

## Economics of Shrimp Culture in Asia

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**Abstract** There is a common belief that the demand for shrimp is so strong that the future of shrimp culture is very bright. However, there is a problem here. The Japanese market for shrimp has been expanding over the past 20 years, and the amount of imported shrimp has reached its ceiling. Since 1980, the amount imported has been 160,000 tons with some allowance. It will be rather difficult to exceed this level with the present price. It is very clear that if imports of shrimp rise above this level, inventory will rapidly increase and price will go down severely. Considering this situation, it is very important to reduce the cost of cultured shrimp because of severe competition in the market.

Various shrimp culture systems in Japan and Southeast Asia are described. They range from extensive to intensive systems. An analysis of their economics reveals some interesting facts. The downward trend of the rate of cost per kilogram in intensive culture is very slow compared to those in extensive and semi-intensive culture while the productivity is rising. This is because in intensive pond culture, the ratio of variable cost to total cost is rather high and variable cost does not change as the productivity rises. In the case of extensive pond culture, the ratio of fixed cost to total cost is rather high, so the decrease in fixed cost per kilogram is very high in accordance with the rise of productivity. Therefore, by simply increasing the productivity slightly, the extensive pond can cut its production cost significantly. If the price of shrimp in the market goes down, the intensive pond system will face extinction since it is difficult to cut production cost.

Cost forecast for cultured shrimp seems to indicate that extensive and semi-intensive methods will become dominant in the Asian region. Presently, productivity of these systems are low but can be greatly improved by using the "continuing method" and "circulating method" of pond management. The continuing method calls for stocking of different-sized shrimp which will be harvested on a staggered basis. The circulating method employs various sizes of compartments and the stock is moved from densely stocked small compartments to progressively larger grow-out ponds.

There has been a rapid expansion of tiger shrimp culture in Taiwan and Southeast Asia recently for the following reasons: (1) high growth rate; (2) high price and broad market; (3) development of technology for hatching and rearing of seedling; and (4) comparative ease with which technical help in culture is obtained from Taiwan and Japan. However, there is a significant demerit. It is not easy in some regions to obtain seedling due to their high price. The supply of seedling of tiger shrimp is absolutely insufficient because of the shortage of mature shrimp. On the other hand, it is easy to get white shrimp seedling at a low price in these regions. In addition to this, the growth rate of white shrimp is similar up to a body length of 12-13 cm in 80-90 days rearing. Cheap cost and a large supply of seedling will easily compensate for the small size. It is therefore important to expand white shrimp culture in Asia. The bright future of white shrimp due to its low production cost is presented in this paper with some data and calculations.

### Demand and supply of shrimp

The total world population of wild shrimp from the sea has increased steadily from 439,000 tons in 1948 to 1.655 million tons in 1977, and has kept about the same production level since then. There is a common belief that due to over-exploitation of shrimp stocks, shrimp production from wild stocks will not increase much in the future. While there may of course be unexploited shrimp resources in the sea, additional shrimp catches from these sources will probably be more than offset by decreases in catches from over-exploited fishing grounds.

In addition, there is a widespread belief that the demand for shrimp is very strong and that it will continue to increase in the future. The basis for this idea is that the price of shrimp will rise due to the shortage of supply. Shrimp culture is expected to fill this gap in supply and demand. The rapid expansion in shrimp culture in Ecuador and Taiwan tends to support this belief.

There is much land suitable for shrimp culture in both tropical and subtropical Asia. Shrimp culture in this region has a long history as a co-product of milkfish culture. More recently, ponds previously specialized for milkfish culture have been converted to shrimp culture. This has resulted in the development of numerous new shrimp pond designs.

There is no problem in this industry's growth if the demand for shrimp is as strong as popular opinion has it. However, who can tell if this assumption is right? For example, take the situation of the Japanese shrimp market. Japan is an important importer of shrimp. Most of the shrimp exported to Japan comes from Asia.

Prior to examining the relationship between shrimp demand and supply in Japan it may be helpful to examine the relationship between supply and demand of cultured yellowtail (*Seriola quinqueradiata*) in Japan. The price as well as total production of cultured yellowtail increased from 1967 to 1975. Fig. 1 shows that the demand for cultured yellowtail

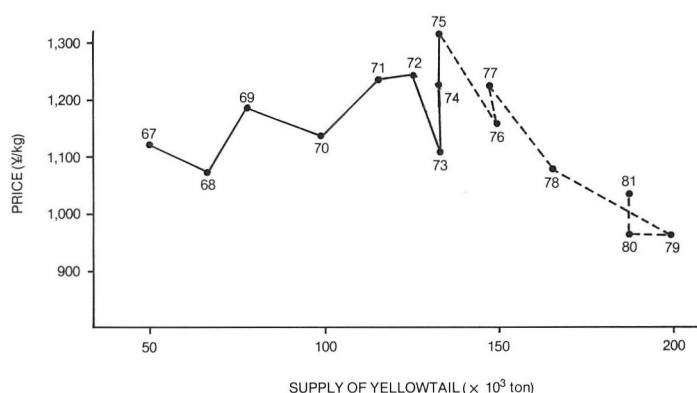


Fig. 1. Relationship between supply and price (deflated by prices in 1980) of cultured yellowtail in Japan. Source: Association of Marine Ranching.

was very strong during this period. However, after 1975, increased production resulted in decreases in price. Supply was greater than demand. Production decreases resulted as some culturists had to stop their operations. In addition, yellowtail culturists were asked to cut their production to a suitable level to stabilize the price of this cultured fish.

In the case of kuruma shrimp (*Penaeus japonicus*) culture in Japan, the relationship between supply and price is quite different (Fig. 2). There are three demand curves in the figures: first is from 1965 to 1972, second from 1973 to 1981 and third, after 1982. These three demand curves have been shifting towards the right. This suggests that the demand for kuruma shrimp is very strong. Thus, either the price will keep the same level despite a large production increase or culturists can expect the trend of higher price to continue in spite of production increases.

Total production of kuruma shrimp in Japan is about 2,000 tons. They are shipped to the market live. However, because of its extravagant price, kuruma shrimp is hardly consumed at home.

Since the Oil Crisis, especially the second one, the yearly

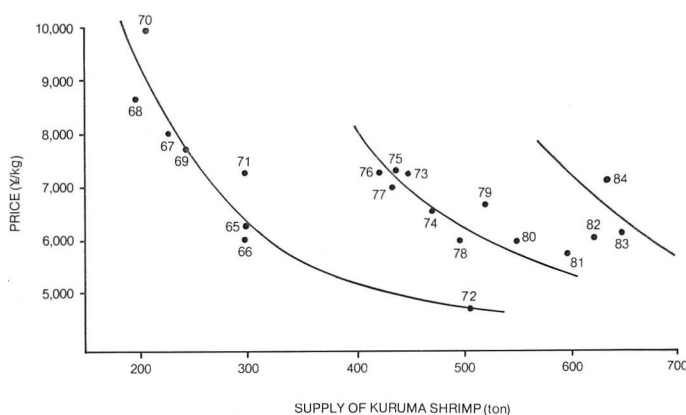


Fig. 2. Relationship between supply and price (deflated by prices in 1980) of cultured kuruma shrimp in Japan. Source: Tsukiji Central Fish Market, Tokyo.

increase in consumer's expenditure per capita in real terms has become stable averaging 2-3% and the value of the consumption became stable during the same time. The reason why the demand for cultured shrimp, a luxury food, has been increasing in this economically stagnant period is complex, and is beyond the scope of this review.

The situation as to the supply and demand of imported frozen shrimp is different. Total imports increased from 20,000 tons in 1965 to 164,000 tons in 1979. After that period they became stable at about 160,000-170,000 tons. On the other hand, the price of imported shrimp increased up to 1972 notwithstanding the increase of imports, but dropped considerably from 1973 to 1975 and since then has fluctuated severely (Fig. 3).

Figure 4 shows the monthly relationship between the amount of imports, price and inventory. It is very clear that since 1982, if imports increase, the amount of inventory will also increase and the price will decrease.

The inventory of imported frozen shrimp in the 1970's was under 20,000 tons and would hardly have influenced the price level. However, the inventory has reached a level of 50,000 tons recently. From 1980 to 1984 the amount of imports has been fairly stable, and only the inventory has increased yearly. This shows that it is becoming difficult to sell frozen shrimp in the Japanese market while keeping the same price level during import increases.

Consumption of imported shrimp is divided into two markets, one out-of-home and the other at-home. Out-of-home consumption seems to have reached its quantitative limit recently (Fig. 5). Thus, there may be little possibility of increasing consumption in quantity at the present price and, although at-home demand is strong, it is not expected to expand further due to the present high price compared to other foods. As Fig. 6 shows, the income elasticity of shrimp is very high compared to other animal protein foods. In Fig. 6, 1.0 in elasticity, for instance, means that if income goes up 10%, consumption of food will increase by 10% in value at home. However, quantity of home consumption has been fairly stable since 1980, so shrimp price must be lowered in order to enlarge its consumption in the present food market in Japan. The intake of animal protein per capita in Japan has reached its ceiling, so that an increase in consumption of one food will be at the expense of another. At present, the competition between animal protein foods is very severe. In these market conditions, price becomes very important in promoting shrimp against other foods. Considering the high price elasticity of shrimp at-home, consumption is sure to increase with a little drop of price.

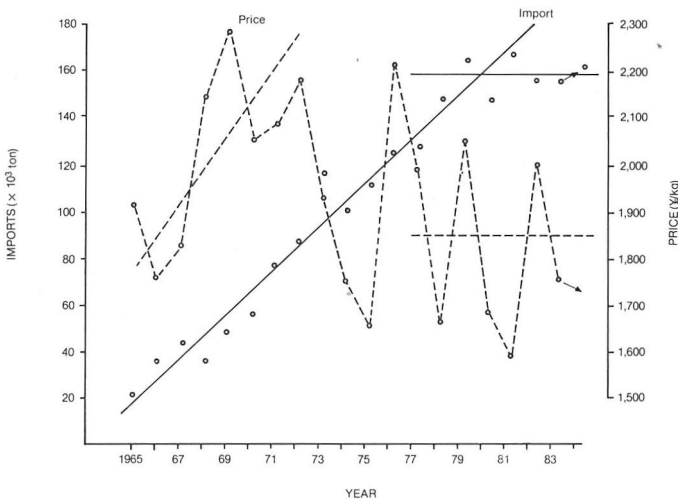
In contrast to the stagnation of the Japanese market, the shrimp market in the U.S.A. has shown rapid expansion since 1982 (Fig. 7). There are two reasons for this: one is a drop in domestic shrimp production (catch fishery) and the other is the increase of exports from Ecuador and Mexico to the U.S.A.

The per capita intake of shrimp has been increasing recently, so exports to the U.S.A. can be expected to increase compared to that of Japan. However, one item to bear in mind is that the intake of fish in the U.S.A. increased in the latter half of the 1960's because of advertisement that fish is better

for health. The demand for fish, however, has become stagnant since 1977 due to their high prices. At present, the price of many fishes are higher than beef. On the other hand, the intake of chicken has continued to increase at its stable price. So even in the U.S.A., price competition in the animal protein market has been severe.

In Europe and other areas, the market for shrimp is expanding, but the size of these markets is still small. Despite the probable decrease in the production of shrimp from the sea, the total supply may increase owing to the worldwide development of shrimp culture.

The especially favourable economic situation in which the consumption and price increased simultaneously will disappear in the near future. There has been a seller's market for shrimp for so long that the "shrimp myth" has become ingrained in many people. The myth is that the price of shrimp will go up forever as if the demand is limitless. As a result, the recent severe fluctuations of price in Japan caused by the imbalance of supply and demand during periods of low price, has given rise to the wrong idea that these fluctuations are



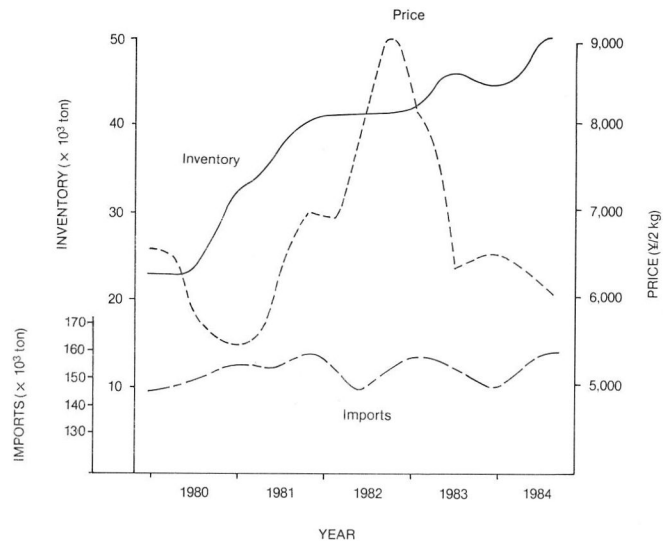
**Fig. 3.** Relationship between quantity of imported frozen shrimp and price (deflated by prices in 1980) in Japan. Source: Fisheries Agency of Japan.

caused by the intrigues of traders and intermediates in the distribution channels. In fact, this severe fluctuation shows that the market is beginning to saturate, when only a shift of supply will cause a severe drop in price. Considering the situation, in order to increase export to Japan and other markets, it is most important to cut the production cost, as the demand based on the present price is now nearing a stable state.

