MARINE SHRIMP FARMING

L. Chim
IFREMER, Laboratoire Aquacole de Nouvelle Calédonie, BP 2059, 98846 Nouméa, New Caledonia

H. Lucien Brun
SEPIA, Immeuble International A2, 13 avenue de la Gare, 78181 Saint Quentin en Yvelines, France

G. Le Moullac
IFREMER, Centre de Tahiti, Vairao, BP 7004, 98719 Taravao, Tahiti, French Polynesia

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Contents

Summary

All reared marine shrimps are selected from the Peneidae family according to their good growth and breeding potentials in captivity. Juveniles’ mass production was set up in Japan in the early 1960s. Nowadays, commercial hatcheries cover nearly all the larval need for world shrimp farming production. Some hatcheries complete the shrimp life

cycle by rearing breeders in captivity. Grow-out techniques, mainly conducted in earthen ponds, are different by their rearing density and input levels. Grow-out lasts about 5 months, and market-size animals are harvested by pond draining.

Processing and packaging take place in specialized plants offering a range of products to targeted markets. Commercialized shrimps are frozen, either head-on or head-less, either raw or cooked. Shrimp farming is carried out in inter-tropical areas, mostