starved for an extended period, especially during the summer, they will possibly be weakened. The period of starvation, then, should not exceed 2 days.

The keeping or maintenance of small seedlings, as explained above, is sometimes done for an extended period of time, 1-3 months or even half a year, before the fish are transported. This procedure, known as suppressed keeping, is practised by stocking the fish under high-density conditions and feeding them just enough food to keep them alive. The usual practice is to stock the fish at the rate of 3,000 to 5,000 for each 3.3 m^2 and to maintain the daily diet at 1/40 - 1/60 of body weight. The water is kept stable without changing the water or adding new water.

The selection of seedlings by size is done by using a screen of different mesh sizes. The screen, made from non-metallic material, placed in the water-flow, and those fish of the desired size are allowed to pass through the mesh.

The selection of Grass Carp seedlings from Silver Carp, which are reared in the same water, is accomplished rather easily, as explained below. The seedlings of the two species are placed in a round container 50 cm in diameter and 90 cm deep and the fish that float up to the surface to gulp are scooped out. Since Silver Carp tend to float up in much larger numbers than Grass Carp, nearly all the Silver Carp in the container can be collected by scooping several times, while the Grass Carp remain in the bottom water. According to information from mainland China, the four species of carp cultivated there (Silver, Grass, Black, and Bighead) are selected correctly by the same procedure.

In closing this section, an important point will be made. When Silver Carp and Grass Carp are reared together in noticeably unequal numbers, the species that is in the minority will show much slower growth than the other one. When there is a greater number of Silver Carp than Grass Carp, there is no problem, but when there are more Grass Carp than Silver Carp, the Grass Carp devour the Silver Carp. If such behaviour is observed in the pond, then there are too many Grass Carp in the water and a number of them must be removed.

REARING OF MEDIUM-SIZED SEEDLINGS

Rearing Pond: For the rearing of medium-sized seedlings, 6-12 cm long, an ordinary rearing pond measuring 500-1,500 m^2 is used. The dimensions of the pond just cited are by no means a rule, but the depth of water in the pond should be about 1.2 m. In practice, the depth of the water has to be 60 cm or more and there must be a distance of 30-50 cm from the surface of the water to the top of the pond wall; because medium-sized seedlings have the habit of jumping out of the water. The intake and outlet gates to the pond must be fitted with screening, especially the former, through which fish frequently escape.

Stocking: The rearing of medium-sized seedlings usually starts from mid-June to early August by stocking a pond with fish 2-3 cm long. However, the procedure described below will, in many ways, save labour while producing medium-sized seedlings. The rearing of fish in the larval stage to the early fingerling stage is started in cage-nets which are placed in a rearing pond provided with ample food. When the fish have grown to the proper size, they are liberated or stocked directly into the pond water.

When the rearing of the seedling fish is scheduled to last until mid-October, the stocking rate should be 150-200 for each m^2 of water. If the two species are reared together, there should be 2-3 Silver Carp for every one Grass Carp stocked. Pond water in which rearing is attempted for the first time should be sterlized and fertilized before it is stocked with fish.

Feeding: To feed medium-sized seedlings, either of two methods may be applied - spreading or casting the food material over the water, or placing dough-shaped food on trays hung in the water. A combination of these two feeding methods is often needed.

The materials used for feeding by spraying include rice-bran, wheat-bran, powder of silkworm pupae, and synthetic fish food. The food is thrown over the water evenly or it is cast about on the water surface at fixed places (feeding stations) in the pond by observing the movement of the fish. The latter method of feeding, compared with the first one, is preferable because Chinese carp can be trained within a short time to swim to the feeding station when they hear certain man-made sounds. This behaviour is not as evident in Chinese carp as it is in Common Carp.

The food prepared in the form of dough is the same as that fed to small seedlings. It is mounted on an earthen-pan or some other kind of dish which is hung in the water. It is advised that as many feeding dishes as possible should be provided and hung in the water a little closer to the water surface than to mid-depth. Generally, when Grass Carp and Silver Carp are cultured together, the Grass Carp pick up the food by keeping their head driven into the dough and occupy the same position for a certain period of time, while Silver Carp swim around the dish and pursue the food substances oozing out of the dough. The materials used to prepare dough food include rice-bran, synthetic fish food, powder of silkworm pupae, etc., they are mixed with boiling water and made into a hard paste. The proportion of these materials is determined in a way that avoids an excess amount of protein elements. Experience shows that synthetic carp food (available on the market) and wheat-bran mixed in equal amounts is satisfactory to maintain the good health of the fish and is also appetizing to them.