**Natural productivity in pond culture**

In aquaculture, especially in pond culture, the use of natural productivity is very important in minimizing production cost. The case of kuruma shrimp culture will be illustrated first.

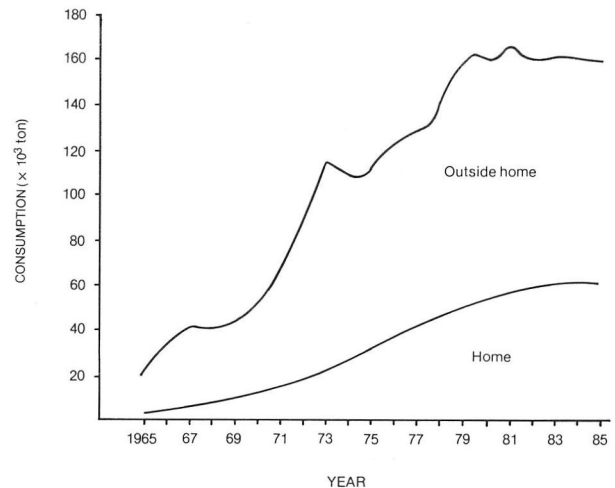
There are three main production centers of kuruma shrimp culture in Japan. In each, the method of culture is different. This results from differences in the growing conditions of



**Fig. 4.** Relationship between imports, inventory and price of imported shrimp (India white shrimp at 16-21 pcs/lb) in Japan. Source: Fisheries Agency in Japan.

shrimp and in economic differences between culture firms in each area. The ponds in the Seto Inland Sea area (type A, pool type on land) have been converted mainly from salt fields no longer in use (Fig. 8). The ponds in the Amakusa area (type B) are constructed in the sea with a concrete dike topped by standing wire-nets. The ponds in the Kagoshima area (type C) are of the circular type on land with water change by pumps.

Although each type of shrimp culture in Japan could be said to be intensive from a general point of view, types A and B are really semi-intensive by Japanese standards. Type C is intensive. The productivity of types A and B is roughly 400-700 g/m<sup>2</sup>. Change of water is produced by tidal movement in types A and B, and rate of change is about 20-90%/day. On the other hand, water in type C is completely changed 3 or 4 times/day. With the large supply of oxygen,



**Fig. 5.** Domestic consumption of imported shrimp in Japan. Source: Field survey.

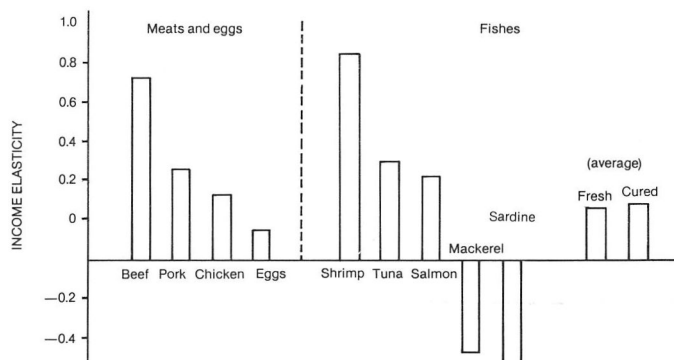


Fig. 6. Income elasticity of meats and fishes in Japan, 1981.

Source: Statistics of home consumption by Japanese Central Government.

high density culture becomes possible. Moreover, with the development of special artificial feeds about 15 years ago, super-intensive culture has been realized.

Before the 1960's, there were many salt fields in the Seto Inland Sea area which were becoming underutilized due to technical innovations in the salt industry. Many of the culturists in the area were able to procure land at a comparatively cheap price. At present, land price is very high, so the construction of new type A ponds is not economical. The main characteristic of type A ponds is that culture technique is aimed at diatom production. Since diatoms do not grow well with either too much or too little water entering the pond, optimum growth is achieved by regulating the water change. In a pond with good diatom growth, the water colour is dark brown. Production of 40 g shrimp (2 pcs/m<sup>2</sup>) without any supplementary feed is possible. This is because diatoms supply oxygen, and animal plankton and detritus (feed for shrimp) are produced naturally. In addition, luxuriant diatom growth may prevent the growth of harmful algae in the pond. Good production conditions for shrimp are thus maintained. For these reasons, the food conversion ratio from feed to shrimp is very low compared to the type C culture system (Table 1).

Type B pond is built along the shore. In the Amakusa area, tidal movement is wide (5-6 m). In the past, the construction cost of a pool type pond with a high concrete dike was prohibitive. Therefore, culturists make low concrete dikes and

set iron piles on them with a wire-net spread between piles to contain the shrimp. At high and low tide the water flows freely in and out of the pond through the nets. The rate of water change is much higher than type A ponds, but regulation of water is difficult. The supply of oxygen to this pond is greater than to type A due to the large amount of inflowing water. However, diatom growth is not as good due to limited water control. The total supply of oxygen is about the same level as type A, so the productivity per square meter is also similar. As the amount of diatoms in this pond is low, the growth of natural feed is smaller than in type A. Accordingly, the conversion ratio is high in this pond and the production cost is high compared to type A.

In the Kagoshima area, it is not possible to build either type A or B ponds due to geographical features. In order to cope with high land prices and wages, high intensive and labour saving facilities had to be designed. All knowledge and techniques in aquaculture, not only in shrimp culture but also other cultures, were utilized in the design of type C ponds. The type C method leads to high production cost per kilogram compared to types A and B because of the high-priced feed and the high feed conversion ratio. In type C, the use of high quality feed makes high density culture possible, but the high rate of water change limits diatom growth. In addition, feed conversion is not good at a high density. Type C neglects natural productivity and is dependent on artificial feeds. This results in high production cost (Table 2).

It is a common belief that the high production cost of this type is due to the high cost of pond construction and other facilities, but this is not true. Even if the fixed cost per unit area is very high, the fixed cost per kilogram of shrimp is lower in type C than in types A and B due to higher productivity per square meter in type C. The high production cost mainly comes from the high conversion ratio and the high price of feed per unit and high electricity. These costs are a consequence of highly artificial techniques ignoring the benefit of natural productivity.

Thus as the use of natural productivity in aquaculture in temperate areas (Japan) is important, it is very clear that it is especially important in aquaculture in Asia. This is because the natural productivity of ponds in tropical and subtropical areas is higher than in temperate areas.

Table 1. Three types of kuruma shrimp culture in Japan.

	Type of pond	Dimension (ha)	Rate of water change (%/day)	Productivity (g/m <sup>2</sup> )		Feed conversion ratio
				Present level	Target at present	
Type A						
I	Pool pond on land	1-5	0.25	300-500	600-800	10-12
II		0.5-1	0.5	400-600	800-1,000	13-15
Type B	Pool pond in the sea	0.5-1	0.9	300-500	600-800	13-15
Type C	Circular pond on land	0.1	4.0	1,500-2,000	3,000-3,500	17-20

Source: Hirasawa, Y. and J. Walford. 1979. The economics of kuruma-ebi shrimp farming. Advances in Aquaculture, FAO. (With modifications by Y.H.)

Note: 1. Some farms are approaching the target productivities.

2. Conversion ratio is based on raw fish. One kg of artificial feed equals 6 kg of raw fish.

Before pursuing this theme, it is best to explain the reason for the existence of different types of culture methods in Japan. In general, a firm operating with a high production cost cannot stay in business in the long run. However, shrimps in ponds in the Seto Inland Sea cannot be overwintered because of low water temperature. Therefore, culturists in this area have to harvest and market shrimp at the end of the year when the price of shrimp is rather low (Fig. 9).

The water temperature in the Amakusa area is a little higher than in the Seto Inland Sea. Here, shrimp can survive the winter in a state of hibernation. Culturists are able to ship shrimps from January to March, having waited for the price recovery after shipments from the Seto Inland Sea. However, the physical strength of these shrimp is poor because the shrimp fast until the middle of March. In addition, shipment of live shrimp requires that shrimp hibernate again. This results in lower survival rates of shrimps transported during this period. Therefore, culturists in Amakusa complete most of their shipments between January and March.

The ponds in the Kagoshima area have a warmer water temperature than those in Amakusa due to the warm Kuroshio current that follows the coast. Thus, shrimp in type C ponds are healthy even in winter since they do not stop feeding. From April to May, the price of cultured shrimp is highest, because at this time of year there are no marketable shrimp from the Seto Inland Sea or Amakusa area and there are no live shrimp caught by fishing boats. The months of April and May are the best time for family outings, and demand for luxury foods becomes high. The supply of live shrimp from Kagoshima fills this market. The type C farms are able to concentrate all their shipment aimed at this period of extra-high price (Fig. 9).

Accordingly, type C ponds can co-exist with types A and B

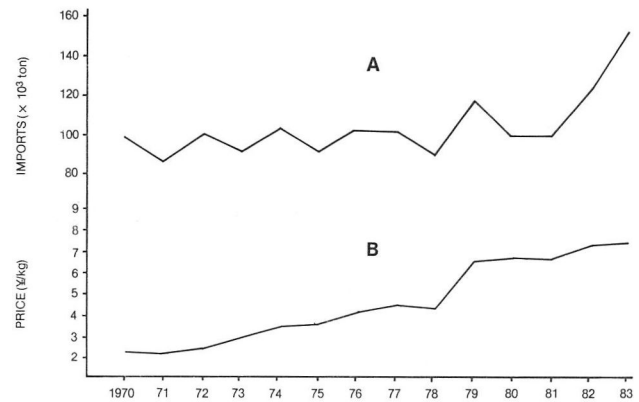


Fig. 7. Amount of imported shrimp (A) and price (B) in the U.S.A. Source: U.S.A. Fisheries Statistics by NMFS.

because they enjoy a higher sale price that offsets their higher costs. There is a trend toward constructing new culture ponds due to the high demand for live kuruma shrimp. However, there is no possibility of making ponds of types A or C, as land costs for the former are too high, and the latter is not efficient from an economic point of view. The new ponds which will be built hereafter may be a combination of types A and B. This new pond will have a lower land cost due to construction in the sea just like type B. However, it will have a high dike and will not use wire-netting. Complete control of water flow will result in high utilization of natural productivity as in type A. The construction cost of these new ponds, pool-type in the sea, is of course higher than that of type B, but the production cost per kilogram is lower than type B. There are many suitable places for the new ponds because they can be located in the sea along the shore.

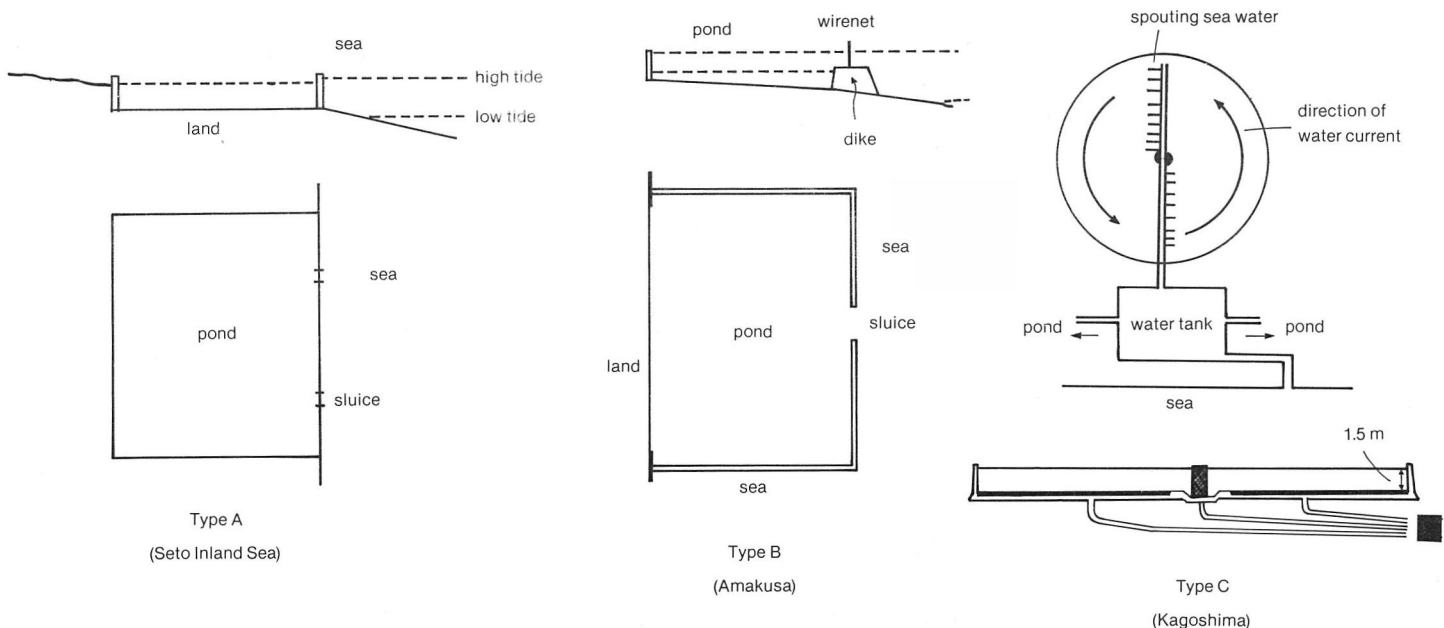
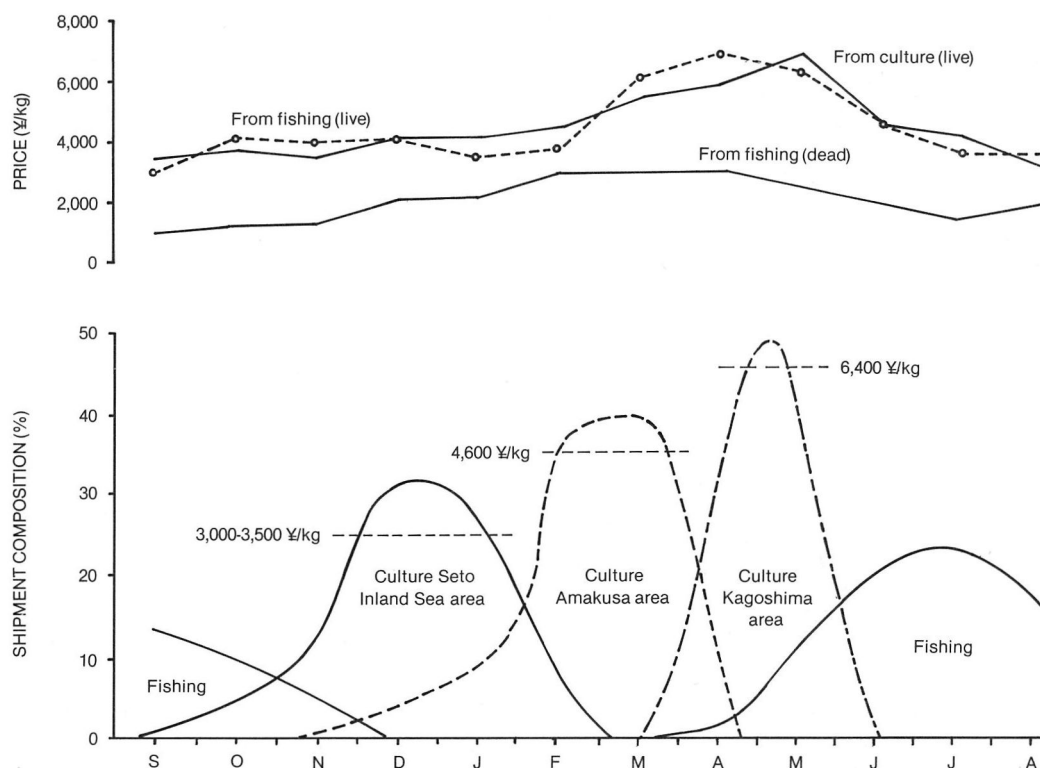


Fig. 8. Structure of different types of kuruma shrimp culture ponds in Japan.



**Fig. 9.** Price of kuruma shrimp (¥/kg) and monthly composition of shipment versus total shipment per year (%) from a given area. Source: Hirasawa, Y. and J. Walford, 1979. The economics of kuruma-ebi shrimp farming. Advances in aquaculture, FAO.

### Types of shrimp culture in Asia

Although there are many different methods of shrimp culture in Asia, they can be classified into the following (Fig. 10):

- A. Trapping pond culture — extensive
- B. Pond culture not specialized in any one species — extensive
  - B-1. Milkfish pond
  - B-2. Salt field pond
  - B-3. Paddy field pond
  - B-4. Pond in delta area
- C. Pond culture specializing mainly in one species — semi-intensive
- D. Pond culture specializing in only one species — intensive

Although there are many ways of defining culture methods as extensive or intensive, in this case, the following will be used:

**Extensive** — Water change, supply of seedling, and feeding are done naturally. Productivity is usually under 200kg/ha including fish.

**Semi-intensive** — Some human work is involved in the above operations.

**Intensive** — The above three operations are carried out by artificial means. Productivity is usually over 3,000 kg/ha.

**Table 2.** Typical example of cost per kilogram in kuruma shrimp culture in Japan, (from field survey).

	Type A	Type B	Type C
Selling price (¥)	6,000	6,500	7,000
Cost (¥)	4,500	5,000	5,600
feed	1,540	1,800	2,400
seedling	60	100	250
wages	1,000	1,000	500
shipment	410	420	450
repair	300	500	600
electricity	100	100	670
rent	50	10	10
depreciation	200	300	150
management and others	840	770	570
Productivity (g/m <sup>2</sup> )	600	6000	3,000
Conversion ratio	12	14	18

### A. Trapping pond culture — extensive

This pond makes use of natural topography and has a sluice gate which can be opened to allow nocturnal shrimp and seedlings into the pond during high tide. After one or two months, when many shrimps have accumulated and have grown a little in the pond, the sluice is again opened fully in the daytime during the lowest tide of the month and shrimp are caught through a trap net behind the sluice. The various species of shrimp and fish caught by this method are mostly of a small size. Many shrimps die and are damaged by the high water pressure and thus their market price is not very high. On the other hand, the operating cost is very small as little manpower is required, once the sluice and pond have been constructed. This method might be described not as aquaculture but as pond-fishing.

At present there are few farms of this type and it is difficult to obtain production data. The exact figures for one farm can be presented. The farm, operated by Dr. Kim C-M., existed two years ago in the southwest part of the Johor Bahru district of Malaysia and had a total of 32 ha of pond area. The average productivity was 167 kg/ha, but this becomes 250 kg/ha when the unused part of the pond is excluded (Tables 3-5). He has stopped his operation and his pond has now become semi-intensive.

### B. Pond culture — extensive

**B-1. Milkfish pond.** This type of pond has a long history as by-product of milkfish culture in the Philippines, Indonesia, Taiwan, etc. The seedlings of shrimp together with milkfish fry enter into the pond through rough bamboo screens at particular times of the year. Although production of 100 kg/ha can be achieved, the productivity of this type of system is usually 50-60 kg/ha.

**B-2. Salt field pond.** Ponds of this type were made from old salt fields and are very numerous in the southern part of Bangkok, Thailand. The pond beds are flat and there are usually two sluices on opposite sides, an intake and an outflow. The force of outflowing water is not very strong, so shrimp can be caught live in cages at the sluice every day, young shrimp being returned to the pond again. As ponds of this type are generally well prepared for culture, the productivity is comparatively high (100-200 kg/ha). More recently, the practice of pumping water at the sluice has been tried. The productivity of these ponds increases two-fold due to a decrease in predators and their damaging effects. The main product of this type of pond is white shrimp, *Penaeus merguensis*, in Thailand. Small shrimps produced naturally are often used as feed for larger ones.

**B-3. Paddy field pond.** After harvest, rice paddy fields are converted to shrimp ponds for the rainy season (November to May), along the southern part of the Indian coast. Sometimes, when culture goes very well, 400 kg/ha can be expected which gives a profit of over two times that of rice culture. However, due to predation the productivity is usually under 200 kg/ha.

**B-4. Pond in delta area.** This type of pond is constructed in flat delta areas where it is easy to build by construction of an earth dike. There have been many such ponds constructed recently in the estuary of the Ganges River in India due to the bright prospects for shrimp farming. Ponds of this type

are rather small in size, but are well arranged for culture. Fig.

11 shows the pond areas in the estuary of the Pontevedra River near Roxas City, Panay Island, Philippines, since 1975. As a result of making ponds, wide areas of the estuary have disappeared. As ponds of this type are located in comparatively good sites, the productivity is fairly high compared to other types of extensive culture. Just as the merit of extensive farming is the ability to save costs and labor, the largest demerit is the difficulty of preventing damage by predators. Often a large population of predators is supported by the shrimp. If predators were prevented from entering the ponds, 400 kg/ha could be expected. Measures to prevent the entrance of predators into the pond are available. Moreover, when the ponds are well managed and are given sufficient fertilizer to grow food-plants before the stocking of seedlings, and the continuing or circulating method of pond use is applied, it may be possible to produce twice as many shrimp a year.

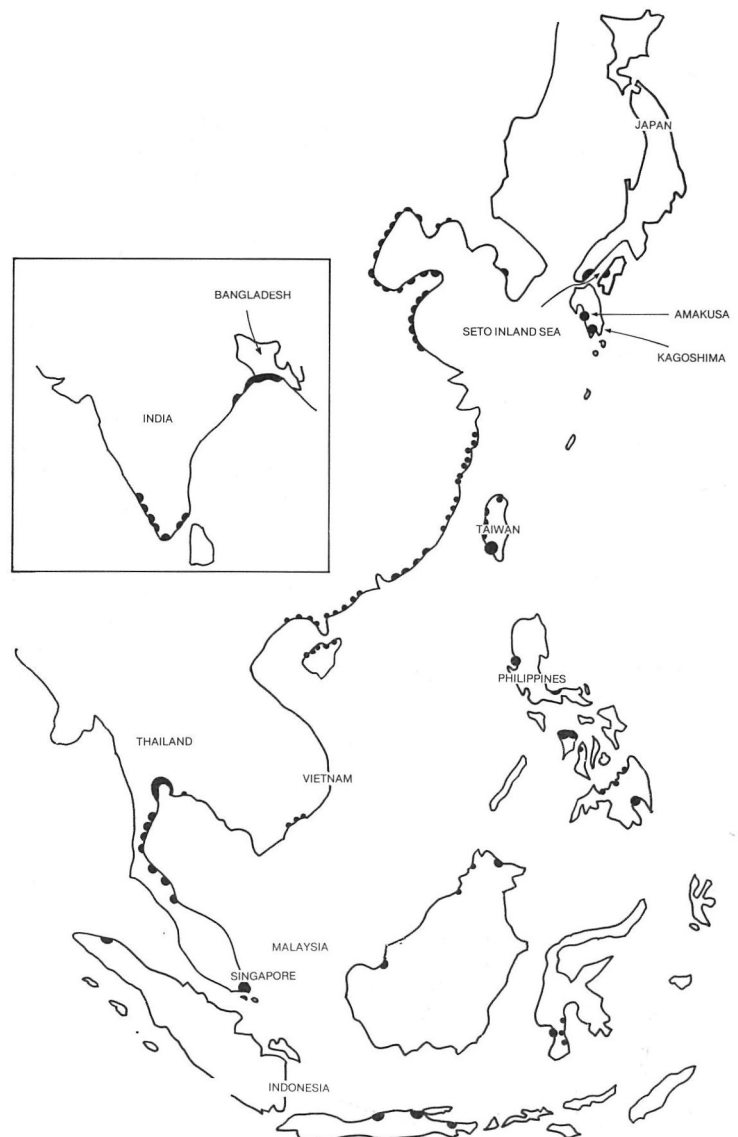


Fig. 10. Map of shrimp culture in Asia. Shaded areas denote location of farms.

**Table 3.** Production of Dr. Kim D-M's trapping pond, Johor Bahru, Malaysia.

	Quantity				Value			
	1980		1981		1980		1981	
	kg	%	kg	%	MS	%	M\$	%
Total	4,527	100.0	5,375	100.0	34,855	100.0	41,923	100.0
Tiger shrimp	50	1.1	128	2.4	1,002	2.9	2,178	5.2
White shrimp	1,120	24.7	1,231	22.9	18,727	53.7	19,935	47.6
Medium-sized shrimp	332	7.3	328	6.1	3,189	9.2	3,183	7.6
Small-sized shrimp	1,311	29.0	1,549	28.8	7,801	22.4	11,015	26.3
Red shrimp	1,714	37.9	2,139	39.8	4,135	11.9	5,612	13.4

### C. Pond culture — semi-intensive

A semi-intensive culture, as opposed to an extensive culture, is one in which the seedlings are bought from artisanal fishermen after being caught along the coast. They are put into the ponds where supplementary feed of trash fish is given. Semi-intensive ponds also require a sluice and ditch in order to manage a good rate of water change.

