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COMMON CARP CULTURE

FROM AN OLD TRADITION INTO A MODERN INDUSTRY

Today, the fish that is the object of the largest aquaculture production in the world is the common carp, *Cyprinus carpio*.

The countries with major carp productions include Bulgaria, China, Czechoslovakia, Germany, Hungary, Indonesia, Iran, Japan, Mexico, Poland, Romania, Thailand, the U.S.A., the U.S.S.R., and Yugoslavia (See **FIG. 1** on page 2).

However, reliable estimates for world carp culture production by country (separate from the capture production) are not available at present, even in FAO fishery statistics.

In China we find evidence that carp aquaculture was conducted earlier than in the rest of the world. We also find that the world's first document recording techniques for fish culture appeared in China in the 5th century BC. History also reveals evidence of a man-made pond being used for the raising of *Tilapia nilotica*, from a transcription of writings on an ancient Egyptian stone relief dating back to 2000 BC. With the exception of this, China's tradition of carp aquaculture seems to be the world's oldest.

In the vast interior regions of China, freshwater fish have long been an extremely important source of animal protein in the diet of its people, and for this reason great efforts have gone into the culture of freshwater fishes since olden times. Of the fish which have been the object of these efforts, the carp is certainly predominent. Entering the Tang age, however, the first emperor prohibited carp aquaculture for the reason that the word "carp" (ri) had the same phonetic sound as his family name. Therefore, the people had to develop mixed aquaculture techniques using the same pond for various fish of the carp family other than common carp; such as grass carp, *Ctenopharyngodon idella*, silver carp, *Hypophthalmichthys molitrix*, striped bighead, *Aristichthys nobilis*, black Chinese roach, *Mylopharyngodon piceus*, etc. These Chinese mixed carp aquaculture techniques have been transmitted from generation to generation. According to FAO information finfish aquaculture production amounted to 3,409,000 tons in China, being comprised mostly of freshwater carps. And in recent years net cage type common carp aquaculture has also been begun even in China to enhance productivity.

Valued as a delicacy, carp has always carried a special significance in China, being, for instance, a gift presented by a lord to his subjects, or a food to be given on special occasions. The traditional significance of carp has also found its way into neighboring Japan's culture, as well. The Japanese have considered carp a symbol of success in association with the ancient Chinese belief that a carp which climbs a waterfall is transformed into a benevolent dragon.

Since the 13th century (Kamakura period) carp also became important as a food in Japan. The fact that the new Samurai warrior class at that time appreciated carp for its high nutritional value, proved to be the start of the Japanese use of carp as an important food. Later, as the times changed and production and trade grew, local industries developed around the natural carp caught in certain areas of the country. The Japanese had always fished for the natural wild carp that thrived in their rivers and lakes, but written records tell us that the first known attempt to raise naturally occurring carp began in the Saku district of the present Nagano Prefecture, in the mountainous central region of Japan, around the end of 16th century. Still later, in the 17th and 18th centuries we see scattered records from the same district of attempts to take wild carp out of their natural environment and achieve spawning and hatching in artificial conditions. By taking wild carp and raising them to sexual maturity in ponds and then conducting spawning and incubation in artificial conditions, a process of cumulative artificial selection for fast-growing, well-meated fish could be carried out over a period of many years.

In Japan, carp aquaculture developed in close association with paddy field rice culture. One culture method involved releasing the fry directly into the water used to flood the rice paddies, while a second involved releasing them in the ponds built for holding paddy irrigation water. Since the early days of civilization in the monsoon regions of Asia, people have practiced an integrated crop - livestock - fish type farming system, and Japan's carp culture tradition can be seen as one manifestation of this type of system.

Carp is a very easy fish to feed. As soon as the automatic feeder set on a regular schedule begins to dispense feed, the carp begin to gather in response to the sound, even from the farthest corners of the pond. In this pond which covers 18 hectares and supports a population of 150,000 carp swimming at large, just one feeding site is enough to provide sufficient feed for all the fish. The top picture shows the carp swarming for feed at feeding time. The large pipe in the foreground of the bottom picture is the dispensing mouth of the feeder.

The spread of such integrated farming involving carp raising and wet-field rice growing, however, was a rather late development in Japan, not becoming a true supplementary production in the villages until the late 18th and early 19th centuries. Furthermore, carp production did not really reach the status of a localized industry until into the 20th century. The reason for this is that the essential elements necessary to sustain a carp culture industry — obtaining and controlling a sufficient volume of water, development of feeds and obtaining the necessary raw materials for them, and the development of demand and marketing activities — all had to be realized first.

The Carp Raising Areas of the World

The common carp belongs to the carp family (*Cyprinidae*). Carp is a warm water type freshwater fish, and constitutes a large group in which between 2,000 and 3,000 species can be found in the various parts of the world. Originally, the habitat of carp extended to virtually all parts of the world, with the exceptions of South America, Australia and Madagascar. The carp found in the abovementioned regions today trace their origins back to fish that were transplanted there from other areas in modern times.

The common carp is one of the larger species of the genus *Cyprius*. They grow to a length of 10～20cm in the first year after hatching and reach maturity at a length of 25～40cm within two to three years. They are characterized by the length of their life span among freshwater fish, and it is not unusual for them grow to a length of 50～70cm either when naturally grow or arificially reared as ornamental fish.

Natural strains of carp inhabit lakes and ponds or the lower stretches of rivers with weak currents. In addition to eating benthic animals and insects inhabiting the lake or river, carp also feed on sea grasses growing above the bottom mud. They can also use their molar type pharyngeal teeth to crack open the shells of shellfish to eat the meat. Generally they can be considered to be primarily omnivorous.

Although carp is a very wide eurythermal fish ranging from 35°C to 0°C, they show the most active feeding habits and grow most rapidly at temperatures between 20° and 30°C.

While the common carp is believed to be originally native to Central Asia, their adaptability to a wide range of water temperatures and food sources in connection with their mild nature and high tolerance to changes in environment has made it possible for them to be transplanted from their place of origin, continental Siberia and Europe, to regions further south, even to the tropics currently.

At present, the world's carp production can be divided largely into two regional groups: (1) the Far East, including Japan, China and Southeast Asia and (2) the Caspian Sea, Black Sea and Eastern Europe. Although the species of carp found in both of these regions are classified zoologically as *Cyprinus carpio*, they are considered to be two different sub-species. The "Yamato-goi" and "Ma-goi" of Japan included in the Far East group are distinguished by their near-cylindrical, spindle-shaped body with low body height and the fact that the entire body is covered with scales. On the other hand, the group that was improved in breeding and is generally referred to as the "doitsu-goi" (German carp) of Eastern Europe, is divided into the four sub-species known as "Schuppen", "Spiegel", "Zeil" and "Nocktkarpfen". All four of these have high body height with a vertically flat shape. And among them, the Spiegel carp is characterized by one or two rows of large scales running along certain portions of the body, while the Nocktkarpfen has no scales whatsoever. The German carp group tends to show faster growth than the common carp of Japan and has smaller visura in the body resulting in greater meat content. It is also more cold-resistive and is a bit more planktivorous in nature compared to Japanese carp. Recognizing this difference, an attempt was made as early as 1905 to bring Spiegel and Nocktkarpfen to Japan from Germany to cross-breed with Yamato-goi. However, cross-bred products did not gain acceptance in Japanese markets, as the scaleless carps appeared so strange to the Japanese customers as food. Farmers thus returned to raising the conventional native species. The presence of German carp strains remains today only in certain types of domestically bred ornamental carp.

Shipment of cultured carp, harvesting and sorting by body-size category.

