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## Overview of Penaeid Shrimp Culture in Asia

Pinij Kungvankij

FAO/UNDP NACA

Aquaculture Department

Southeast Asian Fisheries Development Center

P.O. Box 256, Iloilo City, Philippines

**Abstract** Marine shrimp farming is a century-old practice in some Asian countries. Past sluggish development of the industry is mainly due to the inadequacy of hatchery technology resulting in inconsistent and insufficient supply of shrimp fry hence offsetting large scale development of the industry. Recent success in hatchery techniques coupled with high market demand have generated world-wide interest in developing shrimp farms in Asia. This paper attempts to make an in-depth review of the various aspects confronting the development and expansion of the shrimp farming industry.

The cultural significance of the various penaeid shrimps cultivated in Asia (*Penaeus monodon*, *P. japonicus*, *P. indicus*, *P. merguensis* and *P. orientalis*) is critically reviewed in relation to other subtropical species such as *P. stylirostris* and *P. vannamei* successfully cultivated in South America. The major constraints confronting large scale cultivation of *P. monodon* and other commonly important species are discussed and research gaps outlined. Present status of hatchery techniques is discussed and the need for standardization of viable techniques for technology packaging and verification is highlighted to ensure reliable source of seed supply. The various problems in hatchery development, including development of artificial larval feeds, are emphasized. This paper attempts to compare the technological and financial inputs in high technology with traditional farming practices in the region. The grow-out technology in relation to farming intensity and level of investment are outlined with special reference to the socio-economic condition in Asia. The need to develop viable and appropriate shrimp farming technology within the technical and financial capabilities of the rural small shrimp growers is discussed.

### Introduction

Marine shrimp farming is a century-old practice in many Asian countries. Until a decade ago, this commodity was still generally considered a secondary crop in traditional fish farming practices. In Thailand, Malaysia, Singapore and India, shrimp fry were accidentally trapped in the salt beds and paddy fields around estuarine areas, whereas in Indonesia and the Philippines, marine shrimps enter milkfish ponds during tidal exchange. Only recently have farmers eventually converted these fields into shrimp farms due to the higher income derived from the shrimp harvest compared to the principal crop.

In traditional shrimp farming, wild shrimp fry either enter during tidal water exchange or are intentionally gathered from the wild and stocked directly in ponds. Production is dependent on the seasonal abundance of wild fry which fluctuates widely from year to year. In addition, water depth in rearing ponds is generally shallow which often leads to extreme fluctuations in water temperature and salinity causing large-scale mortality. Predation by carnivorous fishes gaining entrance to the ponds also accounts for considerable loss of shrimps. Production relies almost entirely on natural pond fertility since fertilizers and feeds are not generally used. Consequently, yields are low in the range of 100-300 kg/ha/year.

Over the years, some improvements in the traditional methods of culturing shrimp have gradually evolved. For instance, stocking density could be increased with the aid of a water pump. Furthermore, increasing water depth in the

pond favors shrimp growth since temperature can be maintained and mortality is reduced. Production can also be raised by increasing stocking density in the pond with fry collected from the wild. However, supply of seed from the wild is still inconsistent and insufficient so that large scale development of the industry cannot be realized.

In 1934, Dr. Fujinaga, the world's acknowledged father of shrimp culture, successfully spawned and partially reared larvae of *Penaeus japonicus* in Japan (Hudinaga, 1942). The success in larval rearing and subsequently in the grow-out of shrimp had brought the art to a point where mass culture was possible. In 1963, Mr. Harry Cook of the Galveston Laboratory in Texas, U.S.A. in collaboration with Dr. Fujinaga, successfully spawned and reared the larvae of two American species, *P. setiferus* and *P. aztecus* (Cook and Murphy, 1966). The technique was later adopted in Taiwan, Philippines, Thailand and Malaysia for local species such as *P. monodon*, *P. merguensis*, *P. indicus* and *P. orientalis*.

However, recent developments have shown that, with proper management, yield in traditional ponds can be increased to 500-800 kg/ha/year without supplementary feeding. In the meantime, yields equivalent to 5 ton/ha/year have been obtained in Thailand with supplementary feed (Kungvankij et al., 1976) and 10 ton/ha/year in Taiwan with artificial feed and aeration (Liao, 1977).

The long gestation period in shrimp farming development is partly due to insufficient technical and financial input to demonstrate its commercial viability. Shrimp farming on a commercial scale has been developed into an important food industry through long years of trial and error by shrimp

farmers in such countries as Japan, Taiwan, Indonesia, Thailand, India, Malaysia and Philippines. However, it is new in other Asian countries such as China, Pakistan, Bangladesh, Sri Lanka and many countries in the Indo-Pacific region. High market demand and export price, growing opportunities in shrimp farming, and generation of employment and foreign exchange earnings have encouraged many countries rich in aquatic resources in the region to place high priority on the development of the shrimp culture industry.

### Species cultured

The shrimp species cultured in Asian countries belong to the genera *Penaeus* and *Metapenaeus* of the family Penaeidae. Among the dozen species of these genera, *Penaeus monodon*, *P. japonicus*, *P. merguensis*, *P. indicus*, *P. orientalis* and *Metapenaeus ensis* are the important ones.

#### *Penaeus japonicus* and *P. orientalis*

Aquafarming of *P. japonicus* is well established in Japan and Taiwan. Spawners are readily obtained in large numbers from the wild. It is hardy and can withstand handling. Survival rate for long distance transport of live adult shrimp is high. However, it cannot tolerate low salinity and high temperature and requires sandy bottom for grow-out ponds as well as high protein (about 60%) feed for best growth. The other temperate species, *P. orientalis*, is cultured in China and Korea. It has a single pronounced spawning season during spring. Since both shrimps are temperate species, the period of hatchery operation is relatively limited.

#### *Penaeus monodon*

Known as the tiger or jumbo shrimp, *P. monodon* is the most common or well-known species in Southeast Asian countries. It is the fastest growing of all shrimps tested for culture. In ponds, fry of 3 cm have been grown to a size of 75-100 g in 5 months at the stocking density of 5,000/ha. Forster and Beard (1974) were able to grow *P. monodon* to 25 g in 16 weeks in a tank stocked at 15/m<sup>2</sup>. Kungvankij et al. (1976) grew it to 42 g in 210 days in earthen ponds. Liao (1977) grew it to 35 g in three months in a tank stocked at 15/m<sup>2</sup>. It is euryhaline and grows well at a salinity range of 15-30 ppt. It is hardy and not readily stressed by handling. Presently, the major source of fry for stocking still comes from the wild but the supply is sparse. Although several hatcheries have been established notably in the Philippines Taiwan and Thailand, fry production is not steady due to dependence on spawners which are difficult to obtain in sufficient numbers from the wild. *P. monodon* females are more difficult to mature in captivity than those of other penaeid species, although excellent progress on this aspect is being achieved. Reliable techniques for maturation are also being developed.