Under the same management conditions, including feeding as noted above, it is usually observed that individual Silver Carp grow larger at the same rate while Grass Carp show irregular growth; moreover, the two species in the same pond show considerable differences in size. To adjust this unbalanced rate of growth, it may be necessary to adopt the two types of feeding explained earlier, so that smaller fish, which are too timid to come to the dishes, can take the food supplied by spreading.

It is advised that besides supplying food prepared artificially, an effort be made to grow water-bloom properly, for it will provide nutritional elements to Silver Carp.

The daily ration, though adjusted according to the behaviour of fish in the pond, may be standardized as follows: the amount of food per day should weigh (dry weight) from 1/20 to 1/10 of the total weight of the fish. The food conversion value of these food materials ranges from 1.2 to 1.5 under normal conditions.

<u>Harvesting, Keeping and Selecting</u>: The methods used in the handling of these fish are the same as those used for small seedlings.

The fish reared during spring and summer are harvested after mid-October, when they no longer pursue food and are strong enough to endure handling and shipping over long distances. Also, the climate in this season is suited for the restocking or liberation of fish into natural bodies of water. The seedlings used for restocking at this time of year will generally have a higher survival rate than those stocked during the severe winter months. Further, the seedlings cultured to this stage will, when liberated, show a higher survival rate than fish reared over the winter.

Harvesting is usually done with a drag-net (Fig. 24), and those fish which escape from the net are collected when the pond is drained. After the water is drained, the fish left on the pond bottom are picked up with a dip-net. The fish are still active in pond water over 10°C, and many of them jump over the drag-net. Accordingly, dragging must be done in water that has had its depth adjusted. The net is moved gently so that the fish are not frightened. Extra caution is needed in handling Silver Carp, because slight friction can cause bleeding from their skin and lead eventually to their death.

After being harvested and selected, the fish are kept in the stocking pond where they stay for the winter. The wintering pond, which is rather deep, should be reinforced with plankton by fertilization treatment from mid-October to early November. The nutrition received from the plankton will contribute to the eventual good survival of the fish. For wintering, the stocking rate of fish 9 cm or so in length should be 100-150 in total number, or 700-1,000 g of fish for each square metre of water. This stocking rate will permit artificial feeding in the spring without stock manipulation (Figs. 25 and 26).

Feeding should be started as soon as possible after March. The diet ration should be increased daily.

Rearing of Large Seedlings: The rearing pond, feeding and other management procedures required for the growing of large seedlings are nearly the same as those for medium-sized fish. The stocking rate for large seedlings (15-20 cm long) is 20-30 fish for each square metre of water. The food is supplied substantially whole through the rearing period and feeding is done by spraying or over-casting rather than by giving it in the form of dough mounted on dishes. During the 3 months from August to October the fish will grow from 0.5 g to between 50 and 100 g in weight by substantial feeding, especially during the long summer days when the fish are repeatedly given food. The procedures used for harvesting, wintering and other stages in the rearing of large seedlings do not differ from those practised for smaller fish.

In closing this section, an economically significant method of mixed culture will be introduced for growing Common Carp and Chinese carp seedlings. The specific differences in feeding habits between the fish will make full use of the remains of supplied food, their own excreta, as well as micro-organisms grown in pond water. With this polyculture system, the number of Grass Carp to be stocked may not be in excess, because characteristically the species competes with Common Carp for food at feeding stations. On the other hand, Silver Carp, if stocked in large numbers, will not bother Common Carp.

It is possible to grow the fish to 30-50 g in weight by the time they are harvested in November by stocking them at the rate of 1-2 fish per square metre in August.

FIGURES AND TABLES

Fig. 1. Operation of square-net used for the collection of drifting eggs in the river.

Fig. 2. Picking up the eggs trapped in the square-net.

Fig. 3. Another type of egg-collection net, which is also operated in shore water just off the river bank.