There are many types of semi-intensive culture, varying in the quantity of seedlings, the supply of feeds, and the degree of management of the ponds. Culture types B-1 to B-4 mentioned above may be shifted to semi-intensive culture while retaining basic characteristics. Because a small pond is more easily managed than a larger one, there is a common trend for the size of ponds to become smaller upon entering into the semi-intensive stage. While a pond may easily cover 10 ha when extensively farmed, it usually becomes 3-5 ha when converted to semi-intensive use (as in the Philippines).

In proceeding with the functionalization of the pond, one part becomes specialized as a nursery area. The purpose of the nursery pond is to increase both the survival and growth rates of seedlings by special care. Fingerlings of about 5 cm size become marketable after 3 months in tiger shrimp culture.

As already mentioned for extensive culture, eggs and seedlings of predators may enter the ponds. As their growth rate is faster than that of shrimp, predators will eat the shrimpy

**Table 4.** White shrimp production (kg) in Dr. Kim's Farm, Johor Bahru, Malaysia.

Duration of harvest	Number of harvest						Total
	1	2	3	4	5	6	
Jan. 31-Feb. 3	18.9	38.1	29.7	24.0			110.7
Feb. 5-8	20.4	37.2	46.5	25.2			129.3
Mar. 3-6	29.1	27.3	19.8	19.8			96.0
Apr. 4-8	26.7	40.8	30.0	27.3	40.5		165.3
May 1-6	21.6	15.3	9.6	14.1	12.0		72.6
Jun. 2-8	28.5	27.9	18.9	12.6	7.8		95.7
Jul. 19-21	16.5	33.3	39.3	31.8			120.9
Aug. 1-4	69.6	56.7	22.8	37.2			186.3
Sep. 24-30	13.8	20.1	16.5	4.2	16.5	4.8	75.9
Oct. 25-29	11.4	10.8	5.7	6.3	14.1		48.3
Nov. 23-27	10.2	12.6	12.6	24.0	10.5		69.9
Dec. 23-27	9.6	13.2	12.0	15.9	9.6		60.3
Ave.	22.9	27.8	22.9	20.2	15.8	4.8	102.6

after 2-3 months rearing. The low productivity of extensive culture is mainly due to this problem. However, this can be improved by dividing ponds into appropriate sections. It is possible to prevent predators in the nursery pond. Fingerlings transferred from the nursery pond first to small growing ponds are fairly safe from small predators. When small predators become big enough to eat the small shrimp, the latter have to be shifted again to a second, comparatively larger growing pond. In this pond, medium- and large-sized shrimp can eat eggs and larvae of predators. Thus, it is very easy to prevent damage by predators by simply dividing ponds into suitable sizes and transferring shrimp from pond to pond.

In semi-intensive culture, if a pond is prepared and managed well, a productivity of 500-1,000 kg/crop is possible. In tropical and subtropical areas there are two seasons, the dry and rainy, of which the rainy season is suitable for culture in many places. If ponds make use of either continuing or circulating methods, it is possible to harvest three times in one culture season.

As farms become more semi-intensive, they tend to specialize in only one species of shrimp. At present, however, when shrimp are cultured with milkfish in semi-intensive ponds as in the Philippines, it is not to increase the production of the fish, but to prevent the over-growth of feed plants, such as lab-lab.

### D. Pond culture — intensive

Intensive culture has much variety in its methods and the borderline with semi-intensive culture is not always clear. It is, however, possible to say that a culture is intensive if the change of water, amount of supplementary feeding, and stocking of seedlings are controlled by the operator. These three factors are regulated by the sophistication of techniques available.

The most basic of these three requirements is the change of water. The biomass that can be cultured within a given space is dependent on the dissolved oxygen concentration in water. The number of seedlings and the amount of feed are also dependent on the amount of oxygen available. The relationship is especially clear in pond culture. The continuing and circulating methods of pond use are both designed with the aim of using oxygen in the pond more efficiently.

The Kagoshima type C culture has a productivity of about 25-30 ton/ha despite the growth of shrimps almost stopping during winter. The highest productivity in the Asian area besides Japan is that achieved by culturists in Tungkang, Taiwan. An average production of 15 ton/ha has been achieved.



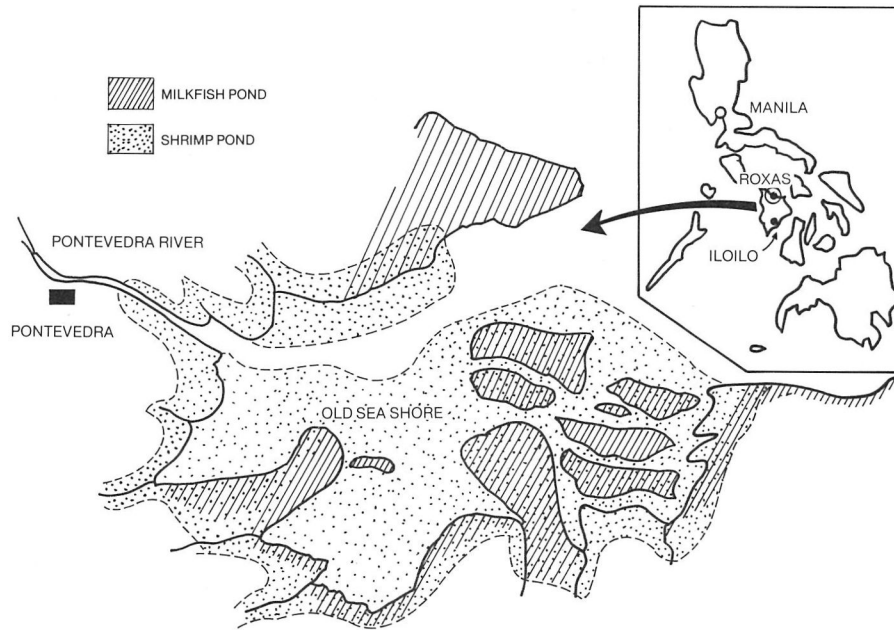


Fig. 11. Distribution of shrimp ponds in the Tinagong Dagat Inlet area near Roxas City, Panay Island, Philippines.

The key to reaching such a high level of productivity as in the Taiwan method is the ability to change water in a very short time (Fig. 12). It is necessary to change all the water in a pond within 2 to 3 hours. Sea water is pumped up directly through a pipe and fresh water is pumped from a well in order to lower the concentration of salt water artificially. Using this method of diluting sea water, it is easily possible to create the most suitable salinity for shrimp at any stage of growth. Salinity requirements change with size, especially in tiger shrimp (*P. monodon*).

Table 5. Cost and earning (MS) of Dr. Kim's Farm, Johor Bahru, Malaysia.

	1979	1980	1981
1. Revenue	20,962	36,809	43,485
shrimp	19,507	34,858	41,881
fish	1,245	1,444	467
others	210	506	1,137
2. Cost	15,086	26,990	26,308
pesticide	1,680	316	2,246
ice	103	—	—
feeds	357	—	—
transportation	87	—	13
wages	5,527	16,568	15,758
basic	2,745	10,470	11,650
fixed reserve	66	1,629	1,485
insurance	—	452	280
temporal	1,840	2,545	2,082
foods	876	1,472	261
others	517	1,887	875
general management	1,376	5,654	3,838
repair	3,330	—	—
tax	2,109	2,565	3,578
fixed asset	1,573	2,565	2,565
exports	536	—	1,013
3. Profit	5,876	9,819	17,177

The most critical time for tiger shrimp culture is the beginning of winter when water temperature falls abruptly. This can cause high mortality as tiger shrimp are particularly weak at low temperatures. At these times of emergency, the speed with which water can be changed is critical. Following an increase in the flow of warm subterranean water, shrimp recover their vitality.

As already shown in Fig. 10, there is a common trend to crowd ponds into specialized areas. In addition to fully utilizing a good environment for shrimp growth, it is often convenient for culturists to crowd together from a socio-economic point of view, especially in developing areas, because of the shortage of infrastructure, the necessity of obtaining seedlings and feeds, and the convenience in selling their products.

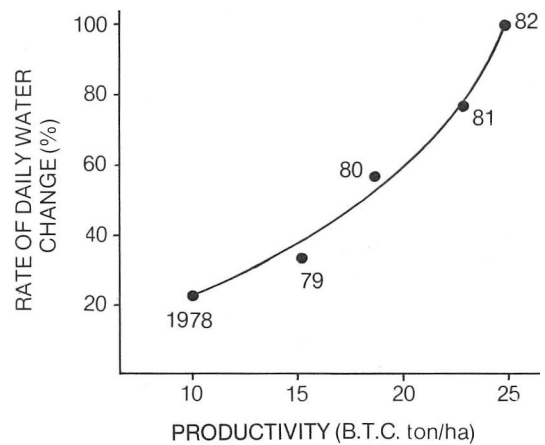


Fig. 12. Relationship between productivity and rate of water change in shrimp culture ponds in Taiwan using black tiger conversion (B.T.C.) method. Source: Pers. comm., M. Chu of Tungking who holds the record for maximum production per hectare in Taiwan.

**Table 6.** Calculation of Black Tiger Conversion (B.T.C.).

	Production (kg)	Price (¥/kg)	B.T.C. (¥/kg)
	A	B*	A X B
Total	3,500		707
Tiger shrimp	100	1,800 (100%)	100
White shrimp			
Large	300	1,300(72.2%)	217
Medium	500	1,000(55.6%)	278
Other shrimps			
Medium	600	200 (11.1%)	67
Small	1,000	50(2.8%)	28
Fish	1,000	30(1.7%)	17

\*Figures in parentheses (B) refer to price of commodity expressed as percent of price of tiger shrimp.

Problems faced in intensive culture include the excessive use of subterranean water that results in the phenomenon of ground water subsidence. Tungkang has experienced this. There is also a general trend to use much more medicine to prevent diseases. In the case of Japanese aquaculture, the use of antibiotic medicine is prohibited, but it is rather difficult to stop usage completely. In addition, there are many cases where sea water and sea beds have been contaminated by leftover feeds and the excrement of cultured fish. There are increasing numbers of previously cultured sea areas no longer suitable for culture in Japan.

#### Productivity and cost study using the B.T.C. method

Between shrimp culturists in Taiwan and Japan, there is not much difference either in productivity or technical level. However, in Asia there are greater differences. The Asian area is so broad that the existence of many types of culture systems and many kinds of cultured shrimps is inevitable. Moreover, differences in farm scale can be very great even in one area. Many areas have a pyramidal type of succession from small to large farms, so that it is difficult to set a stand-

ard scale or average size of farm. At present, there are limited economic statistics on shrimp culture in all Asian countries except Thailand, so that the comparative analysis of productivity, cost, and earning between different culture methods is very difficult. Also there are many kinds of shrimps cultured in various countries. Black tiger shrimp, *P. monodon*, is the main species of one country while white shrimp, *P. merguensis* or *P. indicus*, may be that of another.

This situation makes it difficult to clarify by economic analysis general trends in shrimp culture in the countries in Asia. To cope with the difficulty, the Black Tiger Conversion (B.T.C.) method is introduced.

Table 6 shows a model of calculating B.T.C. from the production of cultured shrimps and fishes using price per weight. The method can be applied to shrimp culture because the price of cultured shrimps is decided mainly by the international market. A common international producer price throughout the world even in different areas and countries is thus possible. In other cultured species, the domestic market is usually larger than the export one so that the price of the cultured product is decided by the demand and supply relationship in the country. In these situations it is not possible to do comparative analysis on production and cost. Fortunately, shrimp culture is one of the cases suitable for analysis on a worldwide scale. In the following figures and tables, the B.T.C. method is used for rough calculation. It is very difficult to obtain exact data as to the prices and quantities of each species in a limited time, so it is used here only to show a basic idea of the B.T.C. method and its usefulness for more refined analysis in the future.

Table 7 shows results of the B.T.C. method using examples from different types of shrimp culture in Asia. These examples were obtained from field survey, so the number of samples is very limited. In the table, the production figure does not include the small-sized shrimps and trash fishes which become feed for large shrimp or are given to workers as an allowance in kind. Examples of kuruma shrimp culture are excluded from the table, because live kuruma shrimps

**Table 7.** Comparison of productivity and costs for typical example of each type of culture (based on field survey in 1981, 1982, 1983). Figures for South India and Ganges are from reports of experts and trading companies in Japan.