#### *Penaeus indicus* and *P. merguensis*

Generally, the characteristics of these species are the same. Based on actual field surveys, there are many fish farmers who cannot distinguish the two species from each other. However, there are some indications of behavioral dif-

ferences between these two species. *P. indicus* prefers sandy substratum and is difficult to harvest by draining the pond, while *P. merguensis*, found most frequently in ponds with muddy bottom, moves out of the pond readily when water is drained. Gravid females of these species are easily obtained in large quantities from the wild and can mature in captivity. Larval rearing techniques are well developed. However, larvae of these species are found to be weaker than other species and juveniles and adults cannot stand rough handling. Large quantities of fry can be obtained from natural grounds and growth rate is relatively high, reaching 12-15 g within the first three months of culture. With the present technology, great difficulty has been encountered after three months of culture in rearing this shrimp without incurring heavy mortality.

#### *Metapenaeus ensis*

This species is very tolerant to low salinity ranging from 5 to 30 ppt and high temperature of 25 to 45°C. Wild fry are abundant, have short growing periods and survival in ponds is usually high. This shrimp usually does not grow to a large size and has a low market price compared to other species. However, studies on the culture of this species are limited. Production usually comes from a trapping pond or as a by-product species in other shrimp farms.

#### *Penaeus vannamei* and *P. stylirostris*

There are two neo-tropical species which have been successfully cultivated in America. In the U.S.A., yields obtained within a culture period of 144 days were 1,320-2,180 kg/ha/crop and 1,722 kg/ha/crop in intensive culture and 747 kg/ha/crop and 776 kg/ha/crop in extensive culture of *P. vannamei* and *P. stylirostris*, respectively (Chamberlain et al., 1981). These species show a fairly fast growing rate in ponds, particularly in countries like Panama and Ecuador. Many farmers and researchers want to adopt their culture in the Southeast Asian region as a substitute for *P. indicus* or *P. merguensis* because of heavy mortality normally encountered for these two species after a culture period of three months. The possibility of transplantation of these animals should be carefully considered as a new environment may not be suitable to allow continuous propagation of such species. Introduction of new pathogenic organisms may also occur and could affect endemic species.

### Present status

#### Hatchery design

Basically, there are two hatchery systems: the large-tank hatchery which was originally developed in Japan and is still popularly used in many countries in the Southeast Asian region (China, Taiwan, Thailand, Philippines, Indonesia, etc.) and the small-tank hatchery that originated from Galveston, Texas, U.S.A. and has been applied in the Philippines and, to some extent, Malaysia and Thailand.

Big-tank hatchery. The big-tank hatchery system was established in Japan by Kittaka in 1964. This was based on the idea of utilizing naturally occurring diatoms in the rearing

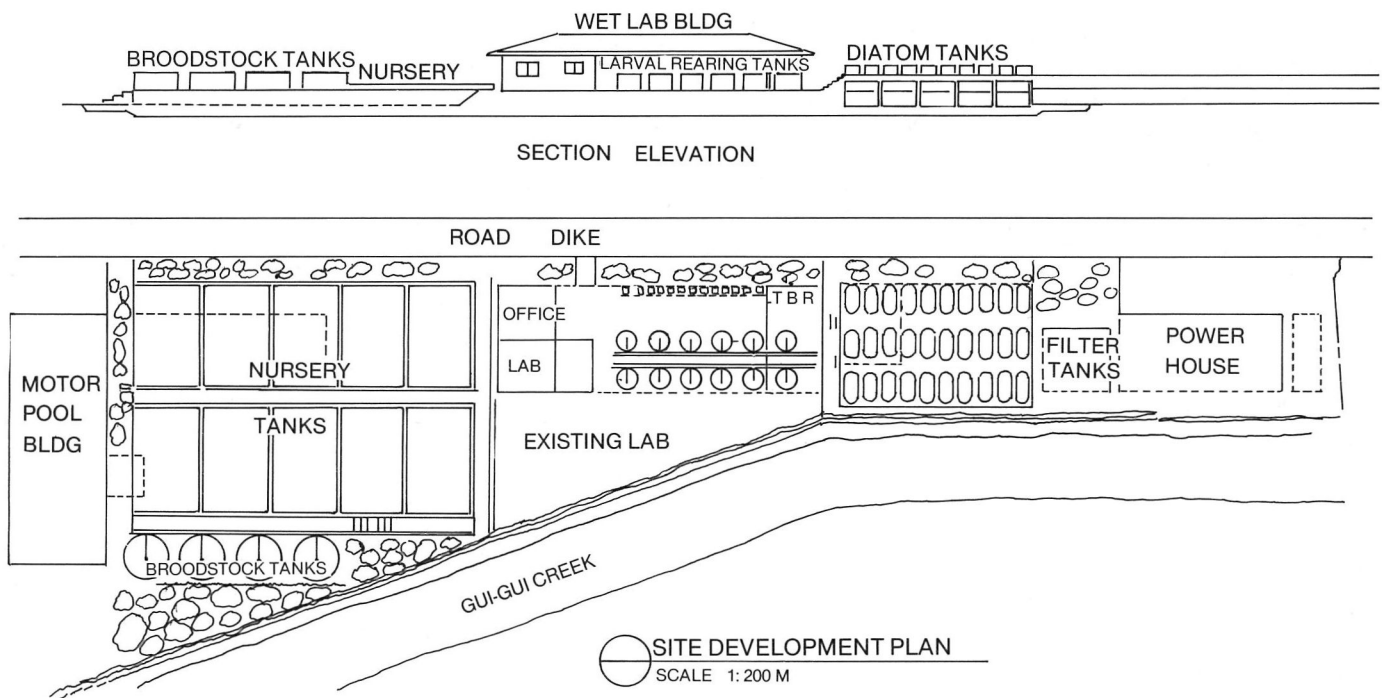


Fig. 1A. Lay-out of medium scale hatchery.

