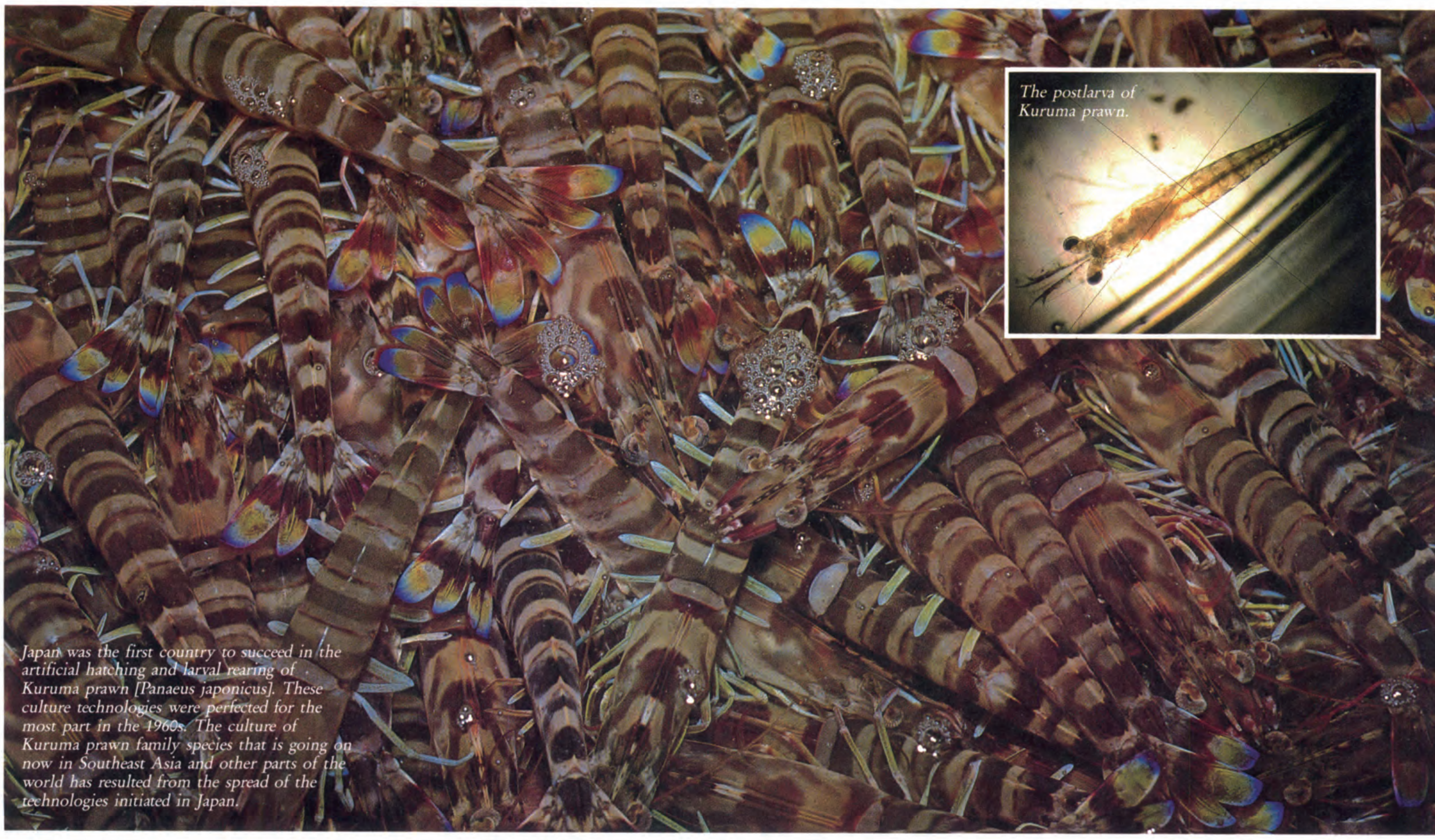
Published by Yamaha
Fishery Journal
No.30

PRAWN CULTURE

Spread of technology sparks industrialization

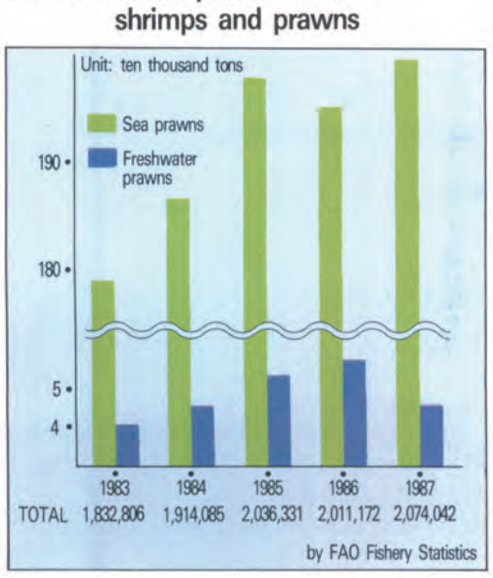


Japan was the first country to succeed in the artificial hatching and larval rearing of Kuruma prawn [Panaeus japonicus]. These culture technologies were perfected for the most part in the 1960s. The culture of Kuruma prawn family species that is going on now in Southeast Asia and other parts of the world has resulted from the spread of the technologies initiated in Japan.

The postlarva of Kuruma prawn.

Today, the culture of shrimps and prawns is spreading at a tremendous rate all over the world. In particular, the development of a culture industry for Penaeidae of the Kuruma prawn family has contributed greatly to the increase in prawn production. The present production of these culture industries is calculated to be about 400,000 tons annually. The main producing areas are Taiwan, India, the ASEAN countries and Equador and its neighboring South American countries.

FIG. 1 : World production of shrimps and prawns



The culture of Penaeidae has been "industrialized" through the development and spread of two kinds of technologies, seed producing technology and man-made composite feeds. And, with advances in feeding methods, these culture industries have shifted from extensive culture methods to semi-intensive or intensive type culture, dramatically increasing their productivity. The potential productivity of this industry in developing countries having environmental conditions suitable for prawn culture is great. And, in these countries which have programs to promote industries that bring in foreign currency, it is expected that the scale of production will continue to grow.
At present, the species of prawns that are the object of culture are the warm water members of the Kuruma prawn family (*Panaeidae*) and the Malaysian prawn or Giant river prawn [*Macro brachium rosenbergii*]. With regard to cold water prawns, only small-scale experiments are presently being conducted. **TABLE 1** shows the prawns that are now the object of commercial culture fishery.
In addition to these species, there are other shrimps and prawns that are used not as the primary but as a secondary object of culture fisheries, including Jinga shrimp [*Metapenaeus affinis*], Yellow shrimp [*Metapenaeus brevicornis*], Shiba shrimp [*Metapenaeus joyneri*] and Speckled shrimp [*Metapenaeus monoceros*].
Also, with regard to the Green tiger prawn [*Penaeus semisulcatus*] and Western king prawn [*Penaeus latisulcatus*] of the Indian Ocean, the Caramote prawn [*Penaeus kerathurus*] of the Mediterranean Sea and Northern Pink shrimp [*Penaeus duorarum*] of the Gulf of Mexico, some aspects of the seed production and raising technologies have been established, but as yet they have not entered the stage of commercial culture fishery.
Among the above mentioned species, Giant tiger prawn, as a low-salinity type that thrives in brackish water zones, enjoys a large area of potential culture grounds. Also, it has a short maturation period and natural seeds can be gathered in abundance, making it especially suitable for culture fishery. For this reason its culture has been rapidly growing in scale in Taiwan since 1980. And now its culture technology is being actively exported from Taiwan to the other countries of Southeast Asia.
Japan is the world's largest consumer of shrimps and prawns. With a per capita consumption of over 2kg annually, it far exceeds the 1kg and 0.5kg consumption of the U.S. and the EC countries respectively. For this reason, Japan presently imports over 200,000 tons of prawns annually from more than 50 countries around the world. In addition, Japan produces between 40 and 60 thousand tons domestically. Of this production, however, only 3,000 tons or so are Kuruma prawns from culture fisheries. By focusing their culture operations on the market for live Kuruma prawns, which command exceptionally high prices, culture fishery operators are able to secure for themselves a sound commercial base.

TABLE 1 : Prawns & shrimps used in commercial culture fishery

FAO name	Species	Area
Fleshy prawn	*Penaeus chinensis*	China
Indian white prawn	*Penaeus indicus*	India
Kuruma prawn	*Penaeus japonicus*	Japan, Taiwan
Banana prawn	*Penaeus merguiensis*	Thailand, India
Giant tiger prawn	*Penaeus monodon*	Taiwan, Indonesia, Thailand, The Philippines
Blue shrimp	*Penaeus stylirostris*	Equador, Peru
White leg shrimp	*Penaeus vannamei*	Equador, Peru
Giant river prawn	*Macrobrachium rosenbergii*	Thailand, Malalysia, Myanmar

The development of Kuruma prawn culture fisheries

An extremely large number of offspring

The reason that species of the Kuruma prawn family have become the successful object of culture fisheries is that they possess three important biological qualities that make them highly suited for culture. Namely: ① they produce an extremely large number of offspring, ② they are a species with a 1-year life cycle and their re-production cycle is very short, and ③ they grow to a substantial middle-sized prawn in a very short period of time.

The egg laying and fertilization patterns for shrimp and prawn species can be divided into two main types:

(1) Dendrobranchiata type - At the time when the berried female releases her eggs in the water, she also releases the sperm she received from the male in the mating process that precedes the spawning. The fertilization and hatching of the eggs then takes place in the sea water. All Kuruma prawn species (Penaeus) belong to this type. This type is typified by the large number of eggs released by each female and the shortness of the larval period.

For example, a parent prawn (spawner) with a body length of 20cm is said to lay between 250 and 800 thousand eggs.

(2) Incubation type (Pleocyemata) - In this type the female attaches the eggs she has laid to her belly, fertilizes and holds them protected there until they hatch. After hatching she then ejects them out into the sea water. This incubation type is seen in lobster [Palinuridea] and crayfish [Astacidea] as well as in such shrimps and prawns as *Caridea* and *Stenopodidea*. Two distinctive features of this type are that the number of eggs are fewer than *Penaeidea* and the incubation period is longer. For example, an Ise lobster *[Panulirus japonicus]* (body length 12~13cm) gives birth to 29,000 eggs and the incubation period lasts a full 8~10 months. Among the *Carides*, Giant river prawn [Macrobrachium rosenbergil] lays 40,000~100,000 eggs and incubation lasts about 20 days.

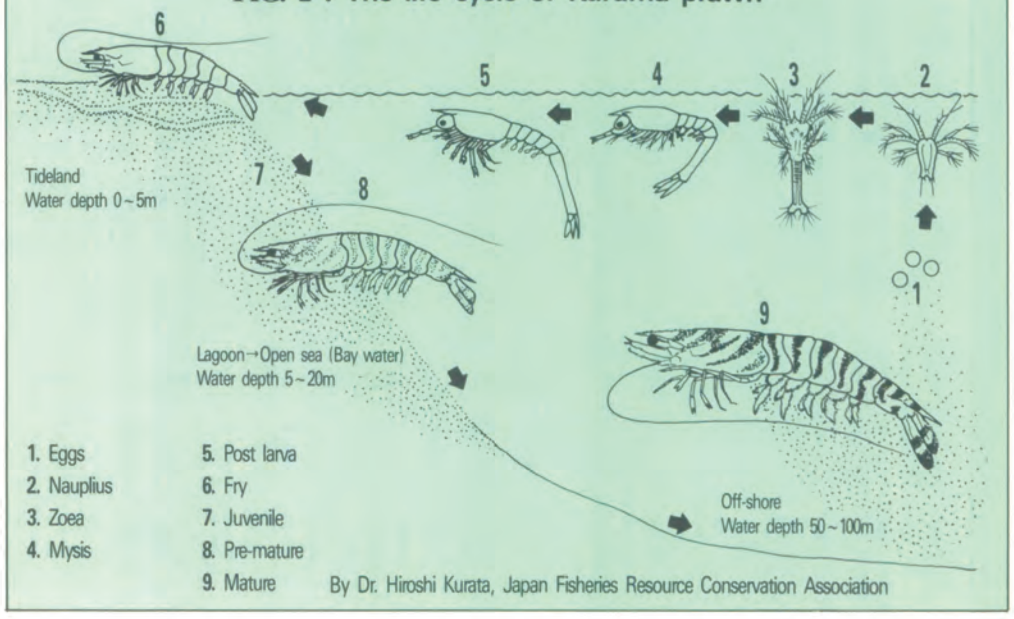
Success in the feeding of larva

The first researcher in the world to undertake the study of artificial hatching methods and the early life cycle of Kuruma prawn [Penaeus japonicus] was Dr. Motosaku Hudinaga (1903~73) of Japan. Dr. Hudinaga first succeeded in the artificial hatching of prawn eggs in 1933. At that time he was able to raise the young in water containers up to the zoea stage. But as they reached the feeding stage of their life cycle they began to die one after another, so the raising process ended in failure. In 1940, however, he tried giving pure cultured *Skeletonema*, a kind of diatom, to the zoea and succeeded in getting them to feed for the first time. In 1955 he tried giving newly hatched brine shrimp young as feed and succeeded in raising the prawn from the mysis stage to the postlarva stage. In this way, after 20 years of research and experimentation he succeeded in developing the theory of artificial hatching and the methods for larvae rearing for the Kuruma prawn. Putting the fruits of this research to use, Dr. Hudinaga began his first attempt at the commercial culture of Kuruma prawn in 1960, using an abandoned saline on the coast of Takamatsu City on the Seto Inland Sea. Following this, beginning around 1962, Kuruma prawn culture based on active feeding techniques started to appear in various parts of Japan. In 1963, Japan's annual production of cultured Kuruma prawn stood at 179 tons, and after that it grew in size every year. In 1987, the annual production was 2,882 tons. This figure is roughly equal to the 2,904 tons of Kuruma prawn caught by boat fisheries.

Toward the realization of complete culture, or "through-culture" operations

The Kuruma prawn family *(Penaeidae)* is a coastal habitat family that changes its living grounds in the different stages of its life cycle. The growth stages and their corresponding living environment and life pattern changes for naturally raised Kuruma prawn are shown in **FIG. 2** and **TABLE 2**.

FIG. 2 : The life cycle of Kuruma prawn



By Dr. Hiroshi Kurata, Japan Fisheries Resource Conservation Association

TABLE 2 : Life stages of the Kuruma prawn

Division	Beginning of stage	Period	Lifestyle	Habitat
Embryo	Fertilization	0.6 day	Floating freely	Off-shore water
Larva	Hatching	30 days	Swimming freely	Off-shore water
Fry	Development of gills	15 days	Bottom life	Tideland
Juvenile	Body development stabilizes	2 months	Bottom life	Tideland→Beach
Pre-mature	Begins sexual development	9 months	Bottom life	Beach→Open sea (Bay water)
Mature	Sexual maturity completed	24 months	Bottom life	Open sea→Off-shore

By Dr. Hiroshi Kurata, Japan Fisheries Resource Conservation Association 1974

Modern marine culture aims to realize control of all stages of production, from the collecting of seeds in a water tank to the raising of mature adults and then saving of eggs to seed the next generation. This is referred to as complete, or "through-culture". In Kuruma prawn culture today, all the steps of the culture process have been perfected, with the exception of raising and keeping parent prawn (spawners) to parent the next culture generation.

The technological objectives of marine culture can be summarized in the following 3 points:

① To improve the survival rate of individuals and achieve a higher concentration of feeding culture than natural seeds, thereby vastly increasing marine production.

② To maintain a favorable life environment throughout the life cycle of the species involved, thus achieving high feeding efficiency.

③ To raise healthy individuals with a taste equal to or better than naturally raised ones.

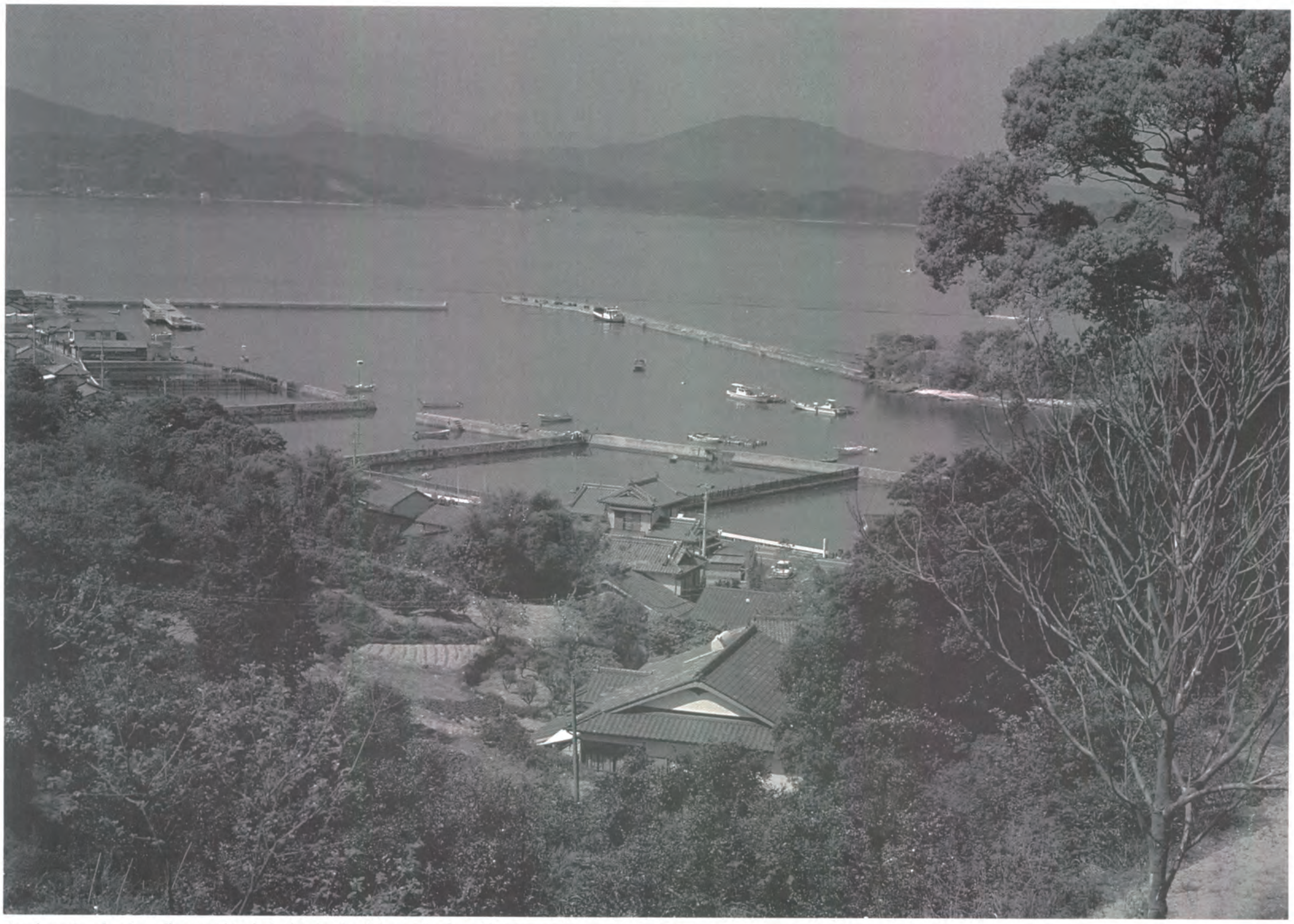
Extensive type and intensive type culture

The type of culture in which an embankment is built to create a brackish water pond with a water gate that is designed to confine the assorted fish and crustacea inside at high tide, and allowing them to feed on organisms inhabiting the pond until they grow mature enough for harvesting, has been widely practiced in Southeast Asia for several hundred years.