FIG. 1: Major common carp producing areas of the world

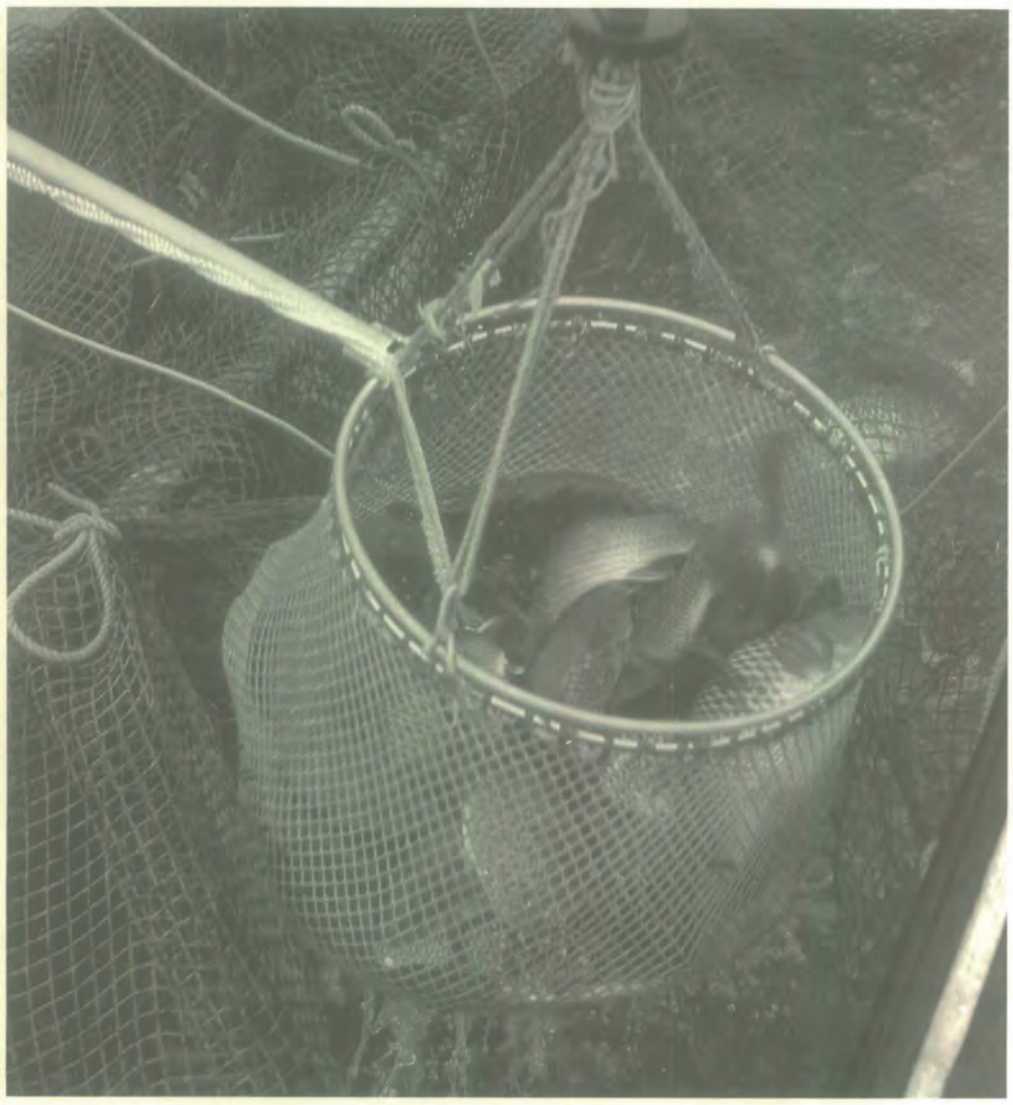
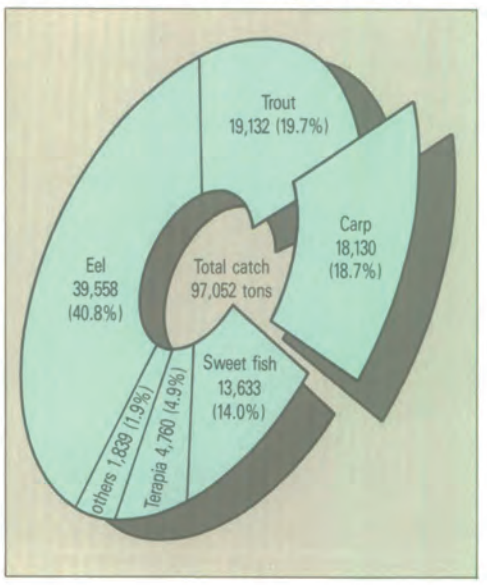


FIG. 2: Aquaculture production of freshwater fishes in Japan (1988)



►*A larger product with about 2 kg body weight.*

Rice Paddy Carp Culture:

The origins of Japanese carp culture

Rice paddy carp culture once prospered here in the Saku district of Nagano Prefecture with its abundant supply of water and extensive system of irrigation canals. In the past, scenes like this of carp being taken out of the center of a rice paddy were commonplace.
(Photo courtesy of the Saku Freshwater Fish Research Association)

Japan's aquaculture of carp as a food source originated in the practice of rice paddy carp culture. In Japan, this rice paddy culture tradition began in the Saku district of Nagano Prefecture. Geographically the Saku district is a basin surrounded by mountains in the central mountainous region of Japan.

The culture of carp for human consumption began in this district in the early 19th century, when farmers began building small ponds in which several dozen carp could be raised. The carp were raised with very little feeding initially, so the production was very small. Around the year 1850, one of the farmers succeeded for the first time in gathering eggs and hatching them. This, in turn, led to attempts to raise carp in rice paddies, a practice that soon spread to the neighboring villages in the district.

The basic aquaculture technology for carp that developed here, including the hatching and rearing of larva, water management, development of feeds and an accounting system for costs and benefits, was learnt by farmers *a posteriori* over a period of one hundred years, before carp aquaculture actually developed as an industry.

The Saku district is a basin at an elevation of about 700 meters that is surrounded by mountains with a river called the Chikuma flowing through its center. Having an extensive system of tributaries, the Chikuma is a river with an abundant water supply. The gentle inclines of the land in the basin enabled the development of a system of irrigation canals that, in turn, led to the development of the district's extensive wetfield (paddy) rice agriculture. The rice paddy carp culture method that evolved here is conducted in the following way:

(1) A pond is built in the farmyard in which parent carp from 5 to 15 years of age are kept for egg-producing purposes.

(2) As the spawning period approaches, parent fish are moved into small spawning ponds at a ratio of one female for every two or three males, and river seaweeds are spread on the water surface. The carp lay their eggs on these seaweeds.

(3) A section of a flooded rice paddy is set aside as a hatching area. Manure or chicken droppings are spread in this section of the paddy, and after the water fleas (*Dophinia* spp.) which will serve as food for the larvae begin to grow, the seaweeds with eggs attached are laid out on the surface of the water and hatching occurs.

(4) When the hatched larvae grow into fry with a body length of 1.3 ~ 3cm, they are removed from the hatching area and released in the rice paddies. While maintaining a suitable water volume in the paddy, water from the irrigation canal is introduced regularly to achieve circulation and thus maintain water quality. The depth in the paddy is kept between 15 ~ 20cm. In the center of the paddy a 3 ~ 4m^2 fish gathering area with a depth of 60 ~ 90cm is made. This gives the fish a retreat when the water temperature rises in the summer months, as well as providing a place to catch the fish easily.

(5) In the early years of rice paddy culture the fish were not fed, but gradually it evolved into a feeding-type culture as the farmers began making their own composite feeds from chrysalises, rice bran, soybean cakes and the like:

(6) To accelerate the cropping of rice in the fall, the water is drained from the paddies. At this time the carp, which have now reached a weight of about 50g are caught. This is done by lowering the water level gradually and scooping up the carp that gather in the central gathering area.

(7) The carp that have been caught are then sold, although a portion of the catch will be kept over the winter in ponds with running water from the irrigation system to be released in the paddies again the next spring and raised until they grow to 2 year-old fish.

The effect of the carp culture on the growth of the rice crop is, of course, of major importance, and through long years of experience the farmers have learned that it actually has a number of positive effects. For example, as the carp swim along the waterways of a paddy between the rice, they circulate the water vertically and thus convey more heat into the ground. This helps promote decomposition of fertilizers. Also, the feed that is given to the carp comes out in the form of excretions that in themselves constitute an excellent form of fertilizer. These factors both serve to stimulate the proper spread and growth of the rice plants. Furthermore, as the carp feed on organisms and small plants on the bottom of the paddy, they help hinder the growth of unwanted plants and, in that way, reduce the labor normally devoted to weeding the rice paddies. However, if too much importance is placed on the carp culture and too much feed is provided for them, it can result in an excess of nitric ingredients in the water. Likewise, if the water level in the paddy is maintained high for the sake of the carp past the time when it would normally be dropped, it can lead to over-growing and falling of the stems and leaves of the rice. Therefore, it is necessary to manage the two activities in a balanced way that brings optimum results for both.

There are several factors that contributed to the development of rice paddy carp culture in the Saku district:

(1) Saku is a cold area where it is impossible to raise both rice and barley in the same year, as in other parts of Japan. Because carp can be raised along with the rice crop from summer into fall, its culture offers the farmers of the region a means to make more efficient use of their land.

(2) The irrigation system developed from the district's abundant water supply has facilitated the development of aquaculture.