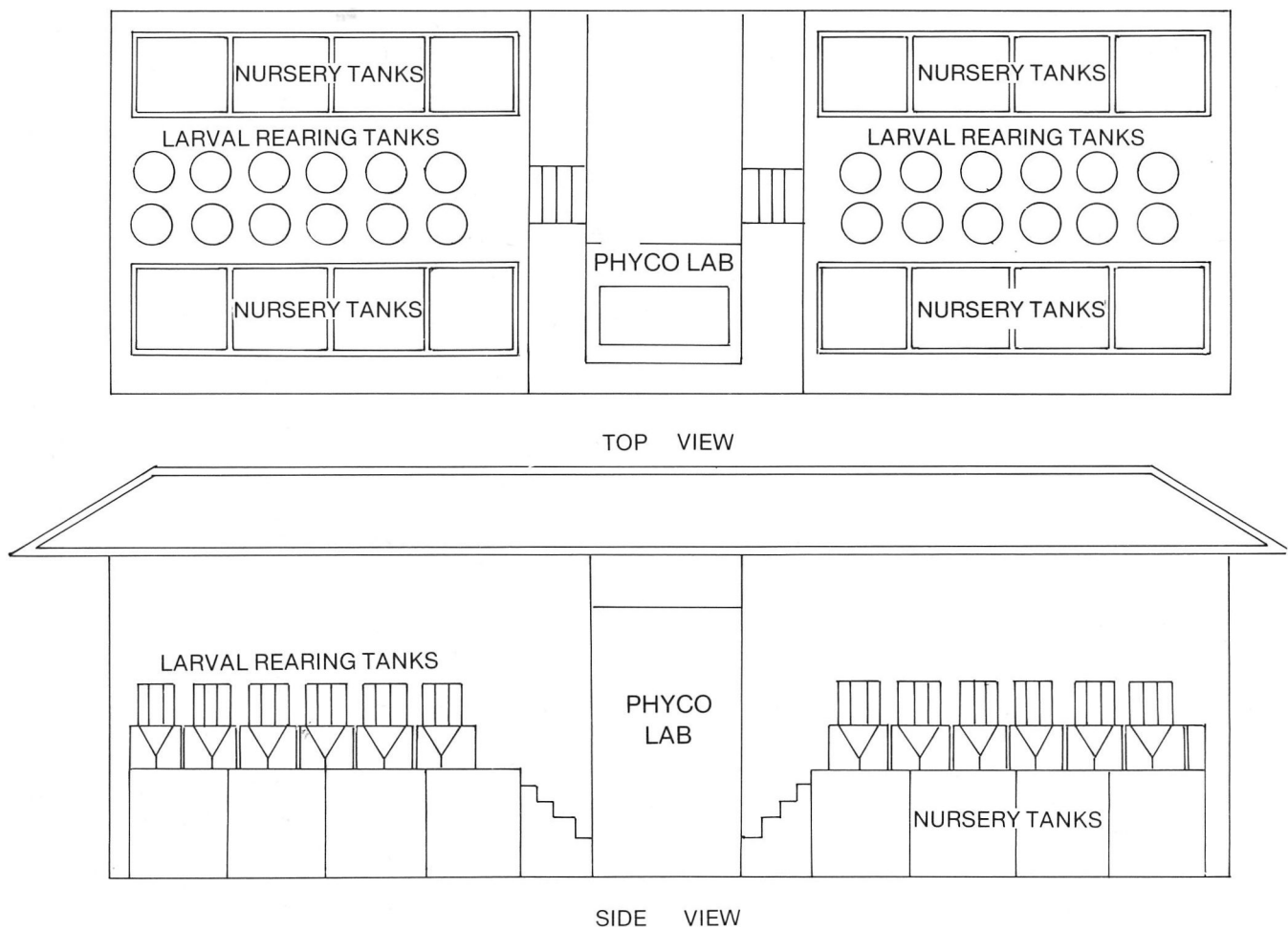


Fig. 1B. Lay-out of combined hatchery system.

water as food for the larvae. To ensure the growth of diatoms, water in the larval rearing tanks is enriched with fertilizer daily. The concrete tanks used are either rectangular or square with a capacity ranging from 40 tons to 2,000 tons, located outdoor or indoor. The depth of the tanks ranges from 1.5 to 2 m. For indoor tanks, transparent roofing is provided to allow sunlight penetration. In this system, spawning, larval rearing and nursery operation are done in the same tank. Technical grade fertilizers are applied directly to the tanks after removal of spawners and hatching of eggs. This operation minimizes the manpower and technical input such as provision for an algal culture room and algal specialist.

**Small-tank hatchery.** This system was developed in the National Marine Fisheries Service in Galveston, Texas, U.S.A. in late 1960. It utilizes separate algal or diatom cultures for controlled feeding of larvae. Due to inconsistent supply of spawners, the design of the hatchery is much smaller in size than the Japanese system. Spawning tanks are separated from larval rearing tanks and both are usually made of plastic or fiberglass. The sizes of larval rearing tanks range from 1000 to 2000 l and the spawning tanks from 100 to 250 l. The stocking density per tank is high (200-300 nauplii/l) so that larvae can be reared only up to P<sub>1</sub>-P<sub>5</sub>. Thus, an earthen pond or concrete nursery tank is necessary for further rearing of juvenile size before stocking in grow-out ponds.

**Combined hatchery system.** Both hatchery systems mentioned above have their advantages and disadvantages in terms of environmental requirements, availability of spawners, etc. (see Table 1). In Japan and China, for instance, where the commonly cultured species are *P. japonicus* and *P. orientalis*, respectively, there are no problems in the availability of spawners and water supply. The capacity

**Table 1.** Comparison between big- and small-tank hatchery systems.

1. Galveston system
  - 1.1 Advantages
    - i) Low initial investment.
    - ii) Only small number of spawners required for one operation.
    - iii) Larvae from nauplius (N) to postlarva 1 (P<sub>1</sub>) could be reared at high density.
    - iv) Easy to control diseases.
  - 1.2 Disadvantages
    - i) Not able to raise larvae up to P<sub>22</sub> at the same density.
    - ii) Nursery ponds required.
    - iii) More manpower required (in the case of mass production).
    - iv) High cost of maintenance.
2. Japanese system
  - 2.1 Advantages
    - i) Larvae can be raised up to P<sub>22</sub> in the same tank.
    - ii) Nursery tanks or ponds not required.
    - iii) Less manpower used for operation.
    - iv) Low cost of maintenance.
  - 2.2 Disadvantages
    - i) High cost of initial investment.
    - ii) Difficult to control diseases.
    - iii) Large number of spawners required for one operation.

of a hatchery tank can be as big as 2,000 m<sup>3</sup>. On the other hand, in some Southeast Asian countries, the supply of *P. monodon* spawners is limited. In addition, farmers prefer bigger-sized larvae for stocking in grow-out ponds. Therefore, a hatchery design for this species has been developed with the combined advantages of both systems to meet the requirements of farmers and maximize tank utilization (Kungvankij, 1982). This system makes use of spawning tanks with capacities of 1,000-2,000 l, larval rearing tanks with capacities of 1,000-3,000 l and nursery tanks with capacities of 30-100 tons capable of rearing the larvae up to P<sub>30</sub> (Fig. 1).

### Hatchery operation

**Spawners.** Spawners are collected by professional fishermen from coastal waters. Although spawning occurs throughout the year, there are distinct periods when majority of the shrimps spawn. There are two pronounced spawning seasons for *P. monodon* in Southeast Asian waters, December to March and June to September. For *P. merguensis* and *P. indicus*, it is from June to September and for *P. japonicus*, April to August.