This is a primitive type of culture fishery making use of natural productive capacity. At first the prawns grew in the brackish water ponds along with milkfish and were harvested as a secondary product of the fish culture. But, with the rise in the price of shrimp and prawn in the 1970's, many culture ponds were modified to produce prawn as their primary product, first in Taiwan and then in Indonesia, India and Thailand. This method, in which naturally occurring fry are enclosed and raised to maturity is called "extensive culture".

Another fundamental type of prawn culture is called "stocking". The Ariake Sea and Shiranui Sea of Japan's southern island, Kyushu, are inland seas that produce abundant amounts of Kuruma prawn. At the end of the 19th century, fish wholesalers got together to buy up large quantities of live prawns caught by bottom drift net fishermen in the Amakusa area of Kyushu. They then raised these prawns in stocking ponds enclosed by nets in a bay and harvested and sold them to the urban markets at a large profit in the winter off-season when supply was low. In the 1960's, when artificially hatched prawn seeds became available the stocking pond operators switched over one after another to culture operations. In other words, they would buy large numbers of prawn fry as seeds, release them in their ponds and feed them until they grew to maturity. This type of culture, which was able to raise prawn at a concentration of more than 10 tons/hectar/year - much higher than the concentration in their natural habitat - is called "intensive culture".

Harvesting cultured Kuruma prawn.



Amakusa, Kyushu. A small area within the harbor breakwall is used for the cultivation pond.

Kuruma prawn culture in Japan

Natural Kuruma prawn *(Penaeus japonicus)* is found widely distributed around the islands of Honshu, Shikoku and Kyushu. They do not grow in the waters of Hokkaido and Northeast Honshu where the average summer water temperature dips below 20°C. Very small numbers of Kuruma prawn are to be found in the Amami Islands and the Ryukyu Islands. The fact that they are not found in the island groups of the South Seas can be attributed to two factors; the lack of tidelands essential for the growth of pre-mature prawns and the lack of low-salinity bay waters with river water flowing into them.

The areas involved in Kuruma prawn culture are shown in **FIG. 3.** In terms of marine geography, the main producing areas for culture fisheries can be divided into four groups:

1) The Seto Inland Sea area

This is the area in which Kuruma prawn culture was first begun. The western sector of the Inland Sea, in Yamaguchi, Oita and Ehime Prefectures, is blessed with such favorable conditions as having extensive unused salines ideal for converting to raising grounds, abundant resources of smaller fishes suitable for feed being caught, and good fishing grounds for catching parent prawn.

2) Amakusa area, Kyushu

As mentioned earlier, this is an area which adopted Kuruma prawn culture technology and facilities to build a culture industry of its own. In this area the tidal drop is especially large and this factor has been used to develop a distinctive method of controlling the quality of the culture pond water, called the "Amakusa Method".

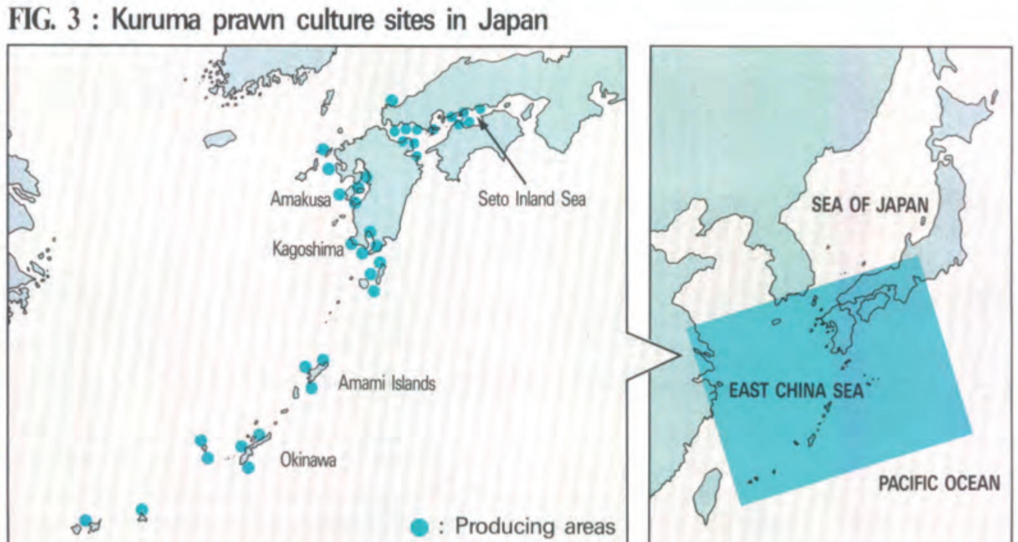
3) Kagoshima area

Building 2,000 ~ 4,000 ton capacity round concrete water tanks on land, sea water is pumped up into the tanks. This water is then circulated and drained off by motorized pumps. This is a typical high-intensity culture fishery that produces between 1.5 and 2.0kg of prawn per sq. meter, but this particular tank method is found only in Kagoshima.

4) Amami and Okinawa area

This area actually lies beyond the southern boundary of the fishing grounds for natural Kuruma prawn. The summer water temperature lies between 33 ~ 34°C and averages 18°C in winter. The water salinity of 37 ~ 38ppt is slightly above the ideal range for Kuruma prawn. Attempts at Kuruma prawn culture were first made around 1970 and full-scale production was begun in 1978 ~ '79. Culture fishery here takes advantage of the warm climate, which allows for year-round rearing. Such negative factors as the inability to catch parent prawns for spawning purposes in the area, the inavailability of fresh feed fish and distance from the main live-prawn markets of Tokyo and Osaka have been solved by the availability of large-class jet air transport in recent years. This has led to a strong wave of private sector investment in facilities. Also, several fishery cooperatives have begun to use prefectural and national grants to invest in Kuruma prawn culture.

FIG. 3 : Kuruma prawn culture sites in Japan



In Japan, according to fishing laws, with the exception of certain harbor areas, almost all coastal water areas are designated for specific fishery rights with the mutual benefit of all fishermen involved as the primary objective. Therefore, in the case of culture fisheries where a certain individual has exclusive use of a given area of fishing ground, the area of fishing ground alloted to such culture operations is rather limited in size.

In the case of Kuruma prawn culture the average area alloted for one culture operation is 3.9 hectar nationally (1987), and such operations are usually carried out by family labor. In Kuruma prawn culture it is considered standard for one laborer to be able to operate 1 ha. of culture pond. When large areas of culture pond are available, it is easy to engage in low-cost type culture operations. But, in Japan this is not possible. So they make their culture operations commercially viable by engaging in high intensity type methods.

Kuruma prawn culture is conducted in four stages, the production of seeds, intermediate raising, cultivation and shipping. Among these, the productive capacity of the cultivation pond and the way the cultivation process is carried on are the two biggest factors influencing overall productivity. And, due to differing natural geographic conditions, each region has developed its own unique variations on the culture process. These regional differences can be seen primarily in the structure of the cultivation pond and the schedule for the cultivation process.

1 Seed production

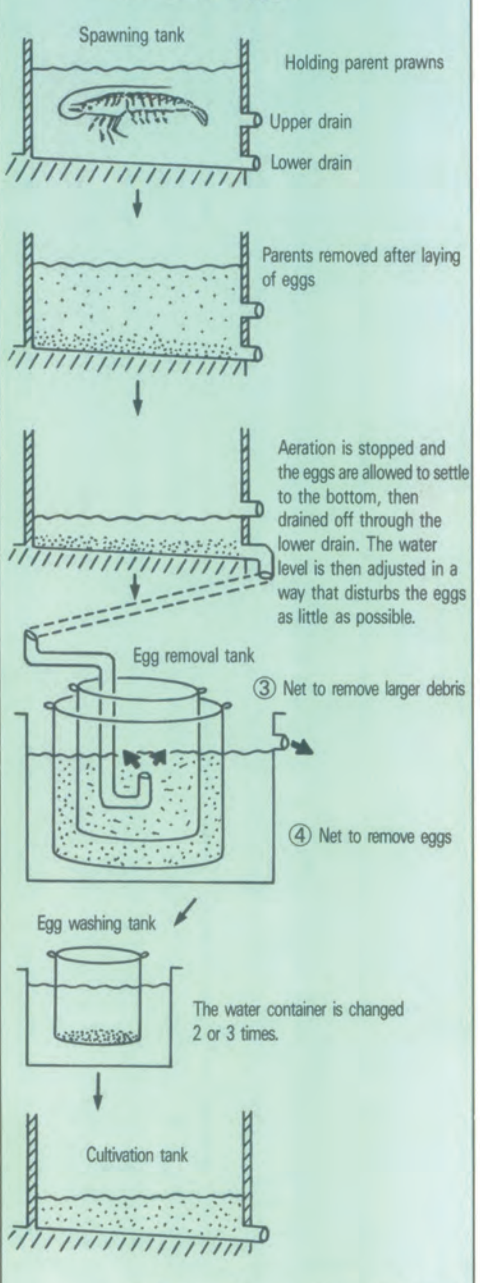
The berried females used for spawning are always naturally grown prawns. The seed producer goes to a market where prawns are being shipped and received and picks out suitable female prawn to buy one by one, examining the belly to make sure they have reached full period and the eggs are ready for laying.

The spawning tank is a concrete water tank. The tank is filled with clean water that has been filtered through sand or charcoal, and the water is aerated. For a 100 cubic meter tank, 20 ~ 50 parent prawns are put in. The most suitable water temperature is between 26° and 28°C. If the water temperature is too low, egg laying does not occur, in which case the water must be heated. If the parent prawns have reached full period, they will usually lay their eggs the first night after being put into the tank. If they don't lay on the first night, they will lay on the second. So, the parents are left in the tank either one day and one night or two days and two nights, then they are removed. If egg laying is allowed to continue for more than two days there will be a considerable size difference between the young, making it difficult to properly control their growth in a single tank.

In the past, after the parents had laid their eggs and been removed from the tank, the eggs were then raised in the same tank. But in recent years, many operators have adopted the pratice of removing the fertilized eggs to another tank as well, to prevent possible contamination from any diseases which the parent prawns might have been carrying. **(FIG. 4)**

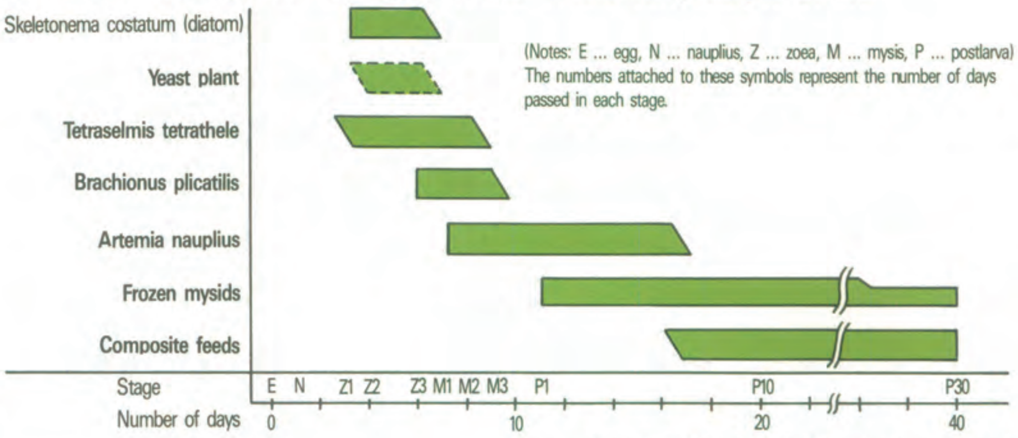
The cultivation tanks to be used are first cleaned thoroughly with a high-pressure washing device to get rid of any attached organisms, and then dried completely before filling with filtered water. The hatching of fertilized eggs begins about twelve or thirteen hours after being released by the parent. The ideal water conditions for the cultivation tank are believed to be a water temperature of 26° and 28°C, a salinity of 33 ~ 35ppt and a pH of 7.0 ~ 8.0. During cold weather a boiler is used to heat the water, while in hot weather a sun screen is hung over the tank to prevent temperature rise. The newly hatched prawns proceed to grow through their nauplius, zoea, mysis and postlarva stages. **(FIG. 5)** During the nauplius stage no feeding is necessary, but as the young enter the zoea stage they begin to feed actively. As the young progress through their growth stages, a progression of feeds is used beginning with phytoplankton, small zooplankton (*Brackionus*) and then, middle-sized zooplankton (*Artemia*), small shrimps and composite feeds. An example of a schedule for feeds can be seen in **FIG. 6.** In the early part of the postlarva stage the young prawns are free swimming organisms, but as they enter the later part (about P30), they begin to display a habit of crawling in the sand. Therefore, when they reach P30 ~ 35 (about 40 ~ 45 days after hatching) they must be removed from the tank and transferred to a cultivation pond with a sand bottom. Although the number of young kept can vary with the size of the cultivation tank, in general, there should be about 20,000 individuals per cubic meter of water at the final stage before transfer. And the original number of eggs with which the tank should be stocked is calculated from this number, based on a 60% survival rate. Under optimal conditions the survival rate from the N stage to P-30 is as high as 80 ~ 90%, but is usually in the range of 50 ~ 60%.

FIG. 4 : The cleaning operation for fertilized eggs



By Mr. Kazuo Momoyama, Yamaguchi Prefectural Fisheries Experimental Station

FIG. 6 : An example of feeding schedule in the early stages of life



(By Mr. Tetsuo Yamasaki, Japan Sea-farming Association, 1987)

FIG. 7 : The aims of seed production

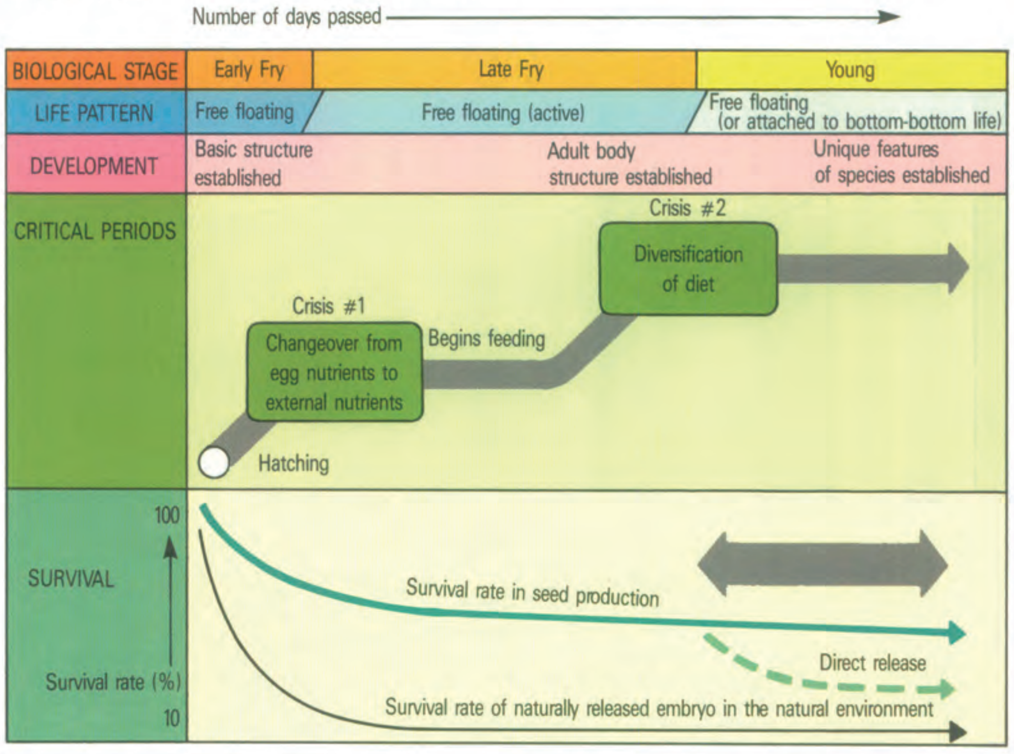
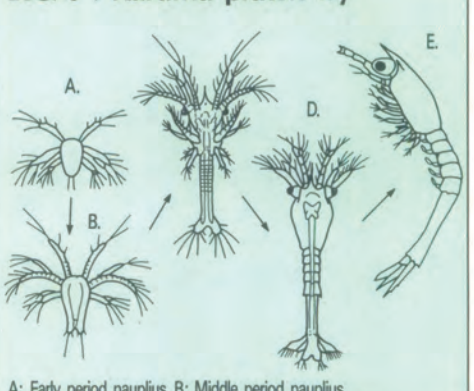


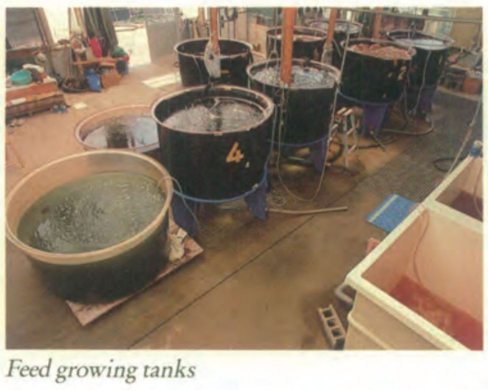
FIG. 5 : Kuruma prawn fry



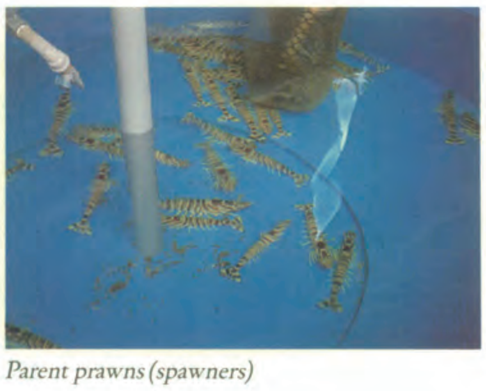
A: Early period nauplius B: Middle period nauplius
C: Middle period zoea D: Early period mysis E: Middle period mysis

(By Japan Animal Encyclopedia, 1965)

A 100-ton type cultivation tank (10×5×2m)



Feed growing tanks



Parent prawns (spawners)

2 Intermediate nursing

Postlarve, P16 stage
(On the 29th day after hatching)

The postlarva stage prawns that have been raised in the cultivation tanks are transferred to an intermediate nursing pond for a 30 ~ 50 day nursing period in which they are raised to a body length of 4cm (0.5 ~ 1.0 grams). After this they are released into a "grow-out pond". For the intermediate nursing pond a separate small-area pond is usually used, but sometimes a small part of the grow-out pond is simply sectioned off with nets to serve as the nursing stage pond.

In the nursing pond a concentration of 70 ~ 80 young per sq. meter of water, or, in the case of high-intensity culture, 130 ~ 150 per sq. meter is maintained. The feed used in this stage is all composite feeds.

The intermediate nursing stage has two aims: One is to prevent the young from being eaten and the other is to control the population intensity.

1) The young are nursed and observed closely in a small, confined area to prevent them from being eaten by other fish. Also, this stage allows the development of sufficient mobility and defensive capacity before the young are released into the grow-out pond.

2) The number of young is also counted carefully at this stage before release into the grow-out pond. This is an essential step in the culture process that enables the control of the culture intensity and aids in determining the amount of feed to be given.

3 Formats of grow-out ponds

There are three basic formats for the construction of a grow-out pond for Kuruma prawn culture:

1. Partial-embankment type
In areas with a large tidal drop, an embankment is built up to a height halfway between the high and low tide water levels and nets are hung along the top of it - Amakusa areas, Kyushu.

2. Full-embankment type
In this type an embankment with a water gate is built in the sea or on land adjacent to the sea - Seto Inland Sea area, Amami/Okinawa area, Amakusa (Kyushu) area.

3. Double-bottomed round tank type
A round tank is built on land near the coast and water pipes and pumps are used to supply and drain the water of the tanks - Kagoshima area.

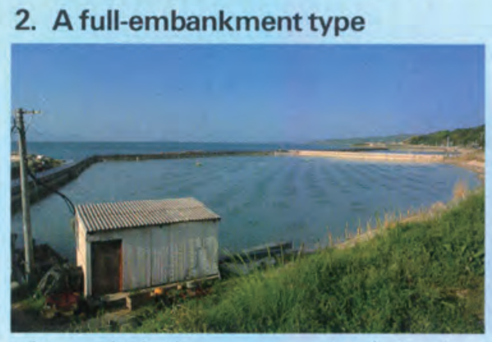
All three of these formats have evolved their unique features in response to aspects of the natural life patterns or the natural productive capacity of the area. These differences are most evident in the method of water exchange and the use of diatoms **(TABLE 3)**.

The effects of diatom growth include;
(1) Increasing the amount of oxygen available in the water through photosynthesis,
(2) The brown water color that diatoms create decreases the amount of sunlight reaching the bottom and thus inhibits the growth of green seaweeds, and
(3) to serve as nourishment for the small zooplankton that the prawn fry feed on.
However, compared to partial-embankment type ponds, the degree to which the cultivation water is being controlled in full-embankment type operations is increasing and the role of diatoms as a nutrient is becoming less important. Furthermore, in the case of double-bottomed round tank culture operations, water exchange is so complete that none of the effects achieved by diatoms are relevant any more. The aim of increasing artificial control of the grow-out pond environment is, of course, to increase productivity. This is done by 1) increasing the number of young the pond is stocked with, 2) replacing natural feeds with composite feeds, 3) increasing control over the pond water to achieve a more balanced life environment, and 4) increasing the harvest for a given area of grow-out pond surface. But, as the intensity of the culture increases so do the stresses on the life system in the pond, making it necessary to prevent feeding and disease-related problems by doing a thorough job of cleaning the pond and improving the sand quality every season. For these purposes the partial-embankment type format is not suitable.
Concerning the intensity of the culture, productivity and production costs, figures differ in the different areas, as shown roughly in **(TABLE 4)**.

1. A partial-embankment type


A partial-embankment type grow-out pond that makes use of tidal drop.

2. A full-embankment type



This pond is built on a coast section facing the outer sea with a rocky bottom.

This pond makes use of a marsh area along the inner shore of a bay.

3. Double-bottomed round tank type

The bottom of the tank is a two-layer construction. Above a rock bed is an open layer, above which a 3-layer bed of drain board, net and then sand is laid. Water is fed into the tank by a supply pipe equipped with spray nozzles that serve to circulate the water around the tank as well. The water flow concentrates peeled shells, leftover feed, and excretions in the center of the tank where they are drained off through the center drain. The tank shown in the photo has a surface area of 1,000m² and a water depth of 2m.

Cross section of a double-bottomed round tank

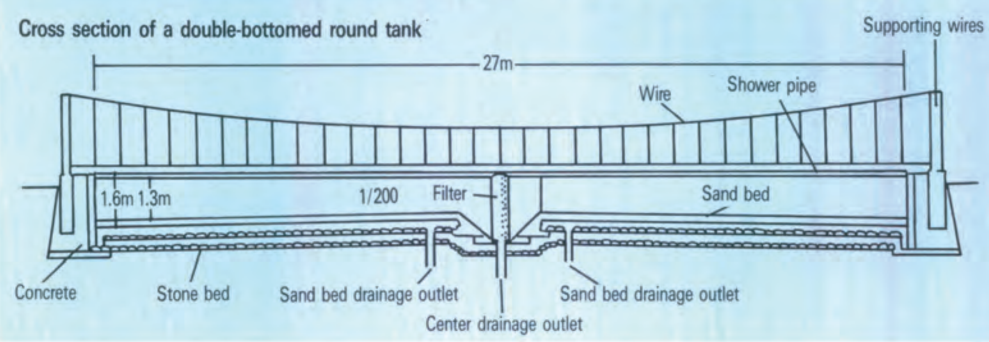


TABLE 3 : Comparison of grow-out pond operating methods

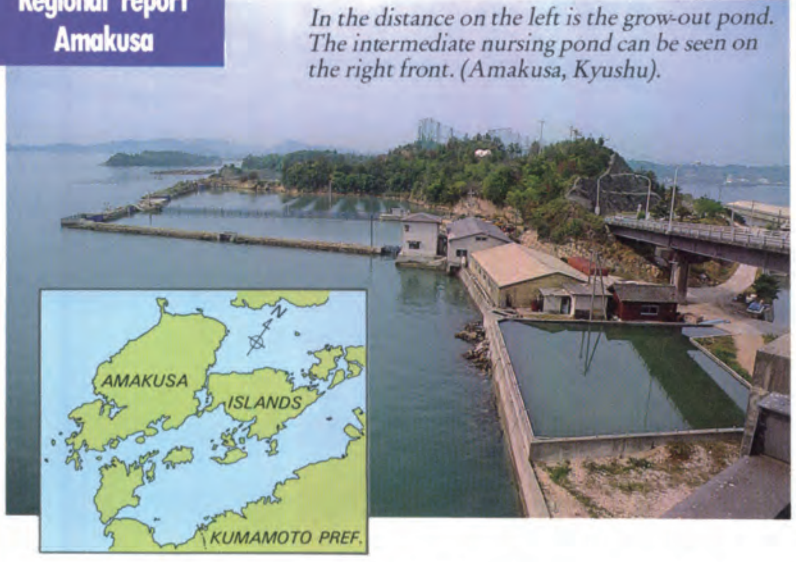
	Water exchange in the pond	Growth of diatoms	Pond cleaning
Partial-embankment type	Water exchange is achieved by means of the overflow of water over the embankment with the rise and fall of the tides. Each day about 1/3 of the water is exchanged. A disadvantage exists in the lack of water exchange at low tide.	Natural condition	After harvesting, water level is lowered in the pond and new sand put in.
Full-embankment type	Exchange is achieved by opening and closing a water gate. At the same time new water is pumped into the pond.	Diatom growth is controlled by watching the water color. The supply of oxygen to the water is the main aim.	After harvesting the pond is completely drained and sun-dried for several days and then sanitized. The bottom sand is also replaced.
Double-bottomed round tank type	A forced exchange of 100～300% of the water is achieved by pump every day.	Diatoms do not grow here	After harvesting the pond is completely drained and sun-dried for several days and then sanitized. The bottom sand is also replaced.

TABLE 4 : Comparison of culture intensity, productivity and cost

Types of grow-out pond	Number of prawns/m²	Number of prawns harvested/m²	Cost/kg of produce
Partial-embankment	20～50	0.4～0.5kg	¥5,000
Full-embankment	40～60	0.6～1.0kg	¥5,500
Double-bottomed round tank	70～80	1.5～2.0kg	¥6,500

Regional report Amakusa

In the distance on the left is the grow-out pond. The intermediate nursing pond can be seen on the right front. (Amakusa, Kyushu).



Moving from partial-embankment ponds that depend on tidal action to full embankment ponds

The Amakusa area of Kyushu is a large inland sea with a winding coastline and many islands. The tidal drop is as high as 6 meters at some points, causing large areas of tideland to be formed along the shores of the peninsulas and islands. As mentioned elsewhere, net-enclosed Kuruma prawn culture operations have existed here since about 1900.
These net-enclosure methods continued to be used for a while, then partial-embankment ponds began to be built in the 1920s. In part, these facilities were intended to make use of the tidal action for water exchange purposes. But another factor was that embankments built in these sand and mud bottom lagoons tended to sink under their own weight, making the cost of building full-embankment type ponds, which could completely shut out tidal waters, too expensive.
After the Second World War, the development of durable synthetic fiber nets made it possible to hang nets along the tops of the embankments to create the partial embankment grow-out pond format found in this area today.
However, about the end of the 1970's, new full-embankment type ponds began to be built in sea areas with rocky bottoms.
The desire to increase productivity in this way came from reports of the excellence of full-embankment type ponds built on former saline in Yamaguchi and Ohita Prefectures.
However, the head of the Kuruma Prawn Culturers Association here, Mr. Masatsugu Shimamori, insists that, "the superiority of full-embankment type culture over partial-embankment type from an economic standpoint has not been sufficiently proven yet". The reason being that, even if one chooses rocky bottom water areas that are easy to build on, the coastal topography will often require an extended embankment length that will raise construction costs. Also, increased culture intensity within the pond leads to increased feed costs. These two factors can therefore consume the added profits that would come from increasing the production per square meter of pond area.
In order to prevent a deterioration of bottom conditions due to a worsening of water quality and build-up of leftover feed, it is necessary to use a higher percentage of composite feeds. One kilogram of these feeds costs about the same as 5～6 kg of raw fish feeds. At present, composite feeds cost about ¥750/kg, whereas raw feed costs ¥30～50/kg. Therefore, as productivity is increased, so does the marginal cost of production.
There are 63 Kuruma prawn culture operations in the Amakusa area, 37 of which are partial-embankment type and 26 are full-embankment. For both types the most common surface area is 1～2 hectar. This range makes up 40% of the total. Today there is little tendency for partial-embankment pond operators to modify their ponds into full-embankment type.
In the Amakusa area culture intensity averages 20 prawns/m² but there is a considerable variation in intensity, from a minimum of 14/m² to a maximum of 47/m². Although the basic costs of partial-embankment and full-embankment types are not known, we know that in this area production is 3～5 tons per hectar of pond surface. And, production cost ranges from ¥5,000 to ¥5,500 per kilogram of prawn. Of this, about ¥2,000 (about 40%) of the cost goes for feed.
"The quality of tidal circulation influences feeding efficiency, and also, the quality of culture technology causes a difference of roughly ¥500/kg in feeding cost," says Mr. Shimamori.

4 Raising (The grow-out stage)

In its natural state, Kuruma prawn spend their early life up until the pre-mature stage in beach and inner bay areas with sand and mud bottoms and a salinity of around 32 ppt. Suitable water temperature is said to range from 10° to 30°C, but, being a warm water species, the higher the water temperature, the faster its growth. The important points of culture technology involve the intensity of pond population, sanitary control of the grow-out pond, control of water quality, types of feed and prevention of diseases.

1. Intensity of pond population

The number of young released in the pond is a vital determinant in the volume of the culture production. The number of young released should be determined by the productive capacity of the pond, and the aim of the culture technology should be to maintain the maximum level of population possible within the limits of pond capacity at each stage of the life cycle. To achieve this, thinning-out or population division techniques are necessary. The body weight of the prawn at the point of transfer from the intermediate nursing pond to the grow-out pond is 0.5～1.0g, and in the case of an embankment type pond the standard intensity level for stocking is 20～30 prawns per square meter. If the water temperature in the grow-out pond remains suitable, the prawns should reach a minimum market size of 10～12g two months after stocking. At this time the first thinning-out harvest and shipping to market can begin. The resulting decrease in population intensity in the pond causes a proportional increase in the growth rate of the remaining population. This thinning-out process allows for an increase in productivity per unit of pond surface area. In Japanese full-embankment and partial-embankment Kuruma prawn culture, the aim is to maintain a productivity of 300g per square meter of pond area. In double-bottomed round tank facilities on land, the intermediate nursing stage is eliminated and the tanks are stocked with postlarva prawns at a level of 150/m^2. Then they employ a technique of thinning out the population into other tanks at various stages in the growth cycle to maintain a suitable intensity.

In addition to thinning-out and population division techniques, in warm areas where prawn rearing can be carried out year-round some areas adopt a "double cropping" method. (See the regional report on this page).

No matter what method is used, however, it is always important to take periodic samples to monitor the prawn size and the population intensty within the pond.

2. Sanitary control of the grow-out pond

When the harvesting has been completed, the pond should be completely drained and the bottom allowed to be dried by the sun to eliminate potentially harmful organisms. It is also wise to remove sludge and to spread lime or other substances to help sterilize the pond. In places where the sand has become dirty it should be replaced with clean sand. Also, during the culture process it is best to make daily dives to inspect the bottom conditions and check for build-up of excess feed. When a large amount of sludge is found, it should be removed by a pump.

3. Controlling water quality

If a pond is too shallow, the temperature on the bottom will rise considerably during the warm season. So it is advisable to keep about 2 meters of water in the pond. The important factors to watch in water quality control are water temperature, pH rating, and the amount of suspended oxygen. Normally, water exchange is conducted based on observations of the water color and transparency. And, to prevent a lack of oxygen near the bottom, a blower or paddle-type water wheel is used to circulate oxygenated water to the bottom.

4. Feed

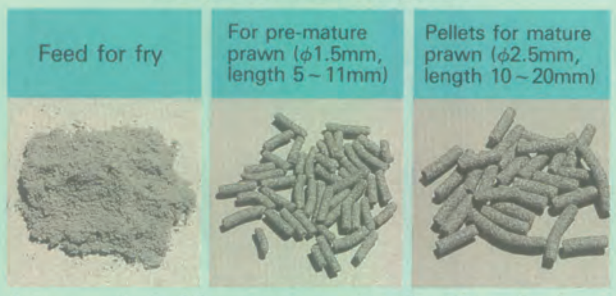
In the past, feed for Kuruma prawn culture included small shrimp species, bivalves and other small fish. But as the scale of culture operations has grown it has become increasingly hard to obtain large volumes of such live feeds on a regular basis. Especially in intensive culture operations, the use of live feeds invites such problems as water contamination and deterioration of the bottom quality. Therefore, in recent years all of the producing areas have been moving toward a greater use of composite feeds.

Up until the first month after the start of the grow-out stage, the daily allotment of feed is divided into 2 or 3 separate feedings. After that, however, the prawns tend to eat less actively during the daytime hours, so feed is distributed only once a day, just before sunset. Since Kuruma prawns have little tendency to move in schools, it is best to distribute the feed as evenly as possible throughout the entire pond area.

5. Prevention of diseases

From what we know at present, there are at least 30 diseases to which the Kuruma prawn is susceptible. Vibriosis, Fusarium and Microsporidians related diseases occur quite commonly among Kuruma prawn. For some diseases, medicines are sometimes added to the feed. But the use of medicines should be avoided whenever possible, because it has the potential to encourage the production of resistant bacteria. By all means, the best way to control disease is the basic maintenance of proper population intensity and the control of bottom and water quality.

Composite feeds for prawn



As composite feed for prawns, products have been developed that use the sinews and innards of scallop and squid meal as their main ingredients. This maker provides 14 different sizes of feed to cover the growth stages from postlarva to mature prawn. They have also developed nutritionally fortified pellets with vitamins and other ingredients.

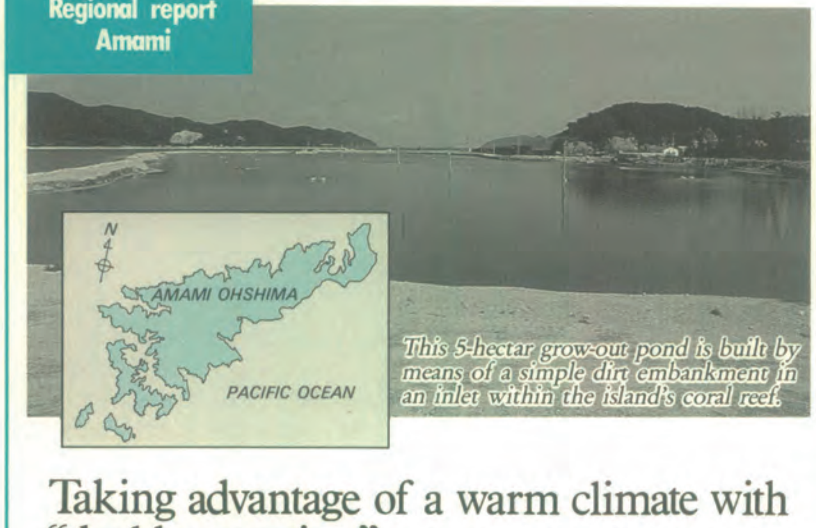
After the harvest is completed, the water is completely drained and the pond allowed to dry out naturally in the sun. If some grooves are made in the bottom sand, sludge will tend to gather there. And making ridges in the bottom sand allows the prawn to find clean surfaces of sand to live on.

A water gate. Outside the gate a fence is built and net strung on it to prevent harmful fish from entering the pond.

A paddle wheel. In addition to contributing to aeration of the water, its motion also helps circulate the water within the pond.

The feed spreading operation. While weaving the boat back and forth across the pond the feed is spread as evenly as possible.

Regional report Amami



This 5-hectar grow-out pond is built by means of a simple dirt embankment in an inlet within the island's coral reef.

Taking advantage of a warm climate with "double cropping"

Dr. Kunihiko Shigeno gathered national and international attention when, as head of the Kagoshima Prefectural Fisheries Experimental Station, he developed the on-land round type culture tank in the late 1960s. After retiring from his official position, Dr. Shigeno established a company to engage in Kuruma prawn culture on Ohshima Island in the Amami archipelago. Having pursued the limits of the biological study of high intensity culture while working at the Experimental Station, Dr. Shigeno intended to put his findings into practice and continue his search for the ideal form of Kuruma prawn culture. In a switch from high-intensity culture, at Amami he decided to experiment with low-intensity culture utilizing a large pond area. The double-bottomed round tank culture facility is a high-consumption facility in terms of both materials and power costs that is no longer suited to the demands of today's society. "All of the circular tank facilities that are still operating profitably today in Kagoshima are ones on which construction was already finished before the onset of the first oil shock," says Dr. Shigeno. He gives three reasons for his decision to undertake culture in large-scale ponds.