(3) Although the water temperature of the Chikuma River itself is below the optimum temperature for carp culture — not rising above the 16 ~ 17°C range even in the summer — by the time its waters enter the irrigation system and finally the paddies, the temperature rises several degrees, making for a favourable culture environment.

(4) The Saku district happens to be one of Japan's silk producing areas, and it was found that the pupae extracted from the silk cocoons in the silk making process make an ideal protein source for carp. This fact led to their use as a primary feed in carp culture. There are several other areas in Japan besides Saku where carp culture prospered, and in almost every case their location overlaps with silk industry areas capable of supplying large amounts of silk pupae.

(5) Historically, the Tokugawa shogunate (government) of Edo Period in Japan (17th ~ 19th centuries), which based its economy on agriculture and levied its taxes in rice, placed top priority on rice production, forbidding the farmers to change their crop at will. There were no restrictions, however, regarding fish culture as a supplementary crop, nor was the fish production subject to taxation. This made cultured carp for human consumption a viable cash crop, a fact that encouraged the farmer's motivation to produce.

The collapse of the Tokugawa shogunate regime ended Japan's fuedal period, and the Meiji government which replaced it in 1868, launched the country on a program of widescale modernization. Under the new government's policies of industrialization, a wide variety of industries began to prosper, and the carp culture industry was no exception to the trend. One reason was the rapid growth of the silk industry in Nagano and the neighboring prefecture, Gumma, which provided the carp industry with an increasingly large supply of silk pupae.

In all the prefectures that witnessed a growth in the silk industry, including Nagano, Gumma, Yamagata, Fukushima and Gifu, a corresponding carp culture industry also prospered. The fact that these were land-locked prefectures where a good supply of marine fish was not available, helped contribute to people's acceptance of carp as an amimal protein source in their diet.

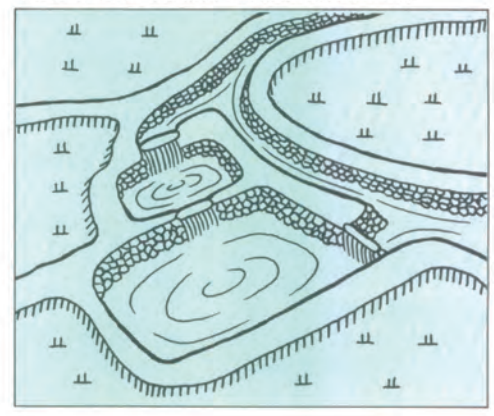
FIG. 5 shows the historical changes in carp aquaculture production in Nagano Prefecture. With the improvement of aquaculture technology, records from the year 1900 show production of 225kg of 2 year-old carp being produced along with a 16.4 bushel harvest of unpolished rice per 10-are of rice field. At that time, 100kg of first-year carp per 10 are of rice paddy was a standard productivity.

In time, carp producers began to organize themselves into cooperatives and extend their sales activities to other prefectures. During the period from 1925 to 1939, carp aquaculture in Nagano Prefecture, centered in the Saku district, grew to an annual production in the range of 2,000 tons.

After the disruptive food crisis years of the Second World War, carp culture began in earnest once again. However, with the modernization of rice farming techniques in the 60's, rice paddy carp culture went into decline. This was due to the onset of mechanization of the rice growing process, as well as the introduction of chemical fertilizers, herbicides and insecticides. Also, improvement of rice strains led to the adoption of types that required less water. All of these factors served to decrease the paddy environment suitable for carp culture. The resulting rapid decrease in rice paddy carp culture was accompanied, however, by an emergence of carp culture in reservoir ponds. With this came a separation of rice agriculture and fish culture into completely separate industrial sectors.

FIG. 4: Flow-through pond

Carp taken out of the rice paddies were placed in this type of pond and fed until November to prepare them for winter.
(Illustration: Saku Freshwater Fish Research Association)



Modern rice paddies where rice production is highly mechanized.

FIG. 3: The river and irrigation canal system of the Saku basin

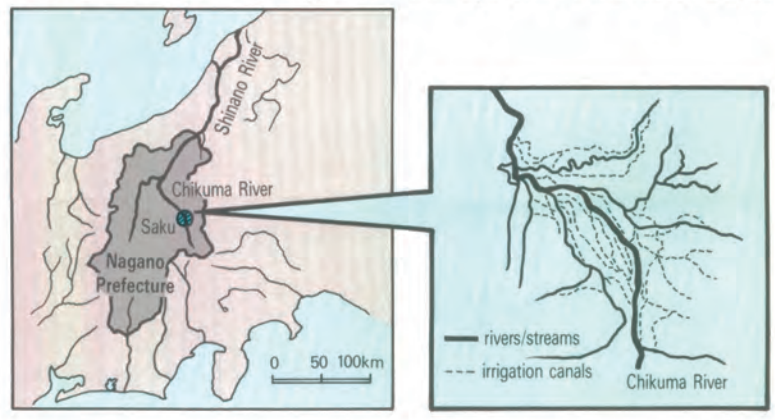
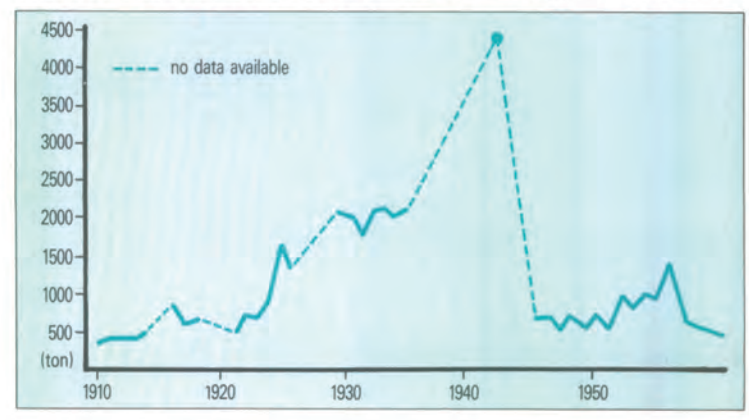


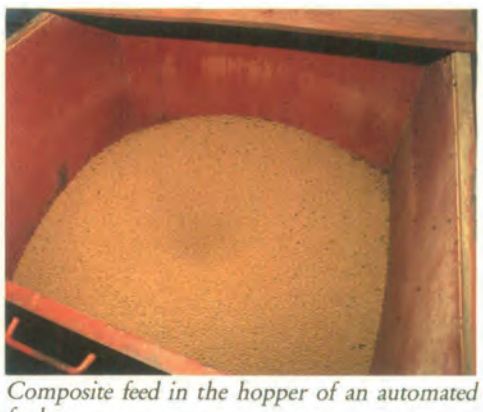
FIG. 5 Annual production of carp for food in Nagano Prefecture



Water, Feed, Labor;
the three elements that determine productivity

The three elements that determine productivity in carp aquaculture are water, feed and labor. (see **TABLE (1)**) These three elements combine in different ways to create the various forms of aquaculture, ranging from open-pond culture, which relies primarily on the natural productive capacity of the pond, to high-intensity types of culture that rely on artificial means to increase productivity. In Japan, carp aquaculture is divided into three major types; reservoir pond culture, flow-through pond culture and net cage culture.

An automated feeder dispenses composite feed.



Composite feed in the hopper of an automated feeder.

A fixed-type net cage

Modernization involving composite feeds and net cages

It can be said that the advent of modern carp aquaculture came about as the result of two factors; the development of composite feeds and the appearance of net cage culture methods.

Composite feeds: Since olden times, carp culture was conducted with home-made feeds. Crushed barley, rice bran, soybean cakes and vegetables were stewed in a cauldron to which pupae of silk worms were added to make a feed for the carp. There is even a saying that one's skill at making feed determined one's skill as a carp culturer. One's choice of materials, the way the feed was made and the way the fish are fed determine not only how the fish will grow but also their susceptibility to disease. Therefore, it was said that three or four years of experience were necessary to become proficient in the art of feeding carp. Furthermore, because new feed had to be cooked every day in a cauldron near the culture pond, the feeding operation placed a large labor demand on the family engaged in carp culture.

In or around the year 1959, research was begun on nutrition for rainbow trout, and between the years 1962～64 pellet type, artificial composite feeds were developed. After this, similar research was conducted on the other important freshwater fishes like carp, eel and sweet fish, and in short time solid-form, dry composite feeds were developed for each. Around the year 1963, the feed manufacturers began to undertake production of the different types of composite feeds for fish culture. From this time began the full-scale switch over from home-made feed to commercial feeds. This adoption of composite feeds meant a major reduction in labor required for the feeding process, and thus led to an increase in the number of operators engaging in carp culture. Eventually, the increase in production that resulted from these changes was also to be one of the factors that led to the appearance of the net cage culture method.