Fig. 4. Stripping of eggs from Grass Carp.

Fig. 5. Fertilization or insemination (dry method) of Grass Carp eggs.

Fig. 6. Dissecting hypophysis from the brain of a Silver Carp.

Fig. 7. Dissected hypophyses are ground in glass mortar.

Fig. 8. Injection of hormone showing the position of syringe thrusting at pectoral fin axis.

Fig. 9. Stripping eggs from a Silver Carp.

Fig. 10. Courtship behaviour demonstrated in a concrete spawning pond by a couple of Silver Carp.

Fig. 11. Collection of eggs flowing down into the outlet ditch connected to the spawning pond.

Fig. 12. Eggs scooped up from the outlet ditch.

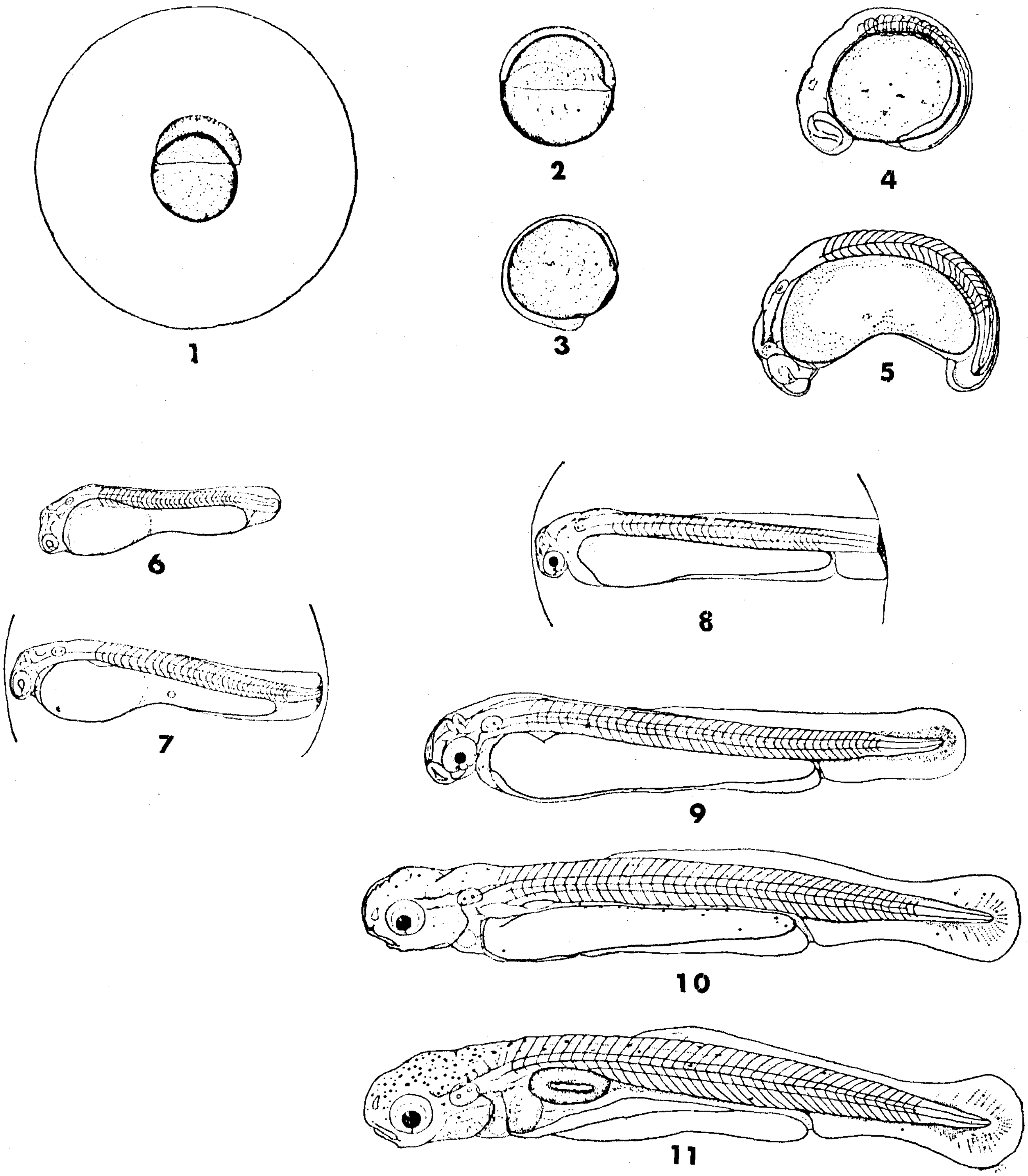

Fig. 13. Embryonic development of Grass Carp.