1. The running cost is low.
2. The burden of culture control operations is reduced.
3. By reducing the stress on the population, healthier prawns can be raised.

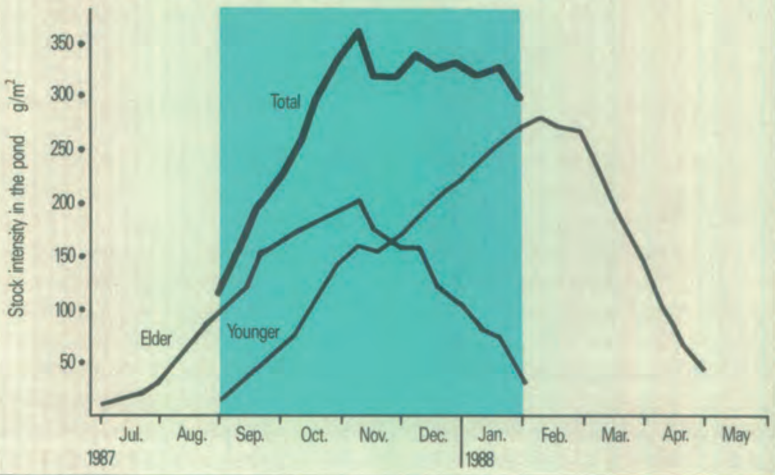
Dr. Shigeno believes that high-intensity culture results in not only the increase of excrements but also an increased interference between individuals in the population that leads to disease and a decrease in feeding efficiency. In choosing sites for his culture ponds, he looked for sites on an outer island that were inlets on the western side of the island which would be less affected by typhoons. In all he chose 12.5 hectar of such inlets and built culture ponds.

«Size of culture grounds»

Pond No.1	3.5 hectar grow-out pond
Pond No.2	1.5 hectar Intermediate nursing pond
Pond No.3	2.5 hectar grow-out pond
Pond No.4	5.0 hectar grow-out pond
Total	12.5 hectar

In four 150-ton water tanks he raises 5～6 million young to the postlarva stage and from these he eventually gets a yearly harvest of 60 tons of Kuruma prawn. The productivity in terms of pond area is a comparatively high level of 5.5 tons/hectar. Although he strictly maintains a population intensity of less than 30 prawns/m^2, he is able to achieve high annual productivity by taking advantage of the warm climate through a year-round culture schedule. As shown in **FIG. 8**, seeds are produced twice a year, in May and August. By releasing the second crop of postlarva into the same grow-out pond as the first, three months later, he is able to keep the population intensity down to the desired level.

FIG. 8 : Double cropping in Kuruma prawn culture



5 Shipment

The Kuruma prawn is a durable species that can survive for up to 10 hours after being taken out of the water. For this reason Japan's cultured Kuruma prawns are all shipped live by air freight to the markets of the major urban centers of Tokyo and Osaka. The demand in these consuming areas comes from high-class restaurants and tempura shops that serve the prawn either as raw sashimi or tempura to gourmet customers at high prices. Because the prawns sold for these purposes must be live, those prawns that die during shipment can only be sold at less than half the price of live ones.

Because live Kuruma prawn cannot be preserved at the marketplace, and because they are a gourmet food for which demand is concentrated around New Years and the flower-viewing season in April, there are large seasonal fluctuations in the market price. Whereas imported frozen prawn sells always between ¥1,700 ~ ¥1,800 per kilogram in the market, live Kuruma prawns are sold throughout the year at ¥5,000 ~ ¥8,000 per kilogram. Live Kuruma prawns and frozen ones therefore, are never the object of competitive price auctioning. **(FIG. 9)**

Another unique characteristic of Japanese Kuruma prawn culture is that each producing area has its own specific season for market shipments. Traditionally, the fishing season for Kuruma prawn caught by gill net and small-scale trawling comes in the warm water months of summer and autumn. Kuruma prawn culture fisheries in the Seto Inland Sea and the Amakusa area, on the other hand, have pursued a policy of beginning their thinning-out harvests in autumn and timing their main shipments of 30 ~ 50 gram prawns in the peak demand season around the end of the year. Because the growth of prawn comes to a stop in winter, and because especially cold weather can often result in weakening and death of the prawns, it is not advantageous to leave the culture pond stocked through the winter season. However, in the warm water areas of Kagoshima, Amami and Okinawa, it is possible to continue feeding and raising during winter. For this reason, these areas target their market shipments for the period from December to April and May. In particular, the months of March and April are a time when no shipments are made from the culture fisheries of the Seto Inland Sea and Amakusa, or from natural prawn fisheries. This fact makes it an excellent period to command high prices for Kuruma prawn shipments. **(FIG. 10)**

FIG. 9 : Market conditions at the Tokyo Central Wholesale Market (1987)

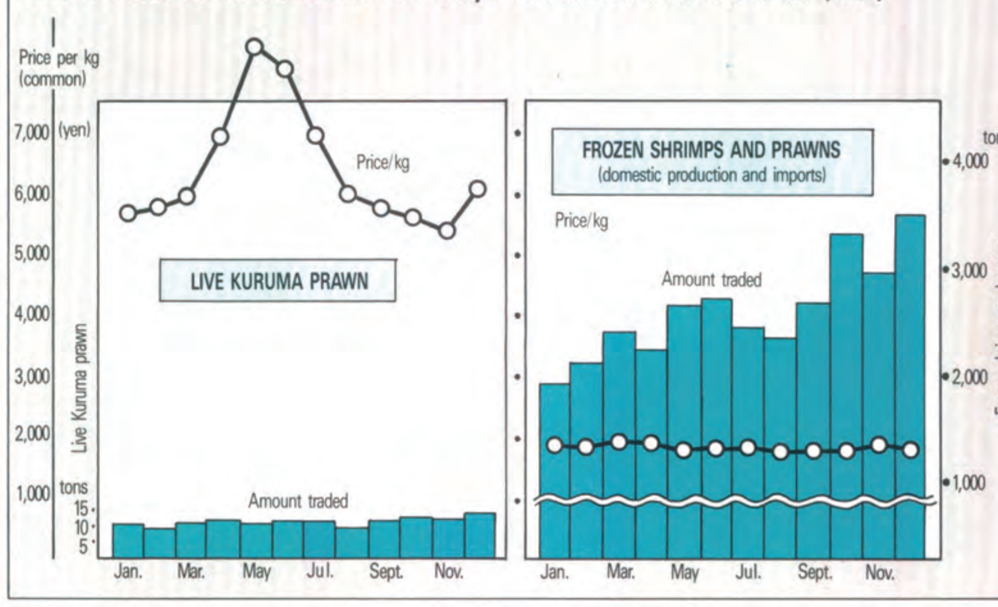
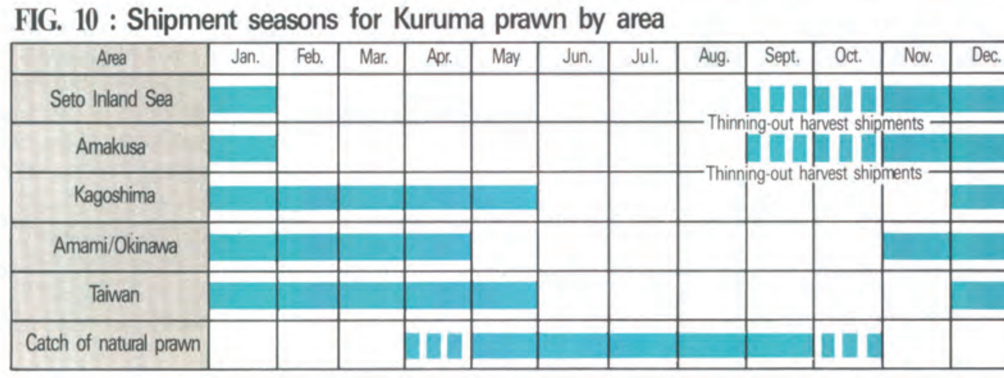
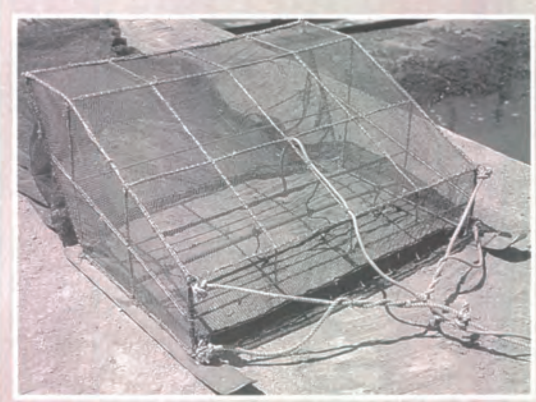