In Japan, hatchery operators can easily procure spawners from fish markets because shrimps are sold live to consumers who prefer live over dead ones. In contrast, hatchery operators in some Southeast Asian countries must deal directly with fishermen to secure live spawners. In most cases, they provide the fishermen with necessary facilities such as aerators, tanks, etc. and teach them proper handling techniques to ensure getting quality spawners.

### Hatchery management

**Big-tank hatchery.** Once the spawners arrive in the hatchery, they are kept in holding tanks and then placed in the hatchery tank just before sunset. The volume of rearing water for spawners in the spawning tank varies from species to species. The normal practice for *P. japonicus* is one spawner/2 m<sup>3</sup>; *P. monodon*, one spawner/5 m<sup>3</sup>; *P. indicus* or *P. merguensis*, one spawner/m<sup>3</sup>. An initial water level of 100 cm (half of total depth) is generally maintained. Spawning usually occurs the night of transfer from holding to larval rearing tank. Spawners are then removed in the early morning of the following day. Often, the number of eggs or nauplii is few, and the spawners may be maintained in the tank for one more night. Soon after hatching, 3 ppm KNO<sub>3</sub> and 0.3 ppm Na<sub>2</sub>HPO<sub>4</sub> are added to fertilize the rearing water. The amount of fertilizers applied thereafter depends on the density of the plankton present in the rearing water. Shrimp larvae begin to feed on plankton when they reach the protozoa stage. During this stage, about 10-20 cm of fresh filtered water is added daily depending upon the density of plankton. If the density of plankton is not enough to feed the larvae, soybean cake, soybean curd, egg yolk, or fertilized eggs of oyster are usually given as supplementary feed. During the mysis stage, rotifer (*Brachionus plicatilis*) or brine shrimp (*Artemia salina*) nauplii are fed. In the early postlarval stage, brine shrimp is usually given as feed. Once the postlarvae reach the sixth day (P<sub>6</sub>), they are fed with minced mussel,

clam meat or formulated larval feeds with a corresponding decrease in ration quantity of brine shrimp nauplii until they reach P<sub>9</sub>. Beyond this stage, the larvae are fed solely with minced mussel, clam meat or artificial diets 3 to 4 times daily. To ensure sufficient amount of algae in the rearing tank, an improvement of this system makes use of pure cultures of diatom before application of fertilizer.

**Small-tank hatchery.** In this system, the algae are cultured separately and fed to the larvae at a pre-determined quantity. *Skeletonema costatum* and *Tetraselmis* sp. are produced generally in 300-l to 1-ton tanks at a density of  $3.5-5 \times 10^6$  cells/ml or at  $3.3-4 \times 10^5$  cells/ml (Mock and Murphy, 1974) in algal culture rooms.

The spawners are placed individually in spawning tanks. Separately spawned egg batches are selected and distributed to larval rearing tanks or discarded as required. Individual spawning also facilitates the removal of dead spawners and unfertilized eggs after hatching of nauplii and the transfer of nauplii to larval rearing tanks. In the larval rearing tanks, algal cells are added daily during the protozoa stage while newly-hatched *Artemia* are given during the mysis and early postlarval stages.

**Combined system.** In the combined system, spawners are placed individually in spawning tanks. The spawner is removed from the tank the morning after spawning. Prior to cleaning, the eggs are either collected and washed or 2/3 of the water is drained from the spawning tank through filter nets and then replenished with new water, thus allowing the eggs to hatch in the same tank. The number of hatched nauplii is estimated, then nauplii are transferred to a bigger tank (20-100 tons) if the count after hatching averages more than 0.5 million (20-30 nauplii/l). In this tank, the larvae are reared until P<sub>25</sub>. On the other hand, if the number of nauplii is less than the minimum requirement for big tanks, stocking is carried out in small larval rearing tanks at the rate of 100-200 larvae/l. The larvae are reared either to P<sub>2</sub> or P<sub>6</sub> after which they are transferred to the big tank and reared to P<sub>25</sub> (Fig. 1A, B).

Both pure algal culture and direct fertilization of rearing water are used in this system. This practice is typical in Taiwan, Thailand and the Philippines.

**Pond culture system**

Although shrimp farming has been developed for more than a century in Southeast Asian countries, most shrimp farmers still follow the traditional method of extensive farming. Such traditional practice is characterized by low production of about 100-300 kg/ha/year, irregular pond size and shape, and relatively low technical and financial input. Due to a high market demand, high export price and low acquisition cost of land, these traditional farms are still commercially profitable despite low production.

Shrimp yield in ponds can be increased by applying modern farming techniques such as intensification of culture operations through regularization of pond sizes, increasing stocking density, employment of aeration, application of formulated feed, etc. This will mean a considerable increase in financial and high technology inputs which most small farmers in developing countries may not be able to afford.

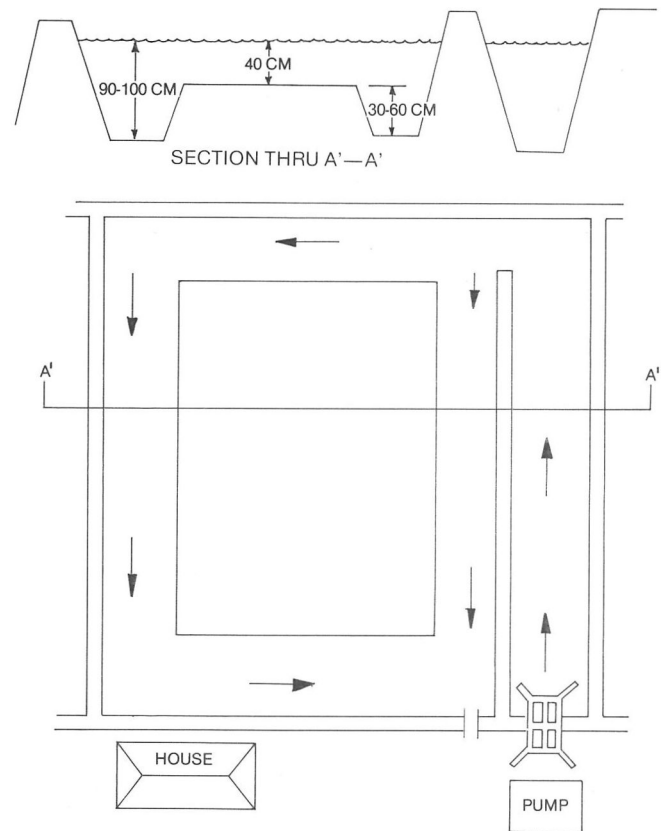


Fig. 2. Typical extensive pond in Thailand.

**Traditional or extensive shrimp farming.** This type of farming system is characterized by irregular shapes and sizes of ponds which range from 3 to 20 ha. Usually, each pond has a peripheral ditch 10-20 m wide and 30-60 cm deep. In Thailand, the middle portion of the pond is slightly elevated to about 40 cm (Fig. 2) while the pond bottom is entirely flat in the Philippines.