Stage 1, 6 h 20 min after fertilization; stage 2, 10 h 30 min; stage 3, 18 h 30 min; stage 4, 23 h 5 min; stage 5, 28 h; stage 6, 32 h 50 min; stage 7, 39 h 20 min; stage 8, 51 h 45 min; stage 9, 1 day; stage 10, 2 days; stage 11, 4 days.

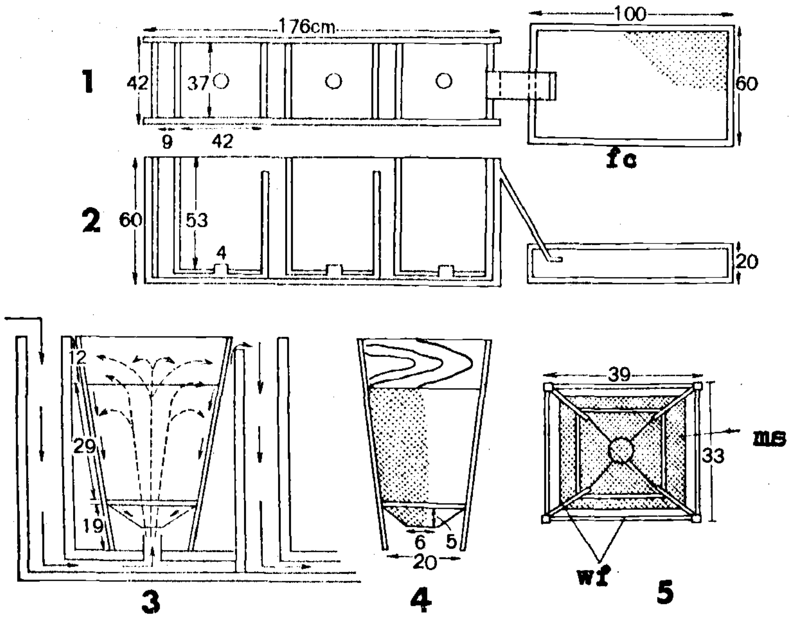

Fig. 14. Hatching apparatus for Chinese Carp eggs designed at Saitama Prefecture Fisheries Experiment Station.

(1) Top view of the box with 3 compartments and fry-receiving container connected to the box. (2) Cross-section view of the same. (3) Details of the construction of one unit of hatching screen-cage inserted in the compartment of box, arrow indicates the direction of water flow. (4) Lateral view of a hatching screen-cage. (5) Top view of the same. Numerals in the figures indicate dimensions in centimetres; wf, wooden-made frame; ms, mosquito screen; and fc, fry-receiving container or box.

Fig. 15. Top view of a hatching box with 3 compartments, each holding a screen-cage.

Fig. 16. Man holding a hatching screen-cage taken out from the box.

Fig. 17. Battery of hatching boxes in operation. Note one fry-receiving container connected to one pair of hatching boxes.

Fig. 18. Series of small concrete ponds which can be adopted for the rearing of larval fish.

Fig. 19. Battery of net cages aligned in a rearing pond for the rearing of larval fish.

Fig. 20. Net cages set along the concrete bank wall and the piping system for water supply.

Fig. 21. Close view of a net cage into which jet water is supplied for aeration.

Fig. 22. Harvest operation of the seedling fish from the cage.

Fig. 23. The net cage in which harvested fry or seedlings are temporarily kept or maintained until the following step.

Fig. 24. Harvesting of small- or medium-sized seedlings in a pond by drag-net.

Fig. 25. Large Grass Carp seedlings, 15-20 cm long.

Fig. 26. Large Silver Carp seedlings, 15-20 cm long.