FIG. 10 : Shipment seasons for Kuruma prawn by area




The shipping room

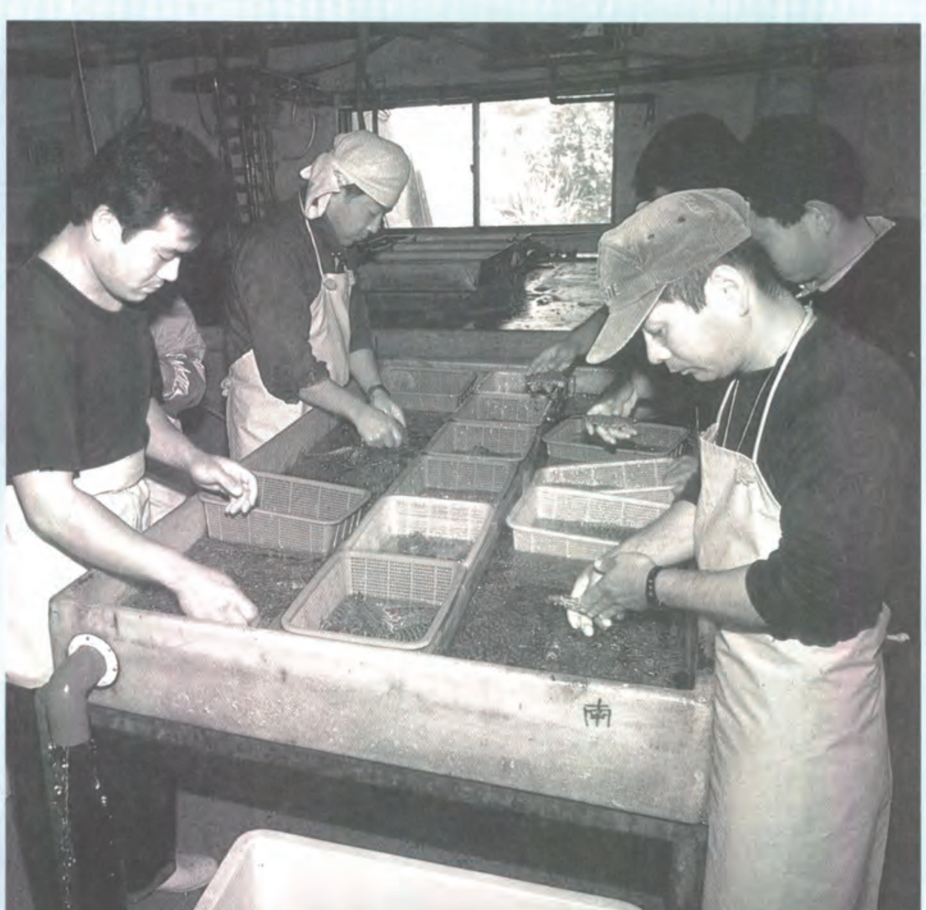
Kuruma prawns that have been harvested are immediately brought to an air conditioned packaging room and placed in a cooling tank. In the cooling tank the water temperature is dropped in stages to about 12°C. Cooling the prawn at this temperature for 20 ~ 30 minutes induces a state of hybernation, after which they are removed to the sorting table. In the sorting process peelers which have just shed and dead prawns are removed and the remaining prawns sorted into small, middle and large sizes. Cardboard shipping boxes are packed up to a given weight with prawns. Before packing, the bottom of the box is lined with dry sawdust that has been well cooled in a refrigerator and additional sawdust is spread over each row of prawns until three layers have been packed into the box. Then the lid is closed.



To harvest the prawn a longline type basket or an "electric net" is used. These traps have the advantage of keeping out peelers that have just shed their skins and allowing prawns that are too small to escape, thereby trapping only prawns suitable for harvest. The electric net functions by sending a 30V, 2A electric shock through the sand from electric terminals fitted on the mouth of the net. The shock causes the prawn to jump out of the sand and get caught in the fore-net. Although they work effectively, there is a fear of reducing the food quality of the prawn because of the electric shocks received.


Kuruma prawn being cooled


Packed in boxes


Sorting

Shipment

Import of frozen shrimp and prawn in Japan

Frozen "consumer packs" of various types of shrimp on display in a supermarket.

Since the removal of trade barriers in 1961, Japanese imports of frozen shrimps and prawns have been constantly on the rise.

In the 1960s, Japanese trading companies began to establish buying routes overseas, and later in 60s and 70s marine producers began to promote a development-and-import program for shrimps and prawns, leading to a steady increase in the size of imports. At the same time, the rising standard of living in Japan resulting from its high economic growth rate also stimulated an increased consumer demand from 1960 to 1970 that supported this growth in imports.

The increase in consumption of shrimps and prawns is largely a result of increased demand from commercial eating-and-drinking establishments. This commercial demand was developed largely through the efforts of middlemen specializing in shrimp and prawn in the Tokyo and Osaka markets. Prior to the removal of tariffs on imports, these middlemen made a business primarily of selling and delivering domestically produced shrimps and prawns to such eating-and-drinking establishments as tempura restaurants, noodle shops and sushi bars. With the growth in business, however, an increasing number of these dealers began to expand into wholesaling activities. At the same time they were directing their efforts at the development of new consumer markets, these shrimp and prawn dealers were also teaching trading company buyers who traveled to the overseas producing areas the fundamentals of sorting and handling methods for shrimp and prawn that would make products more suitable for the Japanese market, thereby aiding their purchasing activities. At present there are five major companies centered in Tokyo or Osaka dealing exclusively with shrimps and prawns that handle 55 ~ 60% of all Japan's imports of frozen products. Entering the 1970s, the commercial demand for shrimps and prawns grew further with the trend toward more eating out, stimulated by the spread of family-style restaurants. This was also accompanied by increased retail sales for home use. This growth in retail sales can be attributed largely to the fact that large supermarket chains began selling shrimps and prawns as important items in their perishables departments.

The growth of retail sales also led to a system by which large volume imported frozen products were defrosted once, repackaged in small "consumer packs", refrozen and then placed in the stores.

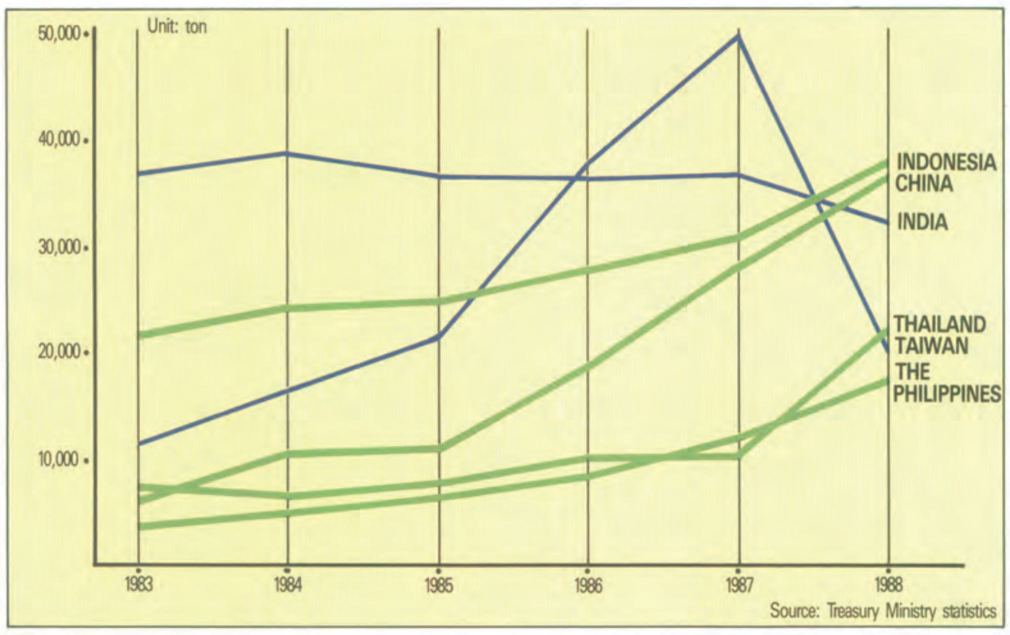
Since 1980, there has been a constant overstock of shrimps and prawns. As a result, there is less speculation involved in pricing for frozen imports in the domestic distribution network and the price of these products for the mass market has become stabilized. In recent years, the major trends in the Japanese shrimp and prawn market are an increase in the variety of species among the frozen imports, including cold-water shrimps, and an increased supply of middle-sized prawns resulting from the spread of culture fisheries.

In the 1970s, the ratio of commercial demand and retail demand was accepted to be about 70% vs. 30%. In recent years that ratio is believed to be closer to 55% vs. 45%, showing a strong increase in retail sales.

The following shows details of the status of import products. **(TABLE 5)** Of note is the fact that since 1987 imports of cultured shrimps and prawns have surpassed the fishery production of natural shrimps and prawns.

The frozen shrimps and prawns imported by Japan can be divided into three types; whole shrimp, shrimp without the head and shelled shrimp. Of these, headless shrimps account for 60% of the total. The purposes for which these shrimps and prawns are used differ clearly with the size of the shrimp. Shrimp with an international rating of 16 ~ 20 or larger are sold to tempura restaurants and noodle shops, middle-size shrimp with a 21 ~ 25 rating and small-size shrimp go for home-use retail sales.

FIG. 11 : Exports of frozen shrimps and prawns to Japan
(The 6 major producing nations)



Source: Treasury Ministry statistics

TABLE 5 : Shrimps and prawns imported by Japan (1988)

Types of import commodities	Tonnage	Value (million yen)
Frozen	258,232	327,202
Live, fresh or chilled	1,961	4,253
Dried, salted or in brine	1,107	629
Total	261,300	332,084

Source: Treasury Ministry Statistics

A wholesale shop in the Tsukiji Market, Tokyo

In 1988, 52 countries exported shrimps and prawns to Japan. The following are the main suppliers of frozen shrimps and prawns.

Concerning Panaeid prawns, the ten leading countries were Indonesia (39,000 tons), China (38,000 tons), India (32,000 tons), Thailand (22,000 tons), Taiwan (21,000 tons), the Philippines (19,000 tons), Vietnam (16,000 tons), Australia (9,000 tons), Bangladesh (6,000 tons) and Madagascar (3,000 tons).

The first ventures in the import of cold-water Pandalid shrimp began in the mid 1970s, and began on a full scale in about 1982. At present the annual volume is about 30,000 tons. The main suppliers are Greenland (13,900 tons). Norway (3,800 tons), Iceland (3,600 tons) Argentina (3,300 tons), Denmark (2,700 tons), etc.