	Intensive		Semi-intensive		Extensive		
	Tungkang	Pontevedra	Pontevedra	South Bangkok	South India	Ganges	Johor Bahru
		(1)	(2)				
Production (kg/ha)	15,000	1,065	520	500	240	315	250
Tiger shrimp	15,000	525	310	—	10	5	6
White shrimp	—	—	—	300	80	160	57
Small-sized shrimp	—	—	10	200	150	150	187
Milkfish	—	540	200	—	—	—	—
Others	—	—	—	—	—	—	—
B.T.C. production	15,000	580	340	280	110	155	115
B.T.C. price (¥/kg)	1,800	1,950	1,950	1,900	1,630	1,710	1,530
B.T.C. cost (¥/kg)	1,620	1,258	1,320	900	1,100	1,000	1,140
Fixed cost	450	650	760	600	990	880	940
Variable cost	1,170	608	560	300	110	120	200
Seedling	230	260	200	—	—	—	—
Feed	730	184	160	—	—	—	—
Others	210	164	200	300	110	120	200

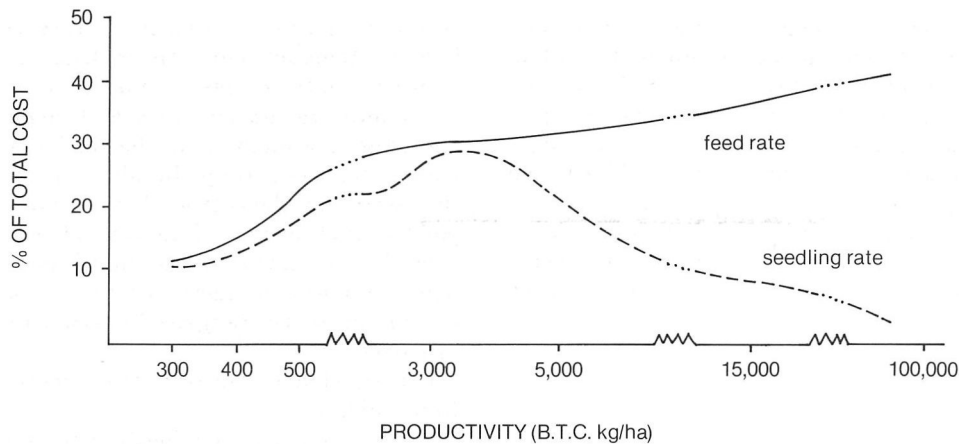


Fig. 13. Relationship between proportion of feed cost and seedling cost (as per cent of total cost) and productivity (B.T.C. method) in Asia. Source: Field survey in Tungking, Taiwan.

have a special domestic market in Japan and imported quantities from outside are few. The price of this shrimp is decided by the domestic production situation. The producer price of B.T.C. is from 1,800-2,000 ¥/kg excluding the examples from India and Malaysia. The price is comparatively low in the case of India due to low wages and inconvenient transport, and in the case of Malaysia due to the large number of shrimp damaged or killed by high water pressure during harvest making up a large part of the total production.

In Asia, it is common for culturists to sell their products to merchants by the pond side, so that the price of shrimp is the producer's price. There is a comparatively wide range of production costs reflecting different economic situations and types of culture in each country. Generally, the production cost of extensive culture is less than that of semi-intensive and intensive culture in proportion to the degree of intensity.

This phenomenon, seen in Japan too, is a general feature of all shrimp culture except for extensive culture ponds having very low productivity. The production cost is highest in Taiwan and lowest in South Bangkok. The ponds in the South Bangkok area are so well prepared that the natural productivity is high enough to produce many small low quality shrimps and *Acetes* spp. which make good feed for white shrimp. In addition, small white shrimp are returned to the ponds, so that the productivity is high compared to other extensive culture systems.

The examples of semi-intensive culture in Table 7 were selected from the Pontevedra area, near Roxas City, Panay Island in the Philippines. This area has more semi-intensive ponds than other countries and the production cost is roughly halfway between that of extensive and intensive.

When the production cost is divided into two parts, fixed cost and variable cost, it happens that in proceeding from extensive to intensive culture, the fixed cost tends to fall. The fixed cost per hectare in the intensive culture is much higher compared to extensive, but the fixed cost per kilogram is lower because of high productivity. As the fixed cost is composed of depreciation, interest, fixed wages, etc., the rate of decrease is very distinct in proportion to the increase in productivity.

On the other hand, the variable cost per kilogram becomes higher when proceeding from extensive to intensive culture. Thus, the high level of variable cost keeps the production cost per kilogram high in step with the order of intensity. In the manufacturing industry, the variable cost per unit product may have only small differences even if the productivity is different between factories. In factories having a high efficiency, the production cost per unit product becomes low in proportion to the decrease in fixed cost and the variable cost per unit will remain at the same level.

The big differences in the variable cost of shrimp culture come mainly from the cost of seedlings and feeds. The seedling cost in kuruma shrimp culture in Japan is very low compared to other areas, because it is easy to get enough mature shrimp from the sea, and recently many culturists have built their own hatcheries to supply seedlings whenever they are needed. On the other hand, the seedling cost per kilogram in semi-intensive culture in Asia is very high, because mature tiger shrimp are few and hatchery technology has not yet reached a high level, except for Taiwan (Fig. 13).

The large differences in the feed cost are preeminent, and the feeding cost will increase at a higher rate than the

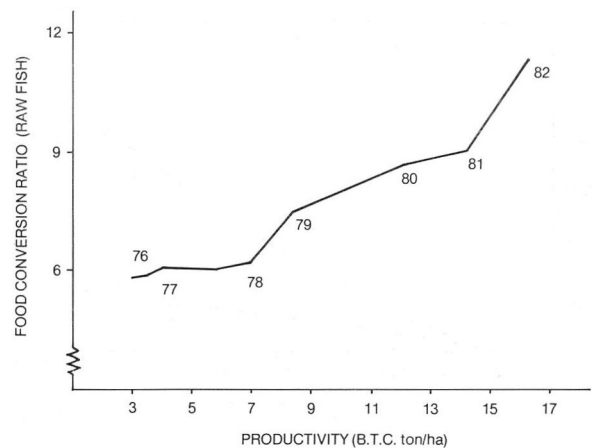


Fig. 14. Relationship between food conversion ratio and productivity (B.T.C. method) in Taiwan. Source: Field survey in Tungking, Taiwan.

decrease in fixed cost. Intensive culturists must turn to more feed to compensate for the loss in natural productivity. Fig. 14 shows this relationship. In Taiwan shrimp culture from 1978 to 1982, the feed conversion ratio became higher in proportion to the increase in productivity. This is tied to high feeding cost. In addition to this, a high quality and high priced feed is needed in super-intensive culture. As already shown in Tables 2 and 6, kuruma shrimp culture is no exception.

In Table 7, the other main costs included in variable cost are temporary workers wages, shipments, repairs, electrici-

ty, etc. Besides semi-intensive culture, the extensive culture in South Bangkok shows the highest variable cost compared to other countries. This is because culturists there put much effort into preparation, such as levelling the pond bottom and digging a ditch along the earthen dike to make a nice habitat for the shrimp. In addition, they remove the mud that settles on the bottom. If they did not do this work, the pond would become a silted wild field within 2-3 years. Moreover, they use electricity to control the flow of water into the pond. It might be more accurate to say that the culture method in South Bangkok is between extensive and semi-intensive.

It is possible to ascertain two important economic trends from Table 7.

1. The fixed cost per hectare is very high in intensive culture, but fixed cost per kilogram is very small compared to semi-intensive and extensive culture.

2. The percentage of variable cost out of total cost per kilogram is very high in intensive culture. This is due to the high cost of feed and seedling.

In Table 7, the productivities of extensive culture are all above 100 kg/ha. Usually, however, productivity of these ponds are under 100 kg/ha. The cost per kilogram in the extensive system having a productivity of 50-60 kg/ha is higher than that of the intensive systems presently used in shrimp culture.

Although a general trend of the economics of shrimp culture may become clear by this rough comparative study of each country and culture method, it is very difficult to say exactly what are true production costs. There are many problems in general comparisons such as what items to include in production cost, how to estimate the proper cost for each item, how to calculate depreciation, interest, and the evaluation of family labor, etc. In Asia, the condition of lease, land price, and interests often vary individually, so it is not easy to determine standard costs for each item.

Despite these difficulties, the cost per kilogram for each culture system can be compared with different levels of productivity. Fig. 15 shows the change in cost that may result from change in productivity using examples of Pontevedra as a semi-intensive case A and Tungkang as an intensive case B from Table 7.

Production cost per kilogram in this calculation is based on a productivity of 580 kg/ha in semi-intensive case A and 15 ton/kg in intensive case B. It is assumed that the variable cost does not change per kilogram and that the fixed cost per kilogram changes in direct proportion to the productivity change. The production cost per kilogram of A and B both decrease with increased productivity, but the rate of decrease is higher in B than A. In this calculation, production cost per kilogram of A at the productivity of 400 kg/ha becomes equal to B at the productivity of 15 ton/ha. To make the comparison clear, the two horizontal lines in Fig. 15 representing the productivity levels of A and B meet at the production cost of ¥1,600/kg.

The reason type B has a gentle cost curve compared to type A is due to its high percentage of variable cost in the total cost per kilogram. This means the percentage of fixed cost per kilogram is low, so that a decrease in this part does

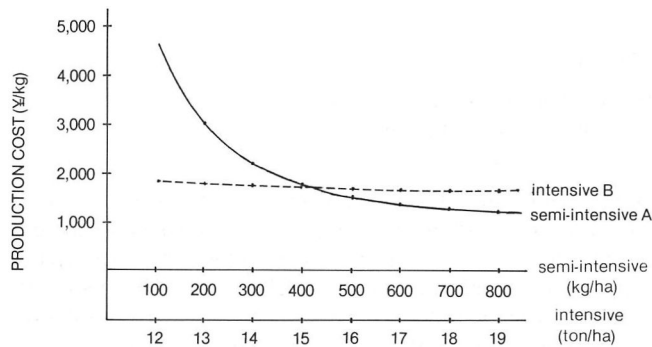


Fig. 15. Production cost versus productivity in semi-intensive (A, Pontevedra) and intensive (B, Tungkang) shrimp culture.

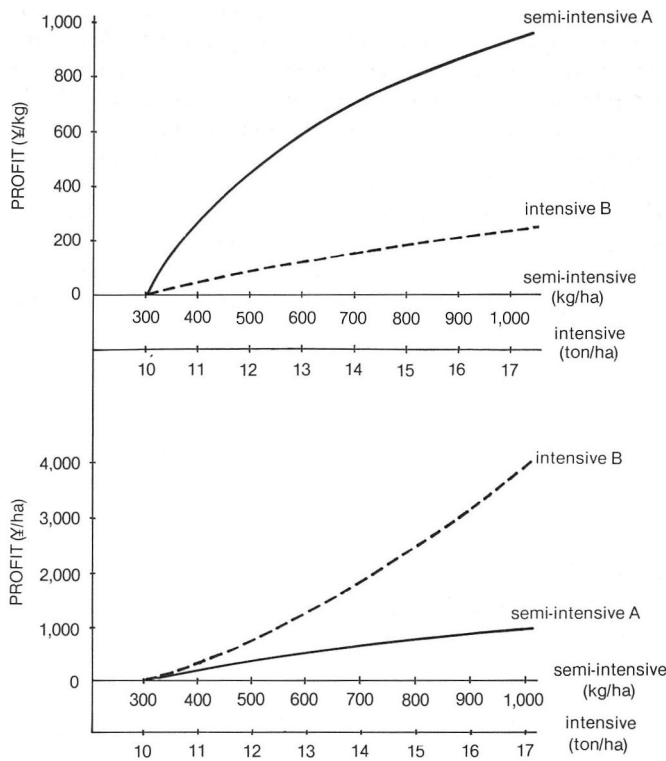


Fig. 16. Profit per kilogram and per hectare at different productivity levels (B.T.C. method).

not heavily influence the whole production cost per kilogram when the productivity increases. Theoretically, production cost per kilogram will eventually approach variable cost per kilogram if productivity is increased to infinity.

It is possible to raise the productivity of A from the level of 400 kg/ha to 1,000 kg/ha in the near future. On the other hand, it would be rather difficult to push up the present level of 15-20 ton/ha in B, because it has already attained a high productivity.