Table 1: Sexual maturity of Grass Carp and Silver Carp collected in the Tone River on the day of spawning (Saitama Prefecture Fisheries Experiment Station, 1957).

Maturation	Grass Carp			Silver Carp		
	Female	Male	Total	Female	Male	Total
Immature	6	-	6	10	-	10
Mature	3	11	14	6	7	13
Total	9	11	20	16	7	23

Note: Immature - the eggs and sperm are not discharged by pressing abdomen of the fish;
Mature - the eggs and sperm are easily discharged by pressing the abdomen.

Table 2: Size of the body, weight of the ovary, and the number of eggs carried by mature female Grass Carp and Silver Carp (Saitama Prefecture Fisheries Experiment Station, 1956-1965).

Total body length (cm)	Body weight (kg)	Ovary weight (kg)	$\frac{\text{Ovary weight}}{\text{Body weight}} \times 100$	No. of eggs (1000)	Remarks
Grass Carp:					
107.0	16.1	3.90	24.2	2245	Collected in the Tone River
96.5	12.6	3.05	23.4	1756	Collected in the Tone River
77.5	7.0	1.98	28.3	1140	Collected in the Tone River
Silver Carp:					
94.0	12.0	2.79	23.3	1392	Collected in the Tone River
88.0	10.6	2.64	25.2	1332	Collected in the Tone River
82.0	7.0	1.20	17.1	498	Reared in pond

Table 3: Embryonic development of Grass Carp observed in the water at 17.5-22.0°C (Saitama Prefecture Fisheries Experiment Station, 1957).

Date	Time (h)	Time elapsed after fertilization (h and min)	Development stages
June 29	1800	1.00	Fertilization
	1905	1.05	First cleavage : two-cell stage
	1920	1.20	Second cleavage: four-cell stage
	1935	1.35	Third cleavage : eight-cell stage
	1950	1.50	Fourth cleavage: sixteen-cell stage
	2320	5.20	Morula stage
June 30	0020	6.20	Morula stage
	0430	10.30	Blastula-early gastrula stage
	0740	13.40	Gastrula stage
	1230	18.30	D-shaped stage: embryo formed: optic vesicle appearing
	1430	20.30	D-shaped stage: seven-somite: ear vesicle appearing
	1705	23.05	D-shaped stage: eighteen-somite
	1915	25.15	D-shaped stage: twenty-somite
	2200	28.00	D-shaped stage: twenty-four - somite
July 1	0020	30.20	Twenty-eight - somite
	0250	32.50	Twenty-eight - somite
	0700	37.00	Thirty-thirty-two - somite: finfold formed: brain ventricle differentiated
	0920	39.20	Thirty-two - somite: digestive duct differentiated
	1400	44.00	Thirty-two-thirty-four - somite: heart rudiment differentiated
	1920	49.20	Thirty-two-thirty-four - somite: heart beating
	2145	51.45	Thirty-five - somite: dark pigments below orbital edge

Table 4: Temperature of water and the time required for the hatching of Silver Carp (from "Textbook of fresh water fish culture in China," 1961).

Average temperature of water (°C)	20	22	23	24	25	26	26.5	27	29.5	30	30.5
Time taken to hatch (h)	50	38	33	31	21	21	21	19.5	17	16	15.5

Table 5: Growth of Grass Carp fry reared in two types of rearing systems (cage net and nursery pond); stocking density per square metre is given in parenthesis (Saitama Prefecture Fisheries Experiment Station, 1961).

Days after hatching	Cage-net (No. 1) 12500		Cage-net (No. 2) 17500		Nursery pond 1620	
	Total body length (mm)	Body weight (mg)	Total body length (mm)	Body weight (mg)	Total body length (mm)	Body weight (mg)
1	8.21	2	8.19	2	8.12	2
2	8.97	3	8.83	3	8.41	3
3	10.11	6	9.13	4	9.32	4
4	11.46	12	10.25	7	9.93	7
5	13.23	19	11.95	13	10.69	8
6	15.23	25	14.18	24	-	-
7	17.36	37	15.32	36	11.70	12
9	19.01	46	18.13	59	13.31	20
12	22.87	124	-	-	15.96	38
14	26.95	220	-	-	-	-
16	-	-	-	-	18.50	43
20	-	-	-	-	21.74	118