Net cage culture: Around the year 1956, research was begun on the concept of raising fish in net cages hung in the water at the Miyazaki Prefectural Fisheries Experimental Station. This method offered numerous advantages, such as lower facility costs than those involved in building an embankment-type reservoir, ease of supervision, high productivity in terms of surface area, etc. For these reasons the method soon spread throughout the freshwater areas of Japan, eventually being adopted in saltwater aquaculture for such fish as yellowtail and red sea bream as well.

In the case of carp, the Ibaraki Prefectural Freshwater Fisheries Experimental Station completed experiments in the practical use of net cages in carp aquaculture in 1964, paving the way for its adoption on the industrial level. Full-scale operation of carp culture on Lake Kasumigaura in Ibaraki began in 1968, after which it showed exceptional growth. Within eight years the carp industry here had surpassed the other leading areas, making it the largest producing area in Japan. **(FIG. 6)**

The status of production and the culture method

According to statistics of the Ministry of Agriculture, Forestry and Fisheries for 1988, a total of 6,913 tons of natural carp were caught in Japanese freshwater areas, 5,345 tons from rivers and 1,568 tons from ponds and lakes. On the other hand, the national production of cultured carp totaled 18,130 tons. While some carp culture is conducted in almost all parts of the country, the major producing areas include Ibaraki Pref. with 5,993 tons, Gumma Pref. with 2,611 tons, Fukushima Pref. with 1,808 tons, Nagano Pref. with 1,578 tons and Fukuoka Pref. with 1,421 tons. These five prefectures accounted for 75% of the nationwide production in 1988.

In carp culture there are three types of culture facilities; **(1)** reservoir pond type, **(2)** in-pond type and **(3)** net cage type.

1) Reservoir pond type: A reservoir pond is a large man-made pond usually of more than 10 hectare, built for the purpose of agricultural irrigation. In this method carp are released in the pond and left to live unrestricted.

2) In-pond type: This type of culture is conducted in ponds built specifically for aquaculture, of which there are two types; the flow-through type and still-water type. The representative culture technique in in-pond type culture is the flow-through pond culture technique. Still-water pond type in-pond culture is conducted in rice paddies converted especially for aquaculture with a one-meter depth of water and covering an area of from 3～30 are. The walls of the pond can be raw dirt embankments or simple panel walls. The culture technique is similar to that of reservoir pond culture.

3) Net cage type: In this method net cage facilities are set up in an area near the shore of a large lake or marsh. There are two types of facilities, float-suspended facilities and fixed facilities.

Selective use of culture facilities as the carp grow

The growth stages of cultured carp are classified in the following way:

● **Spawning and hatching ...** Spawning begins for carp at the time of year when the water temperature climbs to a daytime high of 18°C and a nighttime low of 14°C. In Japan there is some difference between the spawning season in the various regions. In the warmer regions it will begin from mid to late April, while in the colder regions it will begin in mid May or early June. Eggs which have been fertilized will begin hatching in water with a temperature range from 15～20°C within 5 to 9 days after being laid.

● **Larvae ...** Within a week of hatching, a thin hair-like larva with a length of 6～7mm will develop. This is called the "Kego", meaning a hair-larva. Within a month of hatching the larvae will reach a weight of 1 gram and a body length of 25～30mm. At this

TABLE 1: Elements that determine productivity in carp culture

WATER	Water temperature:	The longer the culture water stays within the carp's ideal temperature range of 20～30°C, the better the feeding efficiency and the faster the growth of the carp. Carp culture is therefore limited to the temperate and sub-tropical zones.
	Water volume:	The water should have a good supply of oxygen. Normally, water contains 5～8cc of oxygen per liter. When this concentration falls to about 2cc per liter the carp have difficulty in breathing. Depending on the amount of water available, operators choose between the three types of culture – reservoir pond, flow-through pond and net cage – and this choice in turn determines the concentration of the culture population they will be able to raise.
	Water quality:	**(1)** It must be made certain that industrial wastes do not enter the culture pond. **(2)** Care must be taken to avoid a eutrophication problem if the soil contains too much organic material. **(3)** Too frequent use of high protein feed must be avoided. **(4)** In China, the silver carp, *Hypophthalmichthys molitrix* is cultured together with common carp to maintain water quality in the pond, taking advantage of it's phytoplanktivorous nature.
FEED	In Japan artificial composite feeds are used. Generally speaking, however, fish culture is an industry in which a cheap and reliable source of feed is an essential. In China, fish culture, pig husbandry and vegetable growing are conducted on an inter-dependent basis, and pig wastes are used to enrich the culture pond's nutrient content in a way that reduces feeding costs.	
LABOR	As the scale of a culture operation increases, so does the amount of labor required for the feeding operation. In Japan automatic feeding machines are used to save labor.	

TABLE 2: Composition of composite feed for carp

(percent by weight)

Ingredients	For fry to immature	For adults
Protein (crude)	42～46, and over	30～40, and over
Fat (crude)	3, and over	1.5～10, and over
Fiber (crude)	2.5～5, at most	3～6, at most
Ash (crude)	15～19, at most	13～15, at most
Calcium	1.6～3.3, and over	0.8～1.6, and over
Phosphorus	1.2～2.2, and over	0.9～1.5, and over

TABLE 3: Pellet size of composite feeds for carp

Feeding Purposes (growth stage)		Form and/or gradation	Size (diameter in mm)
Feed taming	(post-larva)	Powder	less than 0.5
	(fry)	Crumble C1	0.5
Feeding	(fry-fingerling)	Crumble C2	1.2
	(yearling-older)	Crumble C3	2.0
	(immature)	Crumble C4	2.7
Feeding	(adult)	Crumble C5	2.4
	(same)	Crumble C6	3.2
	(same)	Crumble C7	4.5
	(same)	Crumble C8	6.4

FIG. 6: Carp aquaculture production in Japan

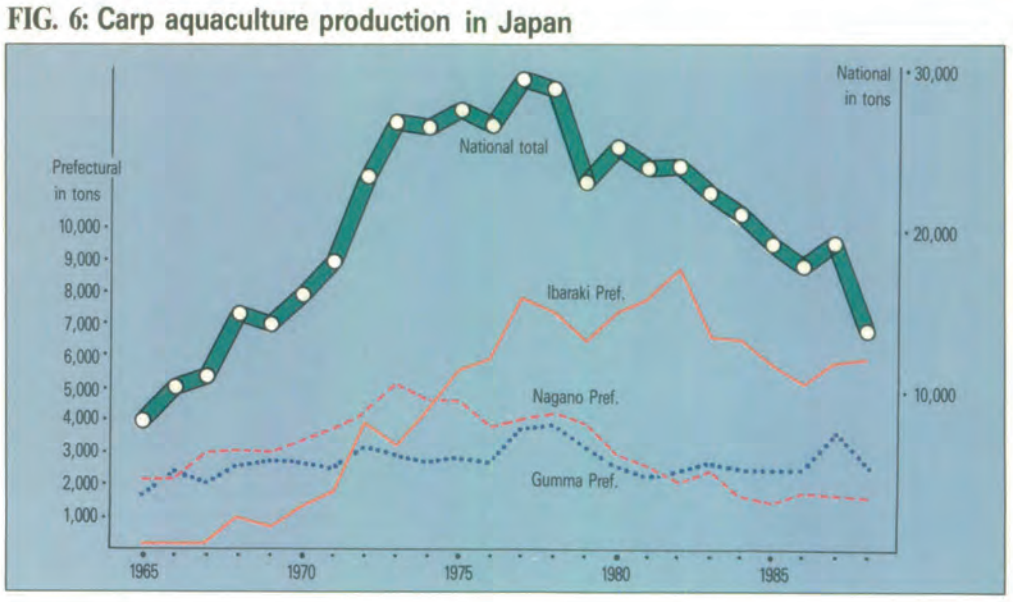
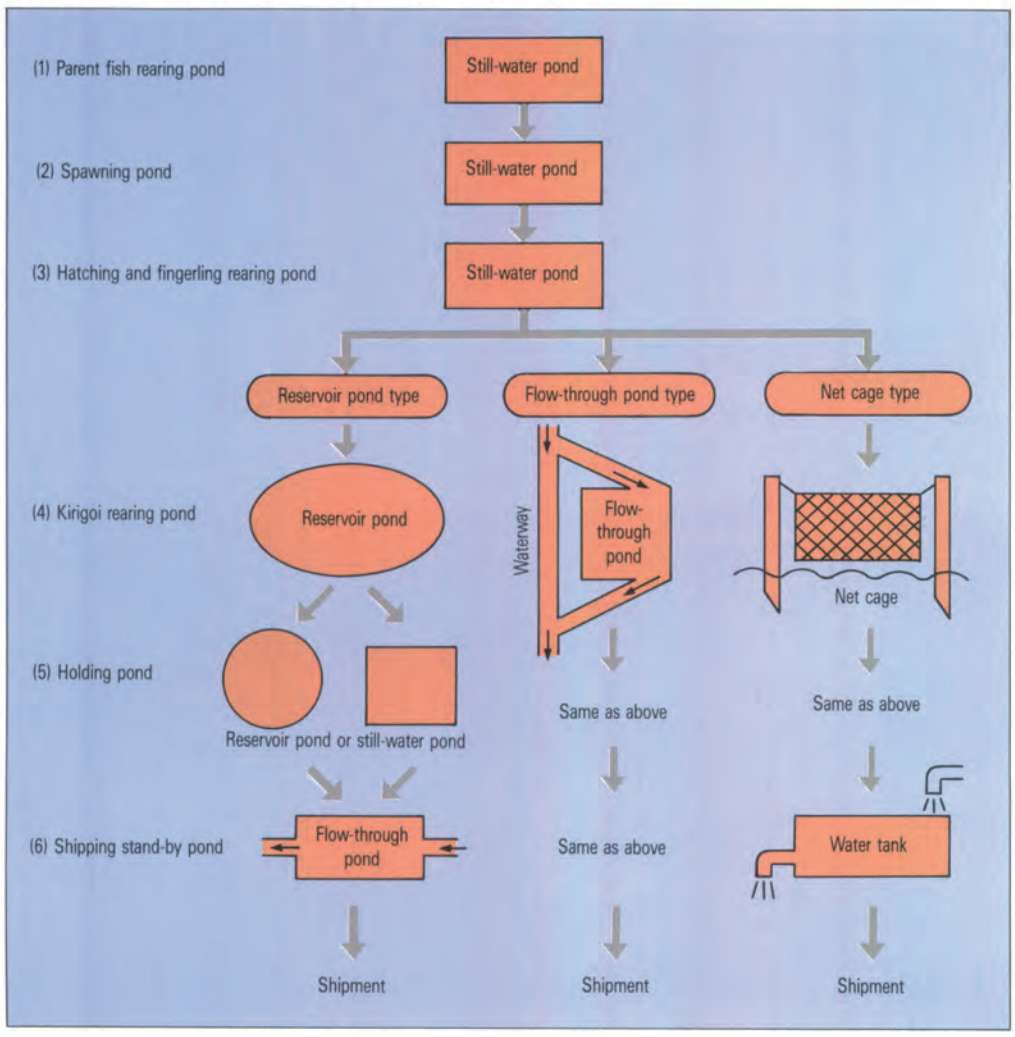