The range in productivity of semi-intensive culture in the Philippines is about 300-500 kg/ha and that of intensive culture in Taiwan is about 15-20 ton/ha. Due to the steep downward cost curve in semi-intensive culture, the production cost per kilogram of over 500 kg/ha in semi-intensive culture cannot be equalled even if the productivity of intensive culture were to increase. On the other hand, at present there are many culturists in Taiwan whose productivity level is over 15 ton/ha, so that semi-intensive culturists having under 400 kg/ha productivity cannot survive in the future when the total production of cultured shrimp from intensive culture continues to increase. From the field survey conducted in 1981-82, productivity in the Pontevedra area (Panay Island, Philippines) is under 200 B.T.C. kg/ha for extensive and 300-400 kg/ha for semi-intensive culture. There are few farms having over 400 kg/ha B.T.C. in that area said to be the most advanced shrimp culture area in the Philippines.

While it is almost certain that the production cost line of extensive culture will be positioned to the lower left part of the semi-intensive line when its productivity is beyond 100 kg/ha, the present level of extensive culture having under 100 kg/ha productivity will be higher than that of intensive culture. These low productivity ponds cannot survive when production from intensive and semi-intensive culture increases.

Costs per kilogram for intensive culture are now lower than those for a large number of the existing semi-intensive and extensive culturists. However, as Fig. 15 indicates, this situation may easily reverse when the productivities of the latter increase a little.

It is assumed in this calculation that the variable cost per kilogram does not change as the productivity level changes. This, however, is not always the case. For example, feed cost will increase following the increase in productivity. As is supported by Fig. 14 and Tables 1 and 2, an increase in the productivity per hectare of high intensive culture is followed by an increase in the food conversion rate. Experience with yellowtail culture in Japan can be used as an example here. The food conversion ratio about 5 years ago was 7-8 and fish grew to about 1 kg during 8 months rearing. Now the conversion is 8-9, and fish only grow to 800 g in the same rearing period. It is said that the reason for this slower growth is due to the deterioration of the sea bottom caused by left-over feeds.

In the case of shrimp culture, good bottom condition in ponds can be maintained if construction allows total water drainage and drying subsequent to the removal of accumulated slime. However, in high density culture, it is difficult to prevent the increase in the feed conversion ratio. On

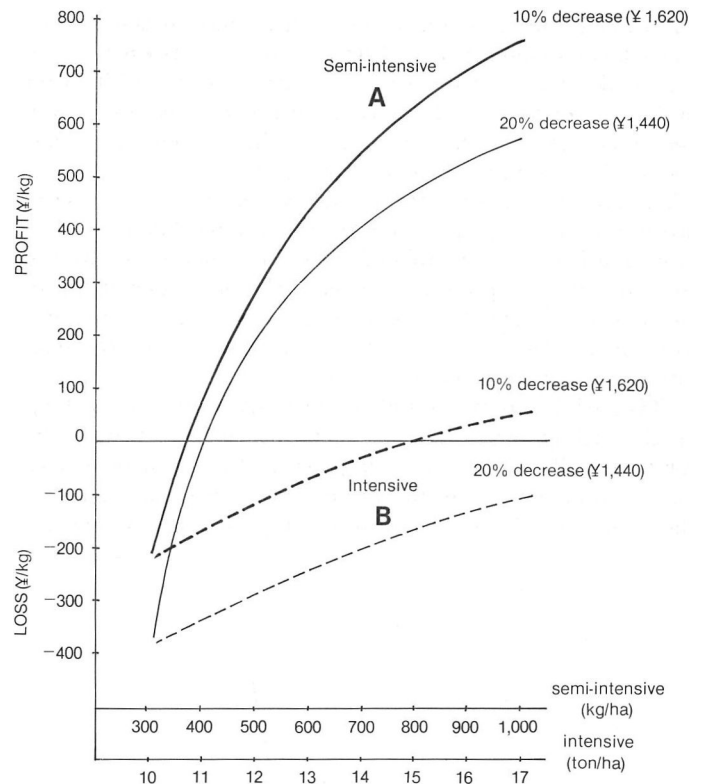


Fig. 17. Profit and loss per kilogram given a decrease (by 10 and 20% of present levels) in selling price.

the other hand, in semi-intensive and extensive culture it is possible to grow adequate feed plants provided that ponds are properly fertilized after the pond bed is completely dried. In these ponds the growth of natural food is rather good, and an increase in seedling number up to a certain point will not cause an increase in the food conversion ratio.

In kuruma shrimp culture, the colour of ponds in which diatoms have grown very well becomes dark brown and the transparency of water falls below 30 cm. High intensive culture in such a pond may show the possibility of rearing large numbers of shrimp at a faster growth rate than in other ponds. Culturists are now trying to produce the dark brown colour of water. Thus, with proper management, it is surely possible to enhance the natural productivity of ponds in Asia.

The cost curves of B as shown in Fig. 15 may in reality rise a little at high levels of productivity because of the drop in feed efficiency. On the other hand, the cost curve in case A may descend more rapidly at initial production levels with increased natural productivity. The result of increasing productivity can be great in semi-intensive and extensive culture.

Intensive culture firms can remain in business only if they have a good selling price to compensate for high costs. Even if the profit per kilogram is small, the intensive culturists will still get adequate profit per hectare from the high intensive ponds due to the high production of shrimp. Fig. 16 illustrates this relationship by productivities and profit. In the figure, the upper graph shows profit per kilogram in A

and B. Both horizontal lines were set to meet at the productivity level of 300 kg/ha in A and 10 ton/ha in B where there is a break-even point for both. Of course, profit per kilogram in A is larger than in B. However, profit per hectare in B is very much greater than in A, even where productivity per hectare is beyond this break-even point.

The object of culturists has always been to gain a large profit and not to gain the high profit rate per kilogram. The intensive firms are capable of achieving much profit by the sheer quantity of production even if the profit per kilogram becomes small. Due to these conditions, culturists are eager to improve their culture methods from extensive to semi-intensive, and from semi-intensive to intensive.

This path has been pursued by intensive culturists as long as the selling price has exceeded the cost. However, the situation will change as soon as the price of shrimp decreases due to an increase in future production. When this happens, the intensive culture firms will not stay in business, because

there are no ways to cut down production cost per kilogram in intensive culture due to high percentage of variable cost. Fig. 17 shows the changes in profitability in A and B in cases where the producer price changes by 10 and 20%. Present producer price of tiger shrimp is about ¥1,800/kg. It is clear that the profit in intensive culture will soon disappear with a small reduction in selling price. On the other hand, semi-intensive culture can remain profitable with a little effort to raise productivity.

The future situation of shrimp culture will be decided by the contribution of each type of culture method to the total production change. Intensive culture will be forced to drop out when the production of extensive and semi-intensive culture becomes dominant. After the dropping out of intensive culture, semi-intensive culture firms may have severe competition from extensive culture. However, semi-intensive firms can survive because there is plenty of room for them to raise productivity. On the other hand, production from extensive culture may not be dominant in the market, even if many new areas suitable for culture are found, because of low productivity.

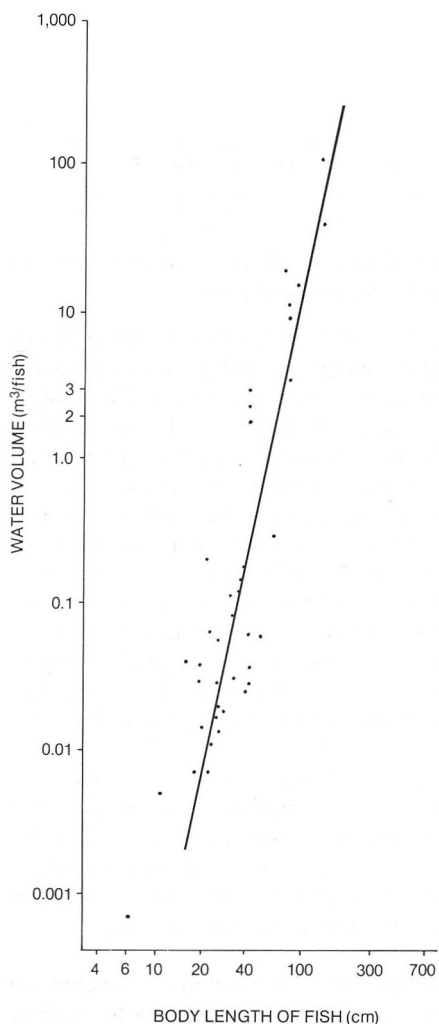
#### Continuing and circulating methods of pond use

Cost forecast for cultured shrimp seems to indicate that extensive and semi-intensive methods will become dominant in the Asian area once they can raise their productivities a little. At present, however, these methods only result in small profit due to their low productivity levels. Therefore, this section deals with how to increase the productivity in extensive and semi-intensive culture without an increase in supplementary feeds. As in the case of extensive culture, it is difficult to raise productivity to a high level as supply is dependent on natural conditions, the only management being practised is to prevent predators and to selectively catch large shrimp.

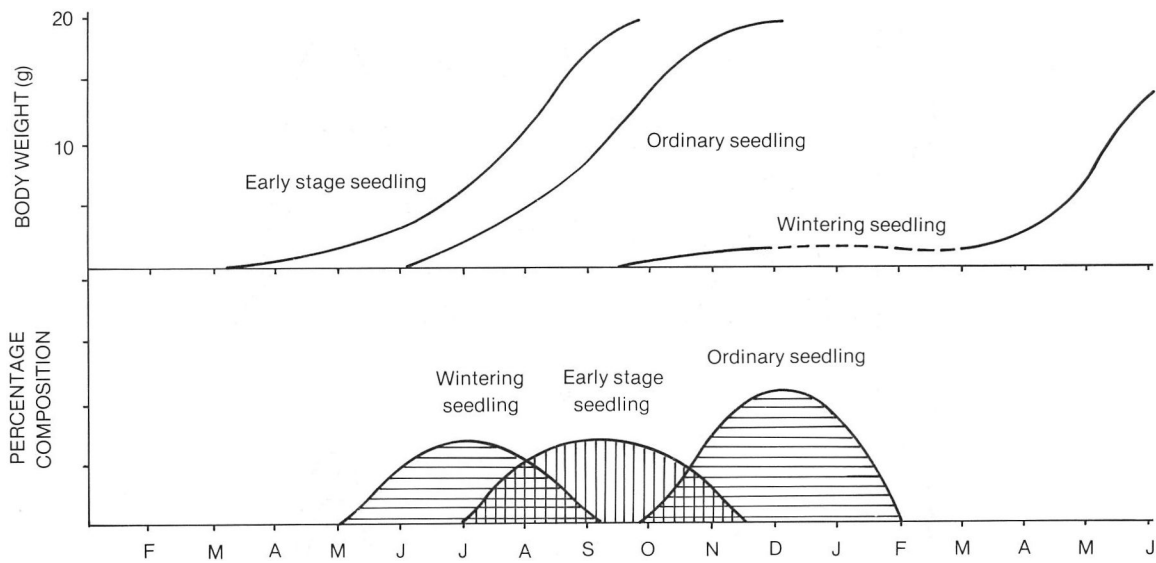
Results of cage culture experience in Japan are presented in Fig. 18. The relationship between the amount of water per piece and the body length of fish in high intensive culture indicates that small fish require a small amount of water and vice-versa. This seems to be a very ordinary phenomenon. However, it is important to show the direct proportion in the relationship. The total weight of fish reared in a cage is solely dependent on the amount of dissolved oxygen, independent of any distinction in fish size.

In shrimp culture, the weight of shrimp in the Seto Inland Sea pond is about 500 g/m<sup>2</sup> at the time of harvest in December. This is the limit to which culturists can stock. In the traditional single harvest method of shrimp culture, seedlings are stocked into ponds in May or June and harvested once in December at the level of 500 g/m<sup>2</sup>.

In this operation, culturists were limited to under 20 pieces of seedling per square meter in the pond as the marketable size is about 25 g per piece. Considering 20% mortality, the number of seedling stocked should be about 25/m<sup>2</sup>. Initially, shrimp are small and there is more than adequate dissolved oxygen in the pond. However as they grow larger, their requirement becomes greater, until reaching over 25 g per piece or 500 g/m<sup>2</sup>. Thus, in the traditional Seto Inland Sea



**Fig. 18.** Relationship between length of fish and quantity of water needed in intensive cage culture of fish in Japan. Source: Ishida, Y. 1977. Annual report of the Kochi Fisheries Laboratory.