Extensive farming has been considered the simplest culture approach. Seedstock normally comes from the wild and supply is seasonally dependent. Shrimp fry found in these farms either accidentally gain entrance during water exchange or are intentionally stocked by the farmer with fry collected from the wild. Extensive farming employs very low stocking density, in the range of about 3,000 to 5,000 fry/ha. In this grow-out scheme, supplementary feed is not given and water management is by tidal fluctuations. Typical examples of traditional shrimp farming are found in Thailand, Indonesia, Philippines and Malaysia.

In Thailand, Indonesia and Malaysia, shrimps occur in ponds by mere opening of the pond gates during high tide. The natural stocks of shrimp seeds are brought in by the incoming water. The gates are then closed at low tide. Trapped fry are allowed to grow inside the pond for two months before harvest. In contrast, shrimp farmers in the Philippines do not rely on natural shrimp seed that come in with the tide water but stock their ponds with fry collected from the wild usually in polyculture with milkfish. The average stocking density ranges between 2,000 to 5,000 fry/ha. In both culture approaches, yield per unit area is very low.

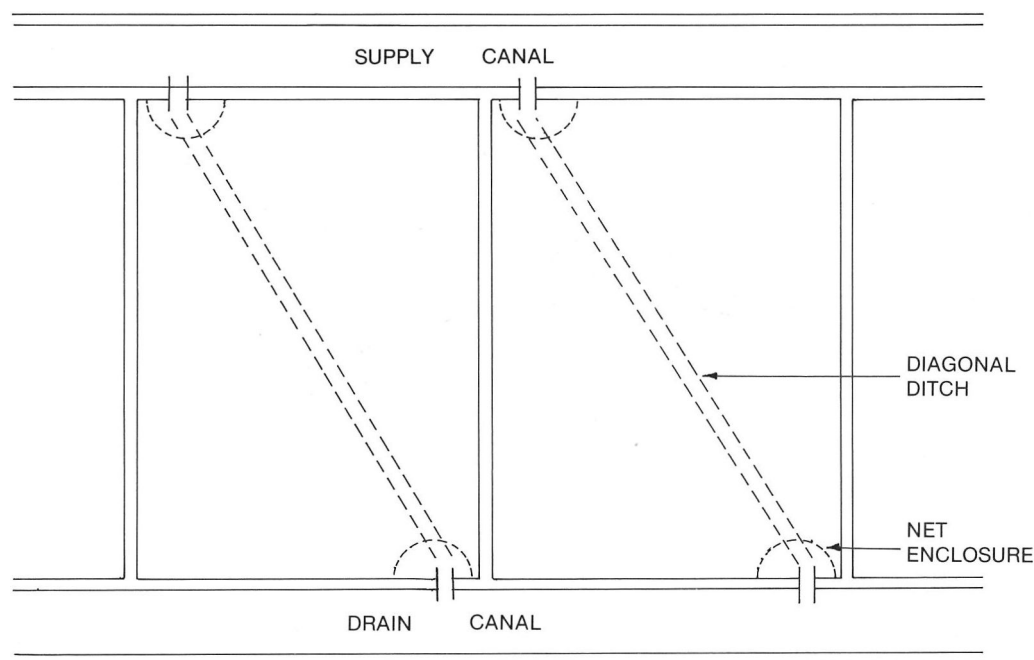


Fig. 3. Typical semi-intensive pond.

During the past decade, improvement and innovations in the extensive shrimp culture method have appreciably increased production. Among these improved techniques are application of lime prior to stocking to condition the soil, use of pesticides to control or eradicate pests and predators, application of organic or inorganic fertilizers to enhance natural food production, increased pond water depth, and increased stocking density either through pumping water daily or direct stocking. These innovations generate higher and more consistent yields. The extensive culture approach, despite many drawbacks, is still the most profitable enterprise for subsistence fish farmers with very low capital.

**Improved traditional or semi-intensive system.** In this farming method, the improvement over the traditional method is the systematic lay-out of ponds. Ponds are generally rectangular in shape with size of about 1-3 ha and depth of 0.8-1.2 m. Each pond has separate inlet and outlet gates to facilitate water exchange, pond preparation and harvesting. A diagonal ditch, 5-10 m wide and 0.3-0.5 m deep extending from inlet to outlet is also constructed to facilitate draining of water and collection of shrimp during harvest (Fig. 3). This also serves as hiding place for shrimp during daytime. This method involves higher stocking rates, use of supplementary feed, and a regular water management scheme. Current practices vary from country to country and within each country, the normal practice of stocking "seeds" in the semi-intensive system varies from 28,000 to 50,000 fry/ha. Feed, either formulated or fresh, are given daily to the stock as supplemental feed in addition to the existing natural food produced through application of fertilizers. This system also requires the use of a water pump to maintain good water quality.

While this approach would substantially increase yield per cropping, the use of supplemental feeds entails additional

cost that generally accounts for the biggest share in operational expenditure. Hence, this deters most subsistence farmers from actually venturing into such level of farming operation.

The Amakusa type or pen culture in Japan can be classified under this level of culture. It is an artificial enclosure constructed along shallow bays and intertidal areas for holding and raising shrimps. It consists of a rectangular or square vertical wall of concrete, constructed to a height of 1 m for holding water during low tide and a wooden frame with nylon netting set on top of the concrete wall to prevent escape of shrimp and facilitate water exchange during high tide. This culture method takes advantage of a large body of water that is constantly renewed through tidal fluctuations and by water current (Fig. 4). The dimensions of the enclosure range from 2,000 to 10,000 m<sup>2</sup> with a depth of 1.0-1.5 m. Stocking rate is between 20 and 30/m<sup>2</sup>. Average production is about 300-400 g/m<sup>2</sup> or about 3-4 ton/ha/year.

**Intensive culture.** This culture operation is the most sophisticated system and requires very high financial and technical inputs. Rearing facilities are either earthen ponds or concrete tanks. The distinct features of this system include the use of hatchery-produced seed, high stocking density, use of formulated diets, application of aeration to increase dissolved oxygen level in ponds, and an intensive water management scheme.

Sizes of pond or tank vary from 500 to 5,000 m<sup>2</sup> as found in Japan, Taiwan, Philippines and Thailand. Dikes may be of pure earthen material, earth coated with plastic sheets or concrete. Most designs include separate inlet and outlet gates or small water inlets for flowthrough purposes. Drain-out system is provided in the form of a centrally located drain pipe, a drain gate (sluice or monk type) or a combination of both (Fig. 5).