FIG. 7: The structure of carp culture facilities



stage it is called an "Aoko", meaning a green-larva. After reaching the "Aoko" stage the larvae can be sold as culture seeds.

● **First year fish ...** By October ~ November in the fall of the year they were born, the young reach a weight of 70 ~ 100g and a body length of around 10cm. In this stage the young are referred to as a "Shinko", meaning a new-young. At the Shinko stage they are transferred to a large culture pond and the rearing operation begins in full-scale.

● **Second year fish ...** When the fish are reared for one and a half to two years after birth, they reach a body weight of 1 ~ 1.5kg. When a carp reaches this size or larger it is referred to as a "Kirigoi", meaning a cutting-carp. The term "Kirigoi" means that the fish is of a size large enough to be cut and prepared for cooking — in other words it means the fish has reached market size. At the largest, "Kirigoi" refers to carp up to about 3kg.

Carp culture facilities consist of (1) a feeding pond for parent fish, (2) a spawning pond, (3) a hatching and rearing pond for first-year fish, (4) a rearing pond for Kirigoi, (5) a holding pond and (6) a pond for preparation for shipment. However, in some cases the same pond is used in succession for (1) parent feeding and (2) spawning. Also, if (3) the hatching and first-year rearing pond is of sufficient size, one corner of it can be sectioned off with a net to keep the parent fish, thus enabling the spawning and hatching stages to be conducted in the same pond.

Regardless of the region, in all cases the spawning, hatching and rearing of the fry is always done in still-water ponds and by the same process. However, in the stage in which Shinko are raised into Kirigoi, clear differences emerge between reservoir pond, flow-through pond and net cage type production methods. (**FIG. 7**) The type of method the culture operator will choose is determined by geographical factors. During the developmental period of carp aquaculture over the past 20 years, however, we can see considerable differences in the success of culture enterprizes in different regions depending on investment capabilities, labor supply, culture technology and management skill.

Carp culture operations can be divided into three basic types:

(1) Operations that conduct spawning and hatching of eggs from parent fish and raise the young to the Shinko stage before selling them to other culture operators.

(2) Operations that buy Shinko from other operators and raise them to Kirigoi before selling them on the market.

(3) Operations that engage in the whole process from spawning and hatching to the production and selling of Kirigoi.

In recent years the carp market in Japan is on the decline, and as a result we see a depletion in the number of lower capital operators engaging in operations of type (1) and (2). On the other hand, the development of Japan's highway system and the advent of effective live-fish trucking services have led to the emergence of a new type of pattern in which large-scale carp culture operations serve as the core of interregional networks of specialized local producers. This factor encourages the continuation of these small-scale specialized culture operations.

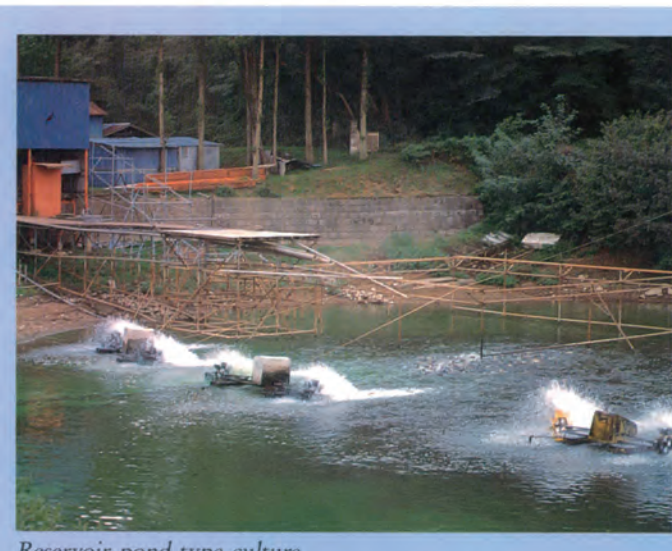
Feeds and feeding

The larvae immediately after hatching are made to feed on the zooplankton known as water flea [*Daphnia* spp.]. The larva pond is spread with manure to induce the growth of phytoplanktons which in turn encourages the growth of zooplanktons, a method which remains unchanged since olden times. In the past, the larvae would be fed on the yokes of boiled eggs or a milk made from soybean when they had eaten up all the available water flea, but today there are composite feeds especially for this stage. After the fry stage, the carp are fed purely on pellet type composite feeds. The composite feeds available on the market today are composed of the proper balance of protein, fat and carbohydrates to fit the nutritional needs of each different type of fish, plus vitamin and mineral additives. The composite is then formed into dry pellets. The materials used in the feeds include brown fish meal, soybean cakes, corn gluten meal, flour, rice bran and animal fats.

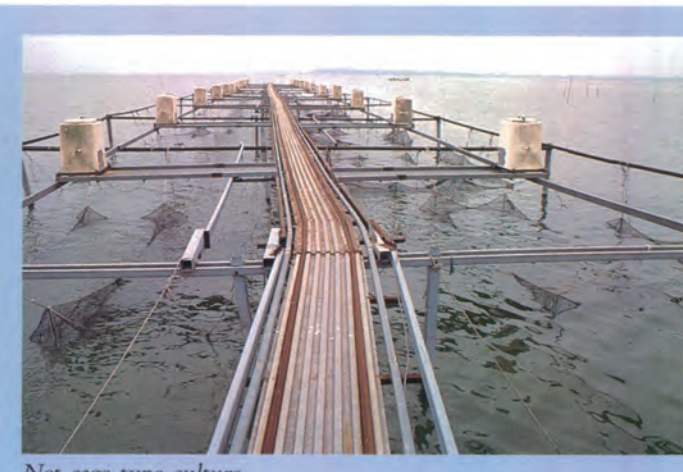
Although there are slight differences between the compositions of the feeds of the various makers, **TABLE 2** shows a representative example. Also, the pellets are made in a gradation of sizes to correspond to the growth stage of the fish. **TABLE 3** shows an example.

Carp have no stomach, which means that they can not eat and store large amounts of food at one time. Therefore, they are constantly eating food in small amounts. For this reason feedings are conducted five or six times a day, and each feeding is administered slowly over a period of 30 minutes to an hour. When the water temperature rises above 20°C in the summer the carp's appetite increases greatly and growth accelerates. So, at this time feedings are increased to 8 to 10 times a day, commencing at dawn and continuing until sunset.

A culture pond for rearing fry (top) and the feeding area (below). A net is hung across the feeding area to prevent predatory loss from birds.



Reservoir pond type culture
Notice the feeding jetty and caretaker's building.
Feed is dispensed from the pipes visible below the feeding jetty by means of blowers.



Net cage type culture
Net cages are set up along both sides of a walkway extending about 150 meters out from shore. The devices above each cage are automated feeding machines (60kg capacity). The walkway is fitted with a pair of rails for the feed transport car.

Shipping preparation tanks for a net cage culture operation. After suspending feedings for the carp in net cages in the lake for 2 or 3 days, the fish are moved to these tanks. Cold subterranean water is used to cool the fish and firm their meat for two days before shipment. The cooling water is constantly circulated.

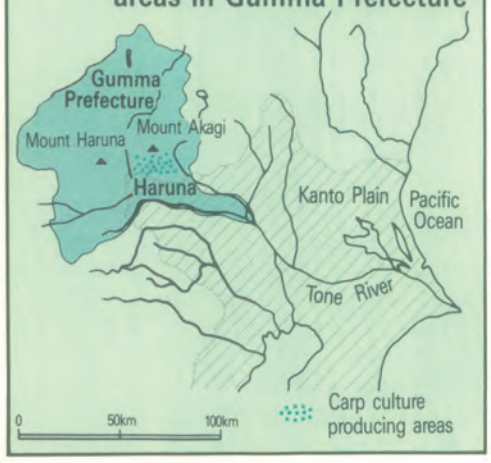
Flow-through type culture
Due to the availability of an abundant open waterway flowing through the town, a resident is able to build a culture pond in his yard. About 3,000 carp are kept in this pond.

Feeding silk pupae to the carp. Silk pupae are high in protein. Since olden times silk pupae have been considered the best food for raising carp with good meat quality. For this reason, a considerable number of operators today continue to give their carp silk pupae along with composite feeds.

EXAMPLE 1

Reservoir pond culture
Haruna, Gumma Pref.

FIG. 8: Carp culture producing areas in Gumma Prefecture



Gumma Prefecture is a landlocked area, a large part of which is taken up by mountains. In its southeast portion is the Akagi piedmont where an alluvial cone is well developed toward the Kanto Plain. Since olden times reservoir ponds for storing rainwater have been seen in all parts of the foothill region.
In the mountainous western region of the prefecture, on the other hand, there are many streams and rivers flowing out of the mountains that eventually flow into the Tone River of the Kanto Plain. Here a system of waterworks developed that diverted water from the middle stretches of these rivers into man-made waterways where in turn it was directed through a system of various sized sluices that divided it for agriculture, hydraulic power, household and drinking purposes.
Taking advantage of these resources, since the mid-19th century Gumma Prefecture has had a prosperous carp culture industry, based primarily on reservoir type culture in the southeast region and flow-through pond type culture in the southwest region.

Releasing carp in an open pond environment after training them to feed

A reservoir pond used for culture

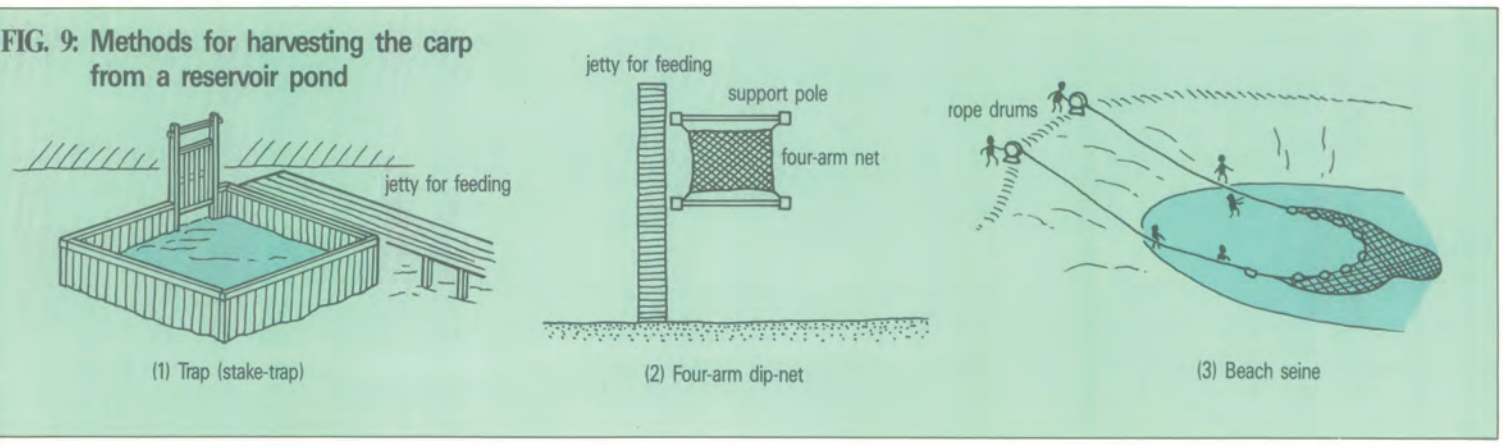
The culture method by which carp are raised in an open pond environment in ponds ranging in size from one hectare at the smallest to 20～30 hectare at the largest, is a method made possible by the nature of carp as an easy fish to train to feed, and is not applicable with other freshwater fishes like rainbow trout or sweet fish. If carp are fed at the same time of day in the same location from the fry stage, they develop a conditioned reflex in their feeding behavior. Even when living in a large pond, almost all the carp will continue to gather in the one prescribed area. They can also learn to respond to the sound made by beating on the feeding jetty at feeding time. Reservoir pond type culture has two big advantages in that no financial outlay is necessary for pond construction and, because it is still water that maintains a relatively high water temperature throughout the year even in cold districts, carp grow at a faster pace. This is a method by which a large quantity of carp can be raised at one time. Because of the fact that reservoir ponds were originally built for irrigation purposes, not all are suited for carp culture. But, if the following conditions are met, they can probably serve a dual purpose as a culture pond.
1) There should be a sufficiently large quantity of water in the pond in summer, the carp's growth period [in order to assure a sufficient supply of dissolved oxygen]
2) It should be possible to lower the water level in autumn [in order to completely harvest all the culture carp]
3) The pond bottom should be flat with not much mud [to facilitate the harvesting process]
Generally speaking, it should be possible to produce 5～10 tons of "Kirigoi" per hectare of pond area. If the pond is outfitted with a waterwheel for aeration purposes it should be possible to produce 20～30 tons per hectare.

To produce one ton of carp requires from 1.3 to 1.7 tons of feed, making for a feed efficiency of 60～80%.
When beginning aquaculture in a reservoir pond, a bridge (jetty) should first be built at a suitable position in the central part of the pond, and a caretaker's shed should also be built by the pond with sufficient space for feed storage. Near the feeding jetty an area of water is enclosed with very fine-meshed net called a "Moji-ami" or "minnow-net", in which the "Shinko" are released. After feeding the Shinko there for 7～10 days, the net is removed and the young are allowed to swim freely throughout the entire area of the pond. Because the young carp are already accustomed to artificial feeding at this stage they will continue to gather at the feeding area at the prescribed time.
One of the problems with reservoir pond type culture is mortality from lack of oxygen. Usually this occurs at a water quality conversion period in conjunction with a conversion in the climatic regime from summer to autumn. At this time, when large quantities of rain water or ground water having a lower temperature than the pond water enter the pond at once, it gathers at the bottom of the pond, pushing the low-oxygen-content water from the highly organic lower layer up to the surface layer of the pond. When this happens, the suffocating carp come up to the surface and stick their snouts out of the water to try to breath in air along with the water (gasping/surfacing). When such a phenomenon is observed, feeding should be reduced or suspended to reduce the carps' activity level and a waterwheel used to aerate the pond