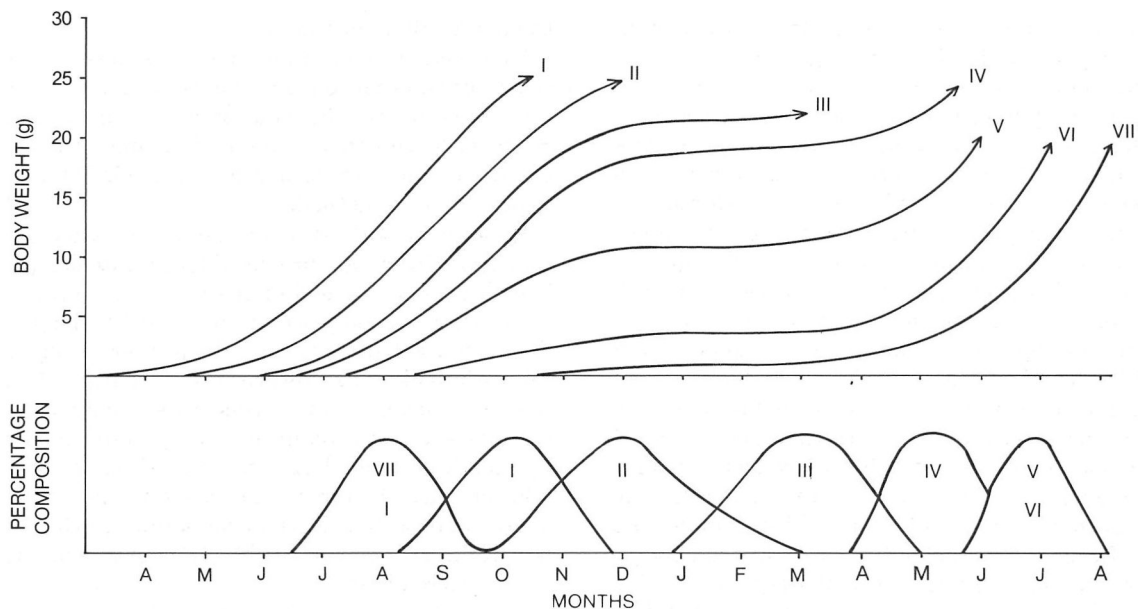
**Fig. 19.** Recent changes in pond use in the Seto Inland Sea (% composition refers to proportion of monthly shipment to total shipment from a given area).

operation there was no alternative other than to ship all the shrimp by December. However, the recent expanding market for live kuruma shrimp may allow a great change in the operation. As a result of the growing market, harvests are carried out many times a year, and culturists are able to raise shrimp throughout the year, and to ship them regularly every month.

Culturists stock early seedlings into the ponds in March, and ordinary seedlings in May or June (Fig. 19). These early seedlings reach a marketable small size of 13-15 g apiece in August or September. Previously, there was no market for such a small size. Culturists have also started to stock seedlings into the pond in August or September as winter seed-

lings in some particular ponds. Winter seedlings can grow to a size of 5-6 cm before the winter hibernation. In the Seto Inland Sea, however, it is necessary to build special nursery ponds for them. It is possible to market these seedlings in July or August the following year when they reach 19-20 g in size. Thus, the harvest period in the Seto Inland Sea area has extended to July through December.

Even with pond capacity stable at 500 g/m<sup>2</sup>, expected production is about twice that of the old culture method. This is possible if seedlings are stocked into the limit of pond capacity, and are harvested regularly every month. Selective harvest of large shrimp allows additional room for smaller shrimp. Ponds can be restocked again with young



**Fig. 20.** Typical use of circular pond, Amakusa or type C (% composition refers to proportion of monthly harvest to total harvest of a given crop, e.g. I, II, etc.). Lines show time of stocking in the pond, culture period and growth; numerals refer to crops.

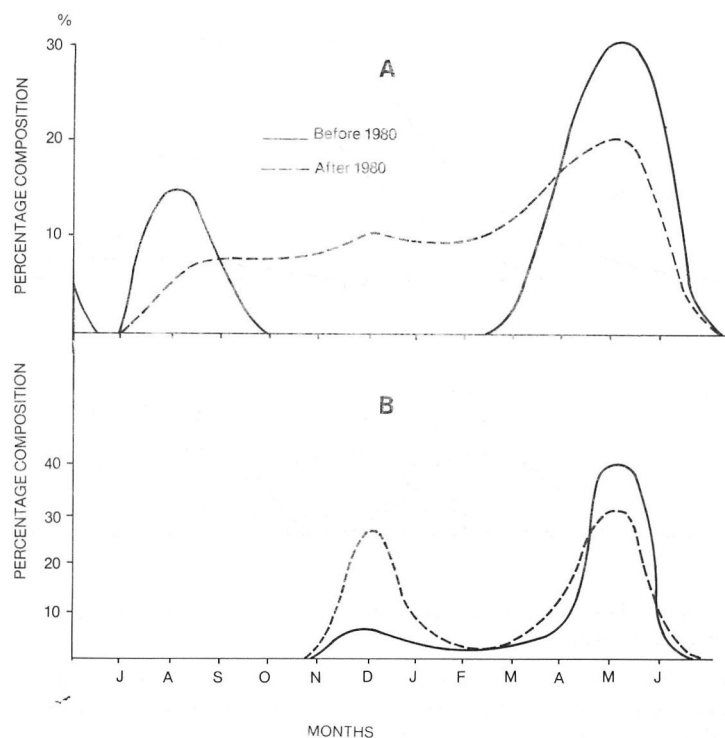


Fig. 21. Change in harvesting period of large (A) and small (B) firms in Japan before and after 1980 (% composition refers to proportion of monthly harvest to total yearly harvest of a given firm.)

shrimp. This is a way of using the pond more efficiently. The present productivity level in the Seto Inland Sea is about 500-600 g/m<sup>2</sup>. Production of 1,000 g/m<sup>2</sup> in the near future is possible when this schedule of stocking and harvest is applied to new operations.

The circular ponds in Kagoshima are a typical example of this operation (Fig. 20). Kuruma shrimp in the ponds here do not hibernate in winter, so it is possible to use a pond throughout the year. Culturists in Kagoshima had been stocking ponds only once a year just as in the Seto Inland Sea. But recently they have started stocking their seedlings into ponds several times a year. Culturists may have planned for peak production in May and April when the highest price occurs. However, the balance or allotment of production for each month becomes important in maximizing profit. Important factors to consider include: managerial techniques of how to use the pond efficiently; expected price every month; periods of restocking seedlings; and growth rate of shrimp

In the traditional operation, harvest and shipment were concentrated in a particular month. Culturists hired a small number of full-time workers and hired many part-time workers during the harvest period. In the new operation, culturists will ship a small fixed quantity of product regularly. Good pond management is achieved by increasing the number of trained full-time workers and hiring fewer part-time workers. In the traditional operation, culturists bought seedlings from the outside due to the shortage of full-time employees. In the new operation, there are enough skilled hands. With more full-time workers, many culturists have started hatcheries. It has become cheaper to produce seedlings than to buy them. In addition, the number of seedlings

stocked and the frequency has been increasing so that it is critical to have adequate seedlings at the appropriate time.

This new way of operation may be called the "continuing method" of pond-use. That is, culturists put in different-sized shrimp approaching the limit of pond capacity and harvest the marketable ones daily. Young shrimp are stocked in the available space. Using this method, the productivity of the pond will almost double.

However, the continuing method is possible only in large-scale farms, because many ponds or many sections of ponds are needed for the distribution of the many sizes of shrimp. Small-scale culturists cannot distribute their shrimp efficiently among a small number of ponds. Thus, they cannot apply this new method.

Recently, small-scale culturists have started to use another strategy. Shrimp are produced for private demand to be sent live as gifts at the end of the year. The shrimp for this demand have a good price of about 10,000 ¥/kg while the ordinary market price is now about 6,500 ¥/kg. However, to sell shrimp like this, culturists have to pack 500 g to 1 kg into every package. This is time-consuming work. Large-scale culturists do not attempt it as they prefer to ship to the big city markets where large amounts of shrimp are accepted at a lower price than in the private gift market. On the other hand, small-scale culturists can adjust to this time-consuming work, as they can easily gather part-time workers from nearby as required.

Figure 21 shows recent changes in marketing periods between large and small firms. Just 3 to 4 years earlier, both types of firms shipped at similar times, but now have clearly changed and followed different patterns.



Besides the "continuing use," another new operating method has been developed. It is called the "circulating use" of ponds. This operation was developed to raise productivity. In the Philippines, culturists have been dividing their ponds into three parts: nursery, intermediate and main growing pond. The nursery pond and intermediate pond allow for better care of small-sized shrimp. This method has been introduced to increase the survival rate of seedlings and juveniles.

In Taiwan, the reason for the high productivity relates to the use of this culture system with effective water change. Fig. 22 illustrates a schedule of pond usage. Two and a half or three harvests are possible when shrimp can be reared all year round. In contrast, in the traditional method of pond-use in South Asia, only one or one and a half harvests are possible in places where shrimp are now reared only in the rainy season. With proper use of the circulating method, it may be possible to harvest three or four times a year.

Culturists in Taiwan stock their seedlings after finishing the previous harvest (Fig. 22). Thus, the pond capacity is not utilized fully while shrimp are small at the beginning and middle of the rearing period. To use a pond more efficiently, it may be best to divide it into several sections of different sizes and to put small shrimp into small sections first. After some growth, they can be shifted into larger sections. Im-

mediately after moving the first batch of shrimp, the small section should be completely cleaned and restocked with another batch of small shrimp to repeat the process. After three months or so, every section of the ponds will be full of different-sized shrimp. In other words, all sections of the ponds are utilized to the upper limit of capacity. Thus, culturists can ship shrimp every month from the main growing section (Fig. 23). The main growing pond area is about half the total pond area. About five harvests in eight months can be expected from a main growing pond during the rainy season. Therefore, two and a half harvests from the whole pond complex can be obtained. If it is possible to raise shrimp throughout the year, it should be possible to harvest six times or so.

Nursery and intermediate ponds are rather small, and do not require much water. Fresh subterranean water can be supplied to these ponds in the same way as in Taiwan, and juvenile shrimp can be supplied at the beginning of culture periods as seedlings can be raised even in the dry season in small well prepared ponds. When this is done, the main growing pond can be used from the start, and more harvests can be achieved.

There are two important conditions in realizing this circulating use of pond. First, the pond must be prepared sufficiently. Nothing can be done with extensive or rough ponds.

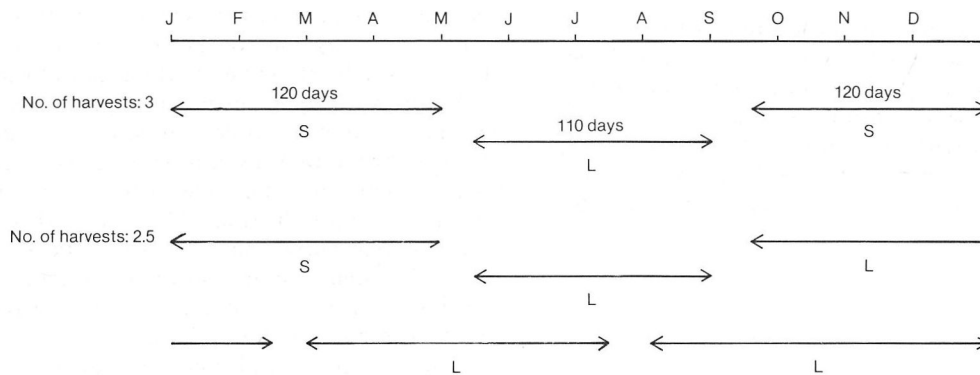


Fig. 22. Present schedule of pond use by month in the Tung kang area, Taiwan. Size of shrimp; S, small (32-35 g); L, large (35-40 g).

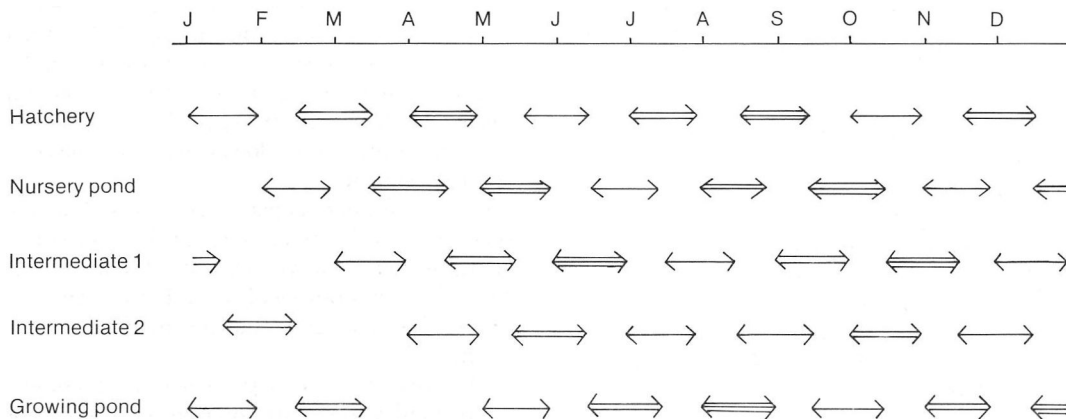


Fig. 23. A model of circulating pond use. Individual stocking or crop (as identified by number of horizontal lines) may be followed through the various production phases.