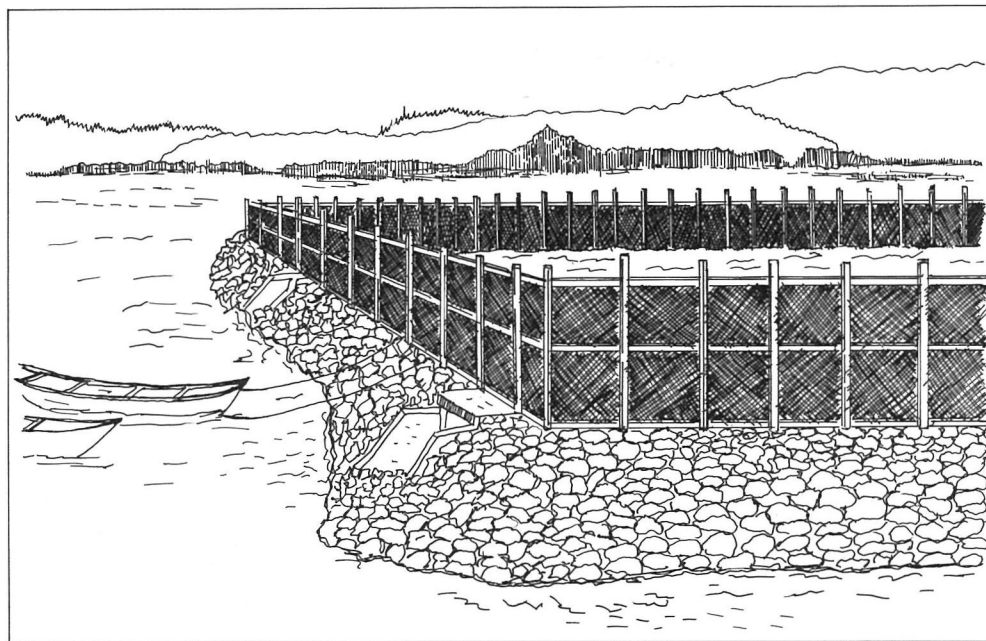


Fig. 4. Amakusa type shrimp farm in Japan.

An excellent intensive culture method for kuruma shrimp called the "Shigueno type" has been developed in Japan. Culture facilities consist of circular concrete tanks with capacities ranging from 1,000 to 2,000 tons and an average height of 2 m. Tank bottom is provided with a sand substrate and water circulation is effected by a flowthrough system (Fig. 6). Shrimp are fed daily with a high protein formulated diet. Stocking density ranges from 200 to 250/m<sup>2</sup> and average production ranges from 1.5 to 3 ton/crop in a 1,000-ton tank and about 10-20 ton/ha/year in earthen ponds with concrete dikes.

**Aquaculture production of shrimps in Asia**

Various hatchery and nursery techniques have been developed over the decade and are being adopted by both private and government hatcheries. However, hatchery seed production of tiger shrimp is still inconsistent and erratic. Meanwhile, 80% of shrimp farms in Asia still operate on the traditional or extensive method which relies on wild fry or fry collected from trapping ponds.

Over 1.5 billion postlarvae of *P. japonicus* and *P. monodon* are produced annually in Taiwan and Japan. The farmer in these countries uses entirely hatchery-bred postlarvae for stocking the pond. In Japan, only 50% of postlarvae produced are used for grow-out ponds while the rest are stocked in open waters.

Among Southeast Asian countries, Philippines, Indonesia and Thailand are the main producers of *P. monodon* postlarvae. The Philippines leads in seed production of tiger shrimp with 300 million per annum, while Thailand and Indonesia produce only about 100 million each per annum. However, there is need for a larger amount of fry to support the growing needs of shrimp farmers. The recent development of shrimp farming techniques and the consequently up-

graded traditional shrimp farming in the region have created the need for more fry.

At least 0.12 million tons of crustaceans were produced through aquafarming in 1983 (Table 2). This represents only 1.2% of total world aquaculture production of about 10 million tons (Table 3). Crustacean production has increased by 73% from 1980 to 1983 (Table 3).

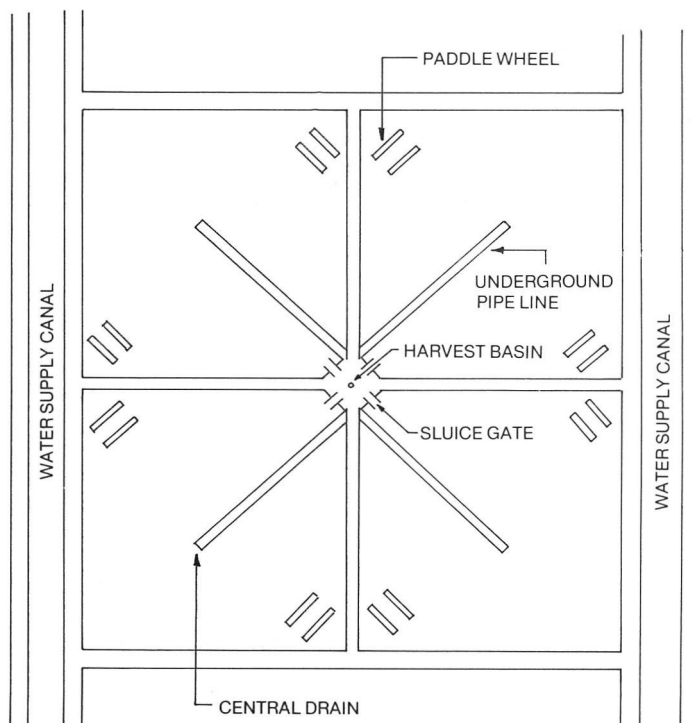
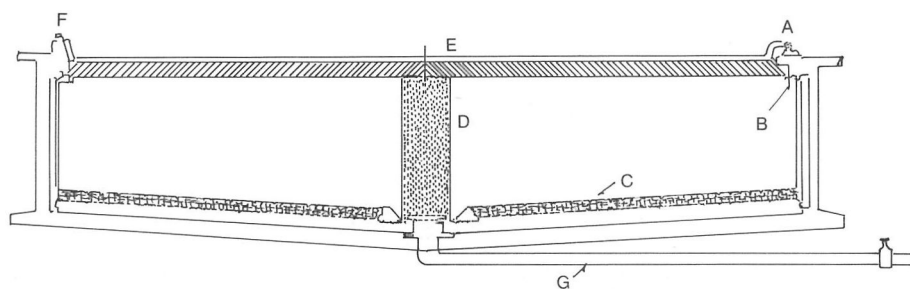


Fig. 5. Intensive pond (earthen with concrete dikes; after Liu and Mancebo, 1982).





**Fig. 6.** Shigueno-type intensive culture tank: A, Gate valve of spray-pipe; B, Aeration bubbling-tube; C, Sand bed; D, Cylindrical screen; E, Spray pipe; F, Gate valve of supply pipe; and G, Drain pipe.

Over 61.1% (Fig. 7) of total crustacean production through aquaculture is produced in Asia (Table 4). Indonesia caps the world's top 10 shrimp producers. Six Asian countries, namely Indonesia, India, Thailand, Taiwan, Philippines and Japan contribute at least 60% of world production of crustaceans.