A feed storage facility

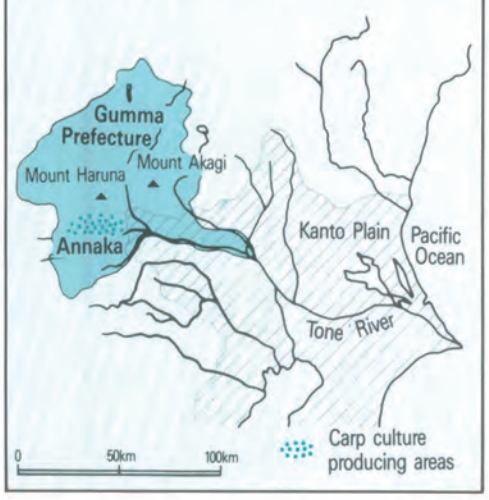
until water conditions return to normal. In order to prevent water inversion in a reservoir pond, chemicals that encourage oxidation of the organic matter in the bottom mud are spread in the pond when the water has been drained in autumn to land the year's catch of fish, thus reforming the bottom quality of the pond.
There are several methods for landing the carp harvest. In the case of a small reservoir pond, a trap like the one shown in **FIG. 9-1** is set up in the pond. The fish are trained to gather in the trap daily for feedings, and when the time for harvesting comes, the door of the trap is closed and the fish scooped out with a net. In a large pond the fish are caught by means of a four-arm dip-net as in **FIG. 9-2**. Two or three days before the planned harvest, a four-arm dip-net is set under water near the feeding jetty and the fish are made to gather above it by dispensing their feed there. When it is observed that a sufficient number of fish have gathered over the net, the ropes are pulled to close the net on the school. In order to catch all the fish, the pond is drained until all the carp are gathered in the deepest section, as shown in **FIG. 9-3**, after which a seine net is used to land them. This job requires a large number of workers. So, during the harvest season each year, every operator specifies the day of his harvest in advance and all the operators assist each other in turn.

FIG. 9: Methods for harvesting the carp from a reservoir pond



EXAMPLE 2

Flow-through pond culture Annaka, Gumma Prefecture



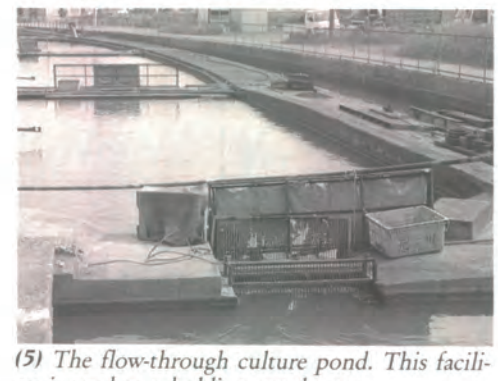
High-intensity culture based on an abundant supply of flowing water

(1) A weir

(2) Gates of water intakes

(3) The righthand waterway leads to the culture pond.

(4) Prefectural waterworks. The waterway at the right feeds the culture pond.

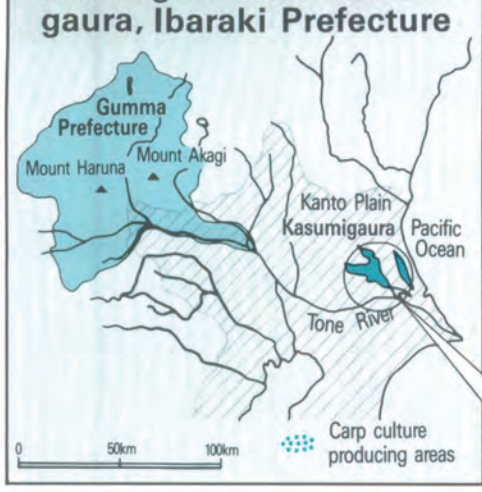


(5) The flow-through culture pond. This facility is used as a holding pond too.

This culture method can provide excellent productivity in areas that are blessed with an abundant year-round supply of temperate flowing water. It is essential that the water temperature of this supply stay at 15° or above for at least four months out of the year. If this standard is not met, the growth of the carp will be slowed to the point that a culture operation will not be profitable. The pond area in this type of culture usually ranges between 50 ~ 300m^2, with a pond of about 100m^2 being the standard size. The size of the pond is chosen not so much out of consideration for the rearing environment as for its workability from an operational standpoint. The pond depth often depends on the contour of the land, but considered in terms of ideal water circulation, a depth of 1.2 to 1.5 meters is best. The unique characteristic of this culture method is that a large amount of water is circulated through a small pond in order to raise a large number of carp. The more water that can be circulated through the pond, the better; because it is known that the biggest factor in determining a pond's productivity is the amount of water that can be moved through it. Because the inflow of new water means an abundant supply of dissolved oxygen in the pond, as well as serving to wash away accumulated wastes from the bottom of the pond, it makes it possible to maintain a higher culture density. In general, with an inflow of 100 liters of water per second, a pond can produce anywhere from one to ten tons of Kirigoi a year. The factors influencing this ten-fold difference in productivity include; fluctuations in the pond's water volume, circulation characteristics of the pond, the surface area of the pond, and the stability of the water quality as influenced by the bottom characteristics and the skill with which the culture process is operated. If an inflow of 200ℓ per sec. can be maintained for a pond with an area of 600m^2, there are cases of operations achieving an annual production of around 20 tons. The advantages of the flow-through pond method are the large production that can be achieved in a small pond area, as well as the ease of landing and shipping operations. Also, it is recognized that raising carp in flowing water gives them firmer, better tasting meat. This fact also eliminates the need for a firming period before shipment as is common with reservoir pond or net cage type culture. On the other hand, feeding efficiency is about 10% lower than that of reservoir pond culture. This is because the lower water temperature of this kind of culture results in a poorer appetite in feeding, and because of the higher metabolic energy expended by the fish from having to swim constantly in flowing water.

EXAMPLE 3

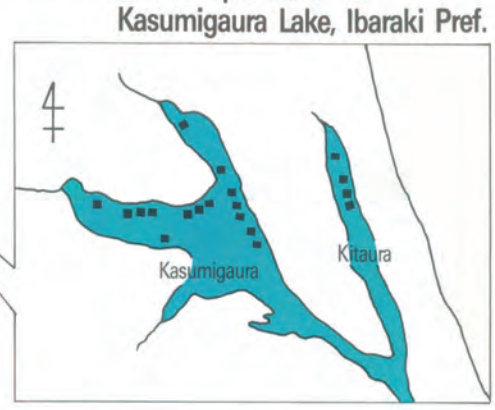
Net cage culture Kasumigaura, Ibaraki Prefecture

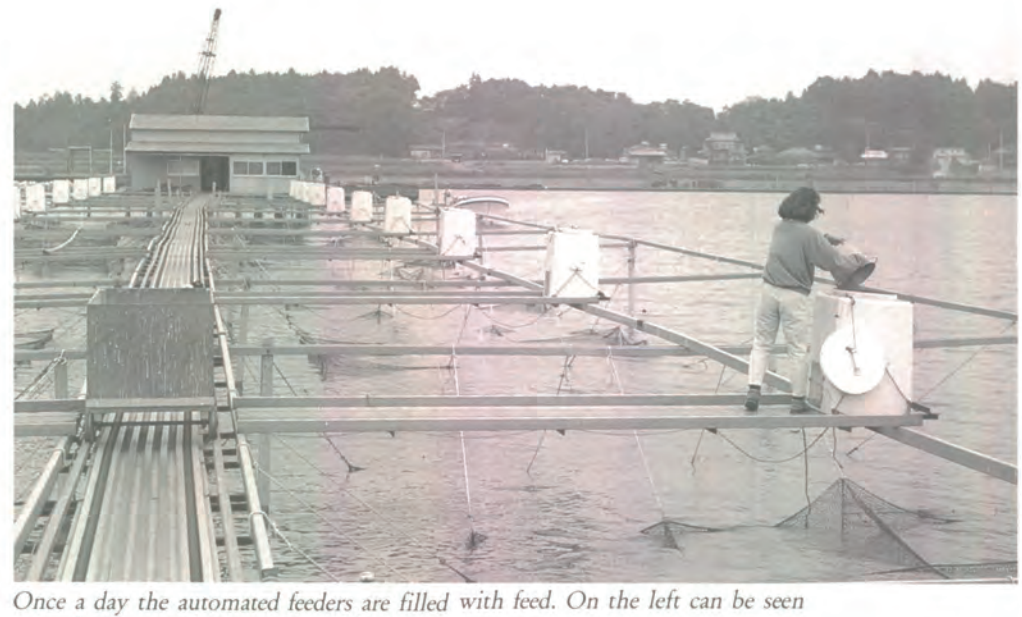


Geologically speaking, the area of the present Kasumigaura Lake was originally a saltwater bay that turned into a lake due to a rise in the crust plate of the Kanto Plain and the alluvia deposited by rivers. It is a shallow lake with an average depth of 4 m. Until the 1950s it was open to the sea by way of an inlet mouth at Choshi, and in addition to freshwater fishes like pond smelt and ice goby, schools of sea bass, herring and salmon entered its waters. At this time fishery for these various species were conducted all along the lake's shores. Entering the 1960s, however, the growing need for freshwater to supply industries along this coast led to the decision on the part of government planners to turn Kasumigaura into a freshwater lake. In 1963 a water gate was completed, and since 1973 the inflow of sea water was completely stopped. Prefectural fishery policy instructed local fishermen to convert from capture fisheries to aquaculture, and this brought about the introduction of carp net cage culture here at Kasumigaura.