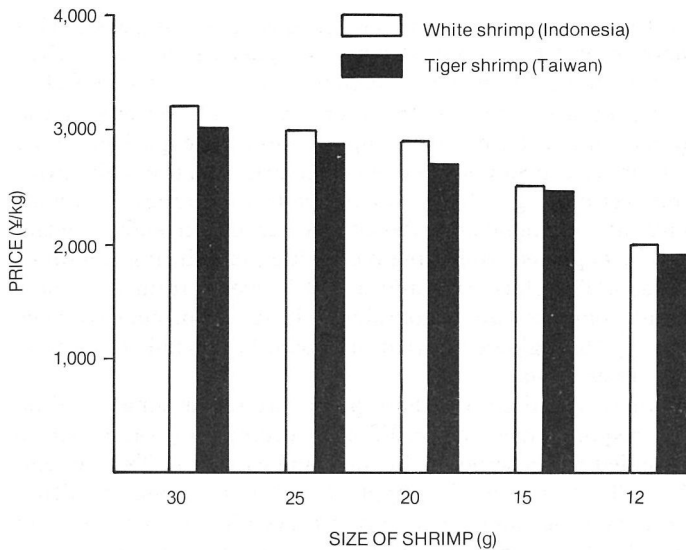


Fig. 24. Wholesale price of shrimp in the Tokyo Fish Market, September 1984.

Ponds with thick mud deposits are not suitable either. Moreover, some experience in dividing whole ponds into sections of varying dimensions is necessary. Second, it is important to be able to obtain plenty of seedlings when they are needed. Although Taiwan is well-supplied with tiger shrimp seedlings, at present it is very difficult in other Asian areas to procure sufficient tiger shrimp seedlings. It may be necessary to start white shrimp culture and also to develop the stunting method of tiger shrimp seedling production.

Although the merit of using the circulating method is pri-

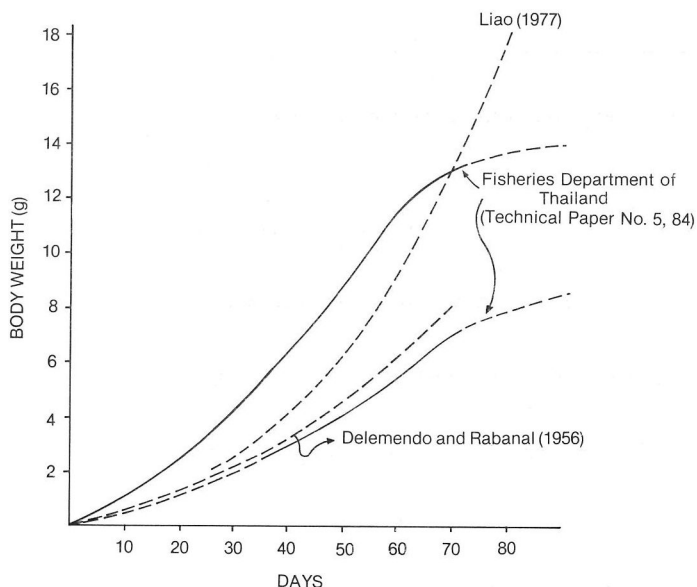


Fig. 25. Growth rate of black tiger shrimp, *Penaeus monodon* (---) and white shrimp, *P. merguensis* (—).

marily to increase production, it is also a way to raise productivity without any increase in supplementary feeding. Variable cost per kilogram is unchanged. Moreover, ponds can be allowed dormant periods by eliminating one harvest. In addition, by decreasing the number of seedlings put into the pond, disease is minimized and the required quantity of subterranean fresh water is reduced.

Of course, there is high initial investment in preparing existing extensive and semi-intensive ponds for this method. This should easily be recovered due to the decrease in the fixed cost per kilogram as productivity increases. It is very important to have good control of water change and to increase production of more natural food.

### The potential for white shrimp culture

In the development of shrimp culture in Asia, one major problem is how to increase the supply of tiger shrimp seedling. Due to the shortage of adults, the high price of seedlings may remain in the near future unless artificial breeding techniques of shrimps are successful. With this situation, there is a possibility that white shrimp culture will expand in addition to tiger shrimp culture.

Shrimp culture in the Asian areas apart from Thailand is directed mainly towards tiger shrimp. Reasons for this include the fact that techniques for larval rearing have already been developed in Taiwan and may soon be available. Secondly, the price of this shrimp is higher than others. In addition, the large size of the shrimp commands a high price and its growth rate is better than that of other species.

The price of tiger shrimp is higher than that of white shrimp in Taiwan, while the prices of tiger shrimp and kuruma shrimp in Taiwan are about the same. But the production conditions for tiger shrimp are better than for kuruma shrimp in Taiwan. Thus, tiger shrimp culture is of great interest there. However, the situation is entirely the reverse in Japan market. The price of tiger shrimp in the Central Fish Market in Tokyo is always cheaper than that of white shrimp at any size (Fig. 24).

Tiger shrimp is a traditional ingredient of Chinese cooking in Taiwan and throughout Southeast Asia. This shrimp commands a special price in the regional market. It is logical to try to culture high-priced fish, so it is also logical that the interest of aquaculturists has been directed to tiger shrimp. However, in the international market, alternatives to tiger shrimp as the object for culture are available. White shrimp is more esteemed than tiger shrimp in the Japanese market. Recently, tiger shrimp export from Taiwan to Japan has increased because of its lower price compared to the same size of white shrimp.

In out-of-home consumption, the black colour of tiger shrimp is not detrimental to marketing, as it is cooked before being served. However, the out-of-home market for shrimp in Japan is now approaching its limit if the price remains the same. The home consumption market, however, is expected to expand.

The weak point of tiger shrimp for home consumption is the difficulty in selling them in retail shops or supermarkets to people who think of shrimps as red or pink. The appearance is the deciding factor for sales, as sashimi, or raw

flesh, is valued at the highest price in Japan. Many supermarkets have in fact tried to sell tiger shrimp, but they have not had any success in expanding sales so far. Importers of tiger shrimp have established a strong base in the out-of-home consumption market, where tiger shrimp is used as a substitute for larger white shrimp because of its comparatively cheap price. However, medium-sized white shrimp is best for home consumption, with its price lower than larger ones and its colour preferred by people.

Figure 25 shows the comparison between the growth rate of tiger shrimp and white shrimp. Starting from P<sub>10</sub>-P<sub>15</sub>, the growth rate of white shrimp is faster within 70 days rearing, but after that the growth rate of both species diverge greatly. In the case of white shrimp culture, it is best to stop rearing at this point where the growth rate of the shrimp goes down severely.

Table 8 shows a rough economic estimation in culturing both species for 240 days. An assumption is that one rearing period for white shrimp is 70 days giving 3.4 harvests and that for tiger shrimp is 120 days giving two harvests. The number of white shrimp seedlings per hectare stocked into ponds is assumed to be twice that of tiger shrimp due to the availability of seed. Assuming the price of white shrimp is 60% that of tiger shrimp (Thailand), revenues per hectare are

**Table 8.** A trial estimation for white shrimp and tiger shrimp culture based on Thailand experiments.

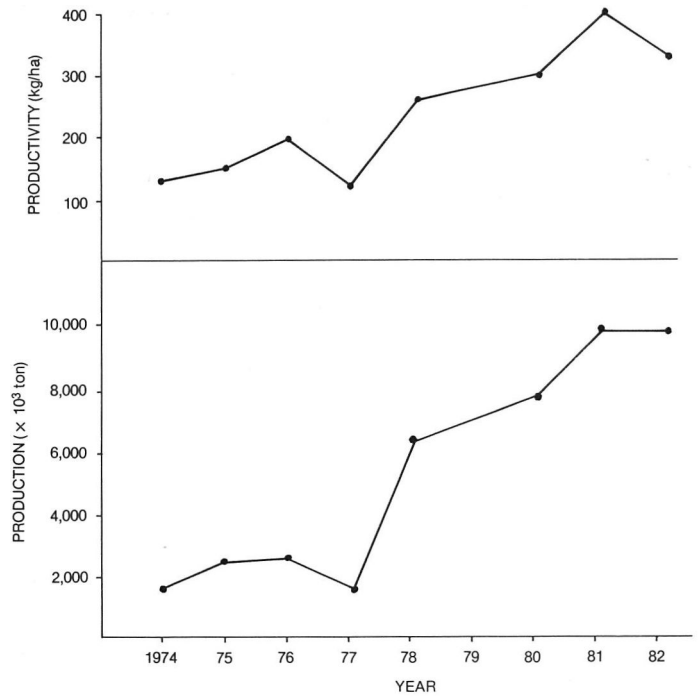
	White shrimps	Tiger shrimps
Size of shipment (g), A	13	35
Rearing period (days), B	70	120
Growth rate (g/day), $C = \frac{A}{B}$	0.19	0.29
Rearing days/year, D	240	240
Number of harvests, $E = \frac{D}{B}$	3.4	2.0
Number of seedlings, F	20,000	10,000
Survival rate (%), G	80	80
Production of one harvest (kg), $H = A \times F \times G$	208	280
One year harvest (kg), I	707	560
Price (¥/kg), J	1,080	1,800
One year revenue ( $\times 10^3$ ¥), $K = I \times J$	764	1,008

**Table 9.** Economic status of white shrimp culture in Thailand (1984).

	Area (ha)			
	0.8-4.6	4.8-9.4	9.6-15.8	16
1. Productivity (kg/ha)	532	506	472	454
2. Producer price (¥/kg)	648	670	620	765
3. Production cost (¥/kg)	297	269	375	365
4. Net profit (¥/kg)	351	401	245	400
5. Return rate (%)*	54.2	59.8	39.5	52.3
6. Total net profit (¥/ha)	187	203	116	182
Number of samples	11	10	6	7

Source: Thailand Agriculture and Cooperative Ministry, Technical Report No. 1, 1984.

\*Return rate (%) =  $\frac{\text{Net profit}}{\text{Producer price}} \times 100$



**Fig. 26.** Production and productivity of white shrimp culture (no feeding) in Thailand. Source: Government of Thailand, 1984. Technical Report No. 1.

about 76% that of tiger shrimp. However, if costs such as seedling costs are considered, profit will be equal or larger in white shrimp culture. Seedling of white shrimp has not been sold due to a good natural supply for extensive culture. At present there is but a small demand for artificial seedling of white shrimp in Thailand or other countries because of richness of natural supply so that there have been no trials to produce white shrimp seedling commercially even in Thailand. Although the price per piece of artificially reared seedling is not clear at present, it is probably about 0.2 to 0.1 times that of tiger shrimp seedling price due to the ease of artificial hatchery rearing from a technical point of view. The ease of rearing white shrimp seedling may provide young shrimp for the main growing pond at the beginning of the culture year. This means that it is possible to harvest over four times a year and to achieve about the same sales as for tiger shrimp culture. Thus, profit will surely be high in white shrimp culture.

There are many adult white shrimp in coastal sea zones and estuary areas. They lay eggs in the ponds and canals naturally. Artificial hatching can be done by laymen. At present in the Philippines, after picking out the seedling of tiger shrimp, the remaining seedlings are discarded. The seedling of tiger shrimp only make up about 10% of the total seedling catch, the rest being mainly white shrimp.

In Thailand, there has been a 50-year history of shrimp culture centered around the white shrimp. Fig. 26 shows a recent development in the shrimp culture of this country. The inner part of the Gulf of Thailand is a main production center of culture. However, new ponds have been sited in the

southern part of the bay recently. While many old ponds were converted from salt fields, most of the new ponds are constructed from mangrove areas.

Table 9 shows some results of extensive culture in the inner part of Thailand. Due to the limited number of samples, it is not possible to point out a general trend in the productivity and cost by farm scale. However, the family farm having a 4.8-9.4 ha pond is the most profitable size based on the profit rate. In Thailand, a government employee who has recently graduated from college or university can earn about 360,000 ¥/year. Culturists can earn about 180,000 ¥/ha in net profit. Thus a person who has a 5-ha pond can live in comfort.

In Thailand, the present average production level is under 200 kg B.T.C./ha. This productivity level is low. However, even extensive culture can reach this level without any supplementary feeds and seedlings. If seedlings can be produced in the hatchery and ponds can be prepared to minimize the entry of predators, it is possible to raise the productivity two-fold. In addition, by use of the circulating or continuing method, productivity can be expected to attain levels of about three or four times present levels.

In addition to the current emphasis on tiger shrimp culture, there are significant opportunities for white shrimp culture in Asia. These must not be overlooked.