About 123,000 tons of crustaceans were produced from aquafarming in 1983. Shrimps are the main crustaceans cultured. Almost 62% of total world crustacean production is produced by nine Asian countries. The main species of shrimp cultured in Asia are *P. monodon*, *P. merguensis*, and *P. indicus* in the warm waters of Southeast Asia, India and Taiwan and *P. japonicus* and *P. orientalis* in the cold waters of Japan, China and Korea.

### Investment in shrimp aquaculture in Asia

Earlier investments in the shrimp industry were confined to the development of small-scale shrimp farms mostly using the fish farmers' personal resources with little or no external financial support. Since shrimp farming is considered a lucrative industry, investment by the private sector has increased considerably in recent years as evidenced by the number of new farms established under various levels of operation. In the last few years, many large-scale multi-million shrimp farms have been developed especially in China, Thailand, Philippines and Malaysia.

On the other hand, investment from the public sector has also increased due to the growing confidence in many countries in shrimp farming as a source of foreign exchange earnings, and as an important component for rural development. However, public investments either through government input or through external aid focus more on small-scale shrimp culture by upgrading traditional shrimp farming practices.

Despite worldwide interest in the shrimp farming industry, large-scale investments in shrimp culture projects are

still relatively limited. Investors are hesitant to venture in large-scale shrimp culture projects mainly because relatively few of these projects have proven to be financially successful in the long-term. Some of the major constraints in attracting private ventures in shrimp culture particularly in countries where there are no traditional shrimp culture practices are the lack of: 1) technicians and scientific personnel with hands-on practical experience in shrimp farming and farm management; 2) relevant technical and economic information on pilot farms; and 3) supply and distribution services of seeds, feeds, fertilizers, etc. The major consideration for private investment is economic viability and the internal rate of return while public venture may place emphasis on social benefits instead of profitability alone.

The non-availability of insurance for aquaculture farms may reflect the instability of the industry. High risk and unstable technology have made it extremely difficult to propose bankable projects which can be accepted by insurance companies. Although insurance schemes are now available in Japan for some technologically advanced, large-scale fish-farms, this is not a common practice in most countries in Asia.

The main financial input in aquafarming is the initial capital needed for the procurement and development of shrimp aquafarming facilities as well as operational costs for feeds, fertilizers and seed which usually amounts to more than 70% of total operational cost.

Successful shrimp culture ventures are dependent on numerous technical, biological and economic factors. Apart from management skill, proper choice of culture sites and suitable technical personnel with hands-on practical experience in shrimp farming practices, are perhaps the most important considerations to ensure success and adequate financial inputs. Experience in most developing countries in Asia seems to demonstrate that at the family level, low

**Table 2.** World aquaculture production in 1983.

Region	Crustacean production	%	Total aquaculture production	%
Africa	26	0.02	43,865	0.43
Asia and Pacific	75,644	61.29	8,412,131	82.38
Europe and Near East	162	0.13	1,221,511	11.96
Latin America	20,188	16.35	220,505	2.16
North America	27,425	22.27	312,691	3.06
Total	123,445MT		10,210,730MT	

**Table 3.** World production of aquaculture commodities.

	1975	%	1980	%	1983	%
Finfish	3,980,492	(65.23)	3,233,326	(37.13)	4,447,946	(43.56)
Mollusk	1,051,341	(17.23)	3,196,308	(36.71)	3,245,530	(31.79)
Crustacean	15,663	(0.25)	71,245	(0.82)	123,445	(1.21)
Seaweed	1,054,793	(17.29)	2,206,484	(25.34)	2,393,782	(23.44)
Total	6,102,289MT		8,707,363MT		10,210,703MT	

capital aquafarms are economically feasible instead of large-scale, capital intensive shrimp farms. However, through sufficient farm management and technical inputs, remarkable success with optimum economic production has been attained in large-scale shrimp farms in many countries in Asia.

**Constraints to shrimp culture development in Asia**

**Spawners**

Inadequate supply of wild spawners remains one of the major constraints in the development of the shrimp farming industry notably that of farming the tiger shrimp *P. monodon*. To ensure consistent supply of spawners of this species, many hatcheries in Southeast Asian countries have been developing techniques for maturing *P. monodon* in captivity but so far results are not consistent. Thus, techniques for gonadal maturation of captured and pond-reared adult tiger shrimp need to be improved.

**Larval feeds**

Natural food still remains the major feed in shrimp larval rearing operations. One of the key factors ensuring success in shrimp hatchery production is the timely supply of the needed food organisms in sufficient quantity. Majority of the hatcheries usually have algal cultures and zooplankton areas to maintain pure stocks of the needed live food such as *Chaetoceros*, *Skeletonema*, *Tetraselmis*, *Chlorella* and *Brachionus*. Algal stocks can be easily maintained in standard culture media whereas pure rotifer stock must be sus-

tained through year-round culture. Very often, contamination by undesirable species occurs as well as failure in diatom bloom especially during the rainy months resulting in lack of food supply for the larvae. Maintenance is not only costly but also requires a specialist for this purpose. On the other hand, in the big-tank hatchery system which utilizes natural diatoms, the major problem encountered is the overbloom of diatoms, of which some such as *Nitzschia* sp. are undesirable species which cannot be eaten by the larvae and may normally attach to their appendages. This makes molting impossible and high mortality occurs particularly in outdoor hatcheries. Failure in diatom bloom may also occur especially during the rainy season leading to lack of food in the larval rearing tanks.

Both private and government sectors have attempted to develop pelleted artificial feeds or microencapsulated diets for larval rearing. It will be advantageous to the shrimp hatchery industry if artificial larval feeds become reliable. Nevertheless, supplemental live food is still needed.

**Development of compound feeds**

Shrimps are usually fed with minced trash fish or mussel and fine rice bran. However, not all portions of the given feeds are consumed. Sometimes, the given feeds may be in excess resulting in pollution of the pond water. This leads to lower feed conversion efficiency and low productivity. For intensive culture, the use of formulated diets is essential especially when the supply of fresh feeds is limited or very costly. Despite the limited studies on the nutritional requirements of shrimps, several formulated diets have already

**Table 4.** Asia and Pacific countries with crustacean production through aquaculture.

	Production (MT)	%	Main species
Indonesia	21,797	28.8	<i>Penaeus monodon</i> , <i>P. merguensis</i> , <i>P. indicus</i>
India	20,700	27.4	<i>P. monodon</i> , <i>P. indicus</i>
Thailand	14,931	19.7	<i>P. monodon</i> , <i>P. merguensis</i>
Taiwan	1,431	15.1	<i>P. monodon</i> , <i>P. japonicus</i> , <i>P. orientalis</i>
Philippines	3,920*	5.2	<i>P. monodon</i> , <i>P. indicus</i>
Japan	2,500	3.3	<i>P. japonicus</i>
Malaysia	245	0.3	<i>P. monodon</i> , <i>P. merguensis</i>
Korea	50	0.06	<i>P. japonicus</i> , <i>P. orientalis</i>
Singapore	39	0.05	<i>P. monodon</i> , <i>P. merguensis</i>
Mauritius	23	0.03	
Total	75,644		

\*The Philippine Shrimp Farming Industry: Risk and opportunities for private investors. Submitted to the Philippine Government by the International Finance Corporation, 1984.

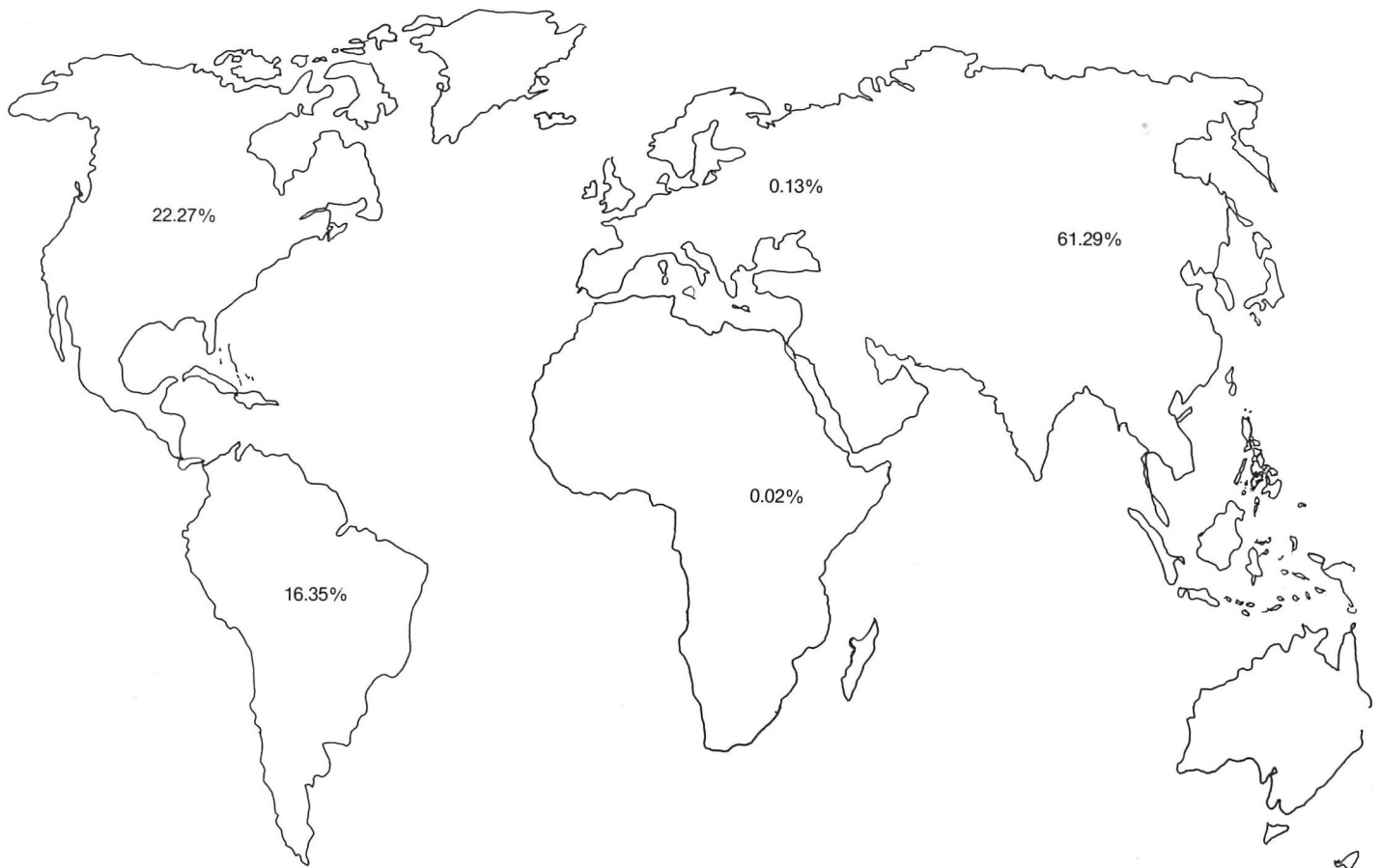


Fig. 7. 1983 world crustacean production (in %), by region.

been developed and commercially produced in some countries. Some of these feeds appear to have better conversion efficiency compared to fresh feeds. However, the prices may be high and supply is insufficient. Since the formulations for these diets are considered trade secrets, manufacturers generally limit production in order to increase market demand especially if the diet shows good feed conversion efficiency. As a result of these conditions, feed cost has hampered the development of intensive shrimp culture.

To offset these problems, more research must be done on the nutritional requirements of shrimp as well as their physiology and biology in order to improve existing formulated diets and develop new ones. Suitable cheap feedstuff must be found and incorporated into the diets. Testing of these diets must be done not only on an experimental scale but also on small commercial scale to ascertain conversion efficiency. Once found to be efficient, production techniques must be standardized, packaged and made freely available to any interested small- or large-scale manufacturing company for commercial production. This will minimize monopoly of feed supply and thus lower the cost and increased feed availability to shrimp farmers thereby paving the way to intensive shrimp farming.

### Diseases

Disease is a serious problem both in hatcheries and rearing ponds. The most serious disease-causing organisms in the

larval stages are *Zoothamnium*, fungi (*Lagenidium*) and bacteria (*Vibrio*) which may contaminate the intake water, or may result from a collapse of *Artemia* population in the pond. General signs of infection include increased opacity of abdominal muscle, expansion of chromatophores (usually appearing reddish in color), and occasionally a dorsal flexure of the third abdominal segment.

It is very difficult and expensive to treat infected larvae. Prevention is always better than cure. The best remedy is to prevent the onset of fungal and bacterial infection. This can be done by separating the spawning tank from the rearing tank and using clean or purified rearing water.

In rearing ponds, black gill disease caused by *Fusarium* spp. also occurs when the bottom of the rearing pond is in bad condition. Body cramps has also been noted in pond-reared *P. monodon* and *P. japonicus* when these were caught in daytime under a hot sun. High mortalities usually follow. Intensive culture using high stocking densities should be avoided until an effective treatment for this disease is found.

### Technology packaging

Although various techniques in shrimp farming have been developed as a result of more than 50 years of research studies, these techniques have yet to be refined, standardized, packaged and tested in different environmental conditions so that appropriate technology can be disseminated to shrimp farmers. The techniques that have been established

in one country may not be applicable to other countries. Hence, shrimp farming techniques are not disclosed and will remain untold until such time that aquaculturists and researchers are confident that research results can be packaged into a standard technology.

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