Increasing production through the use of automated feeders

FIG. 10: The distribution of net cage culture operations on Kasumigaura Lake, Ibaraki Pref.





Once a day the automated feeders are filled with feed. On the left can be seen a push cart used for carrying of feed.

In the course of a year the water temperature in Kasumigaura Lake ranges from 4 to 30°C. Among the species of fish that can be raised year-round in the lake water are carp, American catfish and "silver carp". Tirapia nilotica can only be raised during the summer months when the water temperature rises (late May to early October), while rainbow trout can only be raised here during the winter months (November to April). sweet fish have trouble surviving the summer in these waters, while in the case of "masu trout" and silver salmon the season of suitable water temperature is too short to make their culture possible here.

In the year 1966, 70 fishermen received approval from the prefecture to engage in carp aquaculture. Each operator set up 5 ~ 10 net cages (5m × 5m × 2.5m depth), for which the prefecture subsidized half of the construction costs. The next year the number of fishermen applying for licenses to engage in carp culture more than doubled to 170, and the limits on the number of net cage units a single operator could work was loosened to 80. The first several years from 1966 to 1970 were a period of trial and error for these culture operators. At first, fearing net damage during the typhoon season, facilities were only set up in inlets. But as it was learned that the nets could withstand wind and wave damage, culture facilities spread out into larger areas of the lake with better currents. Aided by improvements in culture techniques and labor reduction with the use of composite feeds, the carp production in Kasumigaura grew rapidly between the years 1971 and 1977. Several factors lay behind this exceptional growth: (*Continued on next page*)

Continued from previous pages

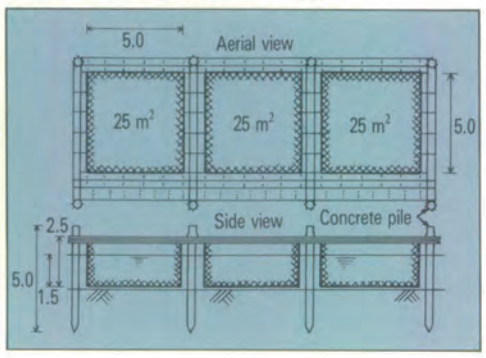
Example [3] Net cage type

1) The water quality and water temperature were both suitable for carp culture.
Also, in the case of net cage culture, even in areas of little natural current the swimming action of the fish themselves serves to circulate water through the cage, thus enabling high-intensity culture. At present, after the Shinko stage about 3,000 fish are raised in one 5m × 5m × 2.5m depth cage.
2) Because the lake is shallow along all the shore areas, jetties can easily be built 100 to 200m out into the lake and net cages set up along both sides of them. With these jetties it is not necessary to depend on boats to reach the cages, facilitating the feeding and monitoring work. This means that it is possible to operate 40 ~ 50 cages with the labor of three or four people within a family.
3) The fishermen of Kasumigaura were able to use the fishery subsidies paid by the central government, to compensate for the drop in water level of the lake due to the national development project for the lake, to help them build facilities and buy materials.
The use of these funds to install automated feeding machines was especially significant in helping to reduce labor and make the operations more efficient.
4) In and around 1970, when carp aquaculture was getting under way here in Kasumigaura, there was a boom of popularity in commercial game fishing ponds in the nearby Tokyo area. For a while this offered a market that spurred a tremendous growth in the carp culture industry. However, the fishing pond boom died out after 4 ~ 5 years and the resulting overproduction caused a large number of culture operators to drop out of the industry. The operators who remained, however, redirected their production to the general consumption market, by focusing on improving product quality and developing sales routes to all parts of the country. As a result, Kasumigaura has become one of the leading producing areas, ranking along with the established centers of Nagano and Gumma.
At present there are 120 licensed net cage carp culture operators in Kasumigaura, of which about 80 are actually engaged in aquaculture operations at the moment. There are now 4,670 individual cage units on Lake Kasumigaura and there is a trend toward intensification of operations in which operators who suspend culture activities lend their facilities to those who are still operating. Each of the active operations works an average of 57 cages, and produces an average of 100 tons a year. As can be seen from the map of example 3, the carp culture facilities are concentrated on the northern shore of the inner part of the lake. There are two reasons for this:
1) These are the areas where traditional capture fisheries were most active, and when the change-over was made from capture fisheries to culture fisheries, it was the fishermen in these areas that tended to have the greatest resources for investment.
2) In summer, predominant southerly winds blow surface waters across the lake to the north shore, bringing with them a convection current. This convection current pushes the low-oxygen-content bottom water layer out into the lake, thus creating a favorable water circulation for net cage culture.
After the lake was closed off to the sea, the effects of aquaculture and stockbreeding, industrial wastes and urban wastes on eutrophication of the lake's water became a problem. In response to this problem, the prefectural fisheries experimental station began supplying carp culture operators with culture seeds for phytoplankton-eating "silver carp", and requiring that they raise them along with the carp. However, because silver carp have almost no commercial value in Japan, its cultue has not really found a place in the fishery.

1) Fish are scooped up into a transport boat (right) from the net cage.

2) A panoramic view of a net cage facility

FIG. 11: Fixed-type net cages



Carp dishes of distinction

In one of the representative works of traditional Japanese literature, the "Tsurezuregusa" written in about 1330, we find the passage, "on a day when I eat a hot carp soup my beard has luster and keeps its form." This much respected work had a big impact on later generations, and this passage in particular helped create the image among intellectuals and dilettantes of the Edo period (17th ~ 19th centuries) of carp as a food not only with a pleasing taste, but with excellent nutritional value. Among the common class, as well, there were numerous sayings regarding carp. Such as: "When you eat Koikoku (carp cooked in miso soup) it warms your body to the core"; or "Eating carp helps restore a woman's vigor after childbirth and helps with her flow of milk."
Since olden times carp has been a favorite food fish with the Japanese people and it has provided an important protein source for those living in inland mountainous areas. Since the period of strong economic growth began in the 1960s, the development of domestic transportation systems has made saltwater fish avilable to all corners of the country, and this fact seems to have driven carp from the Japanese table to some extent. But in certain regions of the country there is still a strong demand for carp.
In Japan there are several traditional ways of preparing carp that have been perfected over time. For this reason, carp tends to be prepared almost exclusively at restaurants, in hotels and tourist areas, but seldom in the household. In Japan there is also an established tradition of enjoying carp prepared in Chinese style at Chinese restaurants. Here are the representative types of carp cuisine:

1. Koikoku: The head and innards are removed from the carp, and the body is cut into sections. Thick miso soup is brought to a boil and the fish pieces put in and boiled. Even after the carp is thoroughly boiled it must be stewed over a slow fire until the meat becomes quite soft. Finally, spices are added before eating.
2. Arai: After cutting the carp meat away in fillets, the meat is washed well in cold water to firm it up. The meat is then dipped in a sauce made of mustard, vinegar and miso or simply soy sauce with horse radish and eaten.
3. Umani: Sections of carp are stewed for a long time in a soup flavored with soy sauce, sugar and mirin (sweet sake) until the bones become soft, then eaten.
4. Chinese style fried carp: After removing just the innards, the entire fish is fried in oil slowly. Meanwhile, a variety of chopped vegetables are stir fried and mixed into a sticky sauce made by dissolving starch in water. Finally, the vegetable sauce is poured over the fried carp on the serving plate.

Some carp culture operators and wholesalers believe the reason that demand for carp fails to grow is the high level of the culinary tradition surrounding carp. These people believe that the way to increase demand is to develop new processed foods using carp which can be sold in supermarkets, and they are seriously involved in seeking out such directions for development.

Various recipes for carp at a restaurant specializing in carp in Saku:
① Koikoku ② Arai ③ Umani ④ Salt grilled ⑤ Deep fried

Traditional Japanese carp restaurant

Small parcel shipments of carp are prepared. Ten fish weighing about 1.5 kg each are put live into each plastic bag along with well water and an injection of oxygen from an oxygen cylinder. Each box is destined for a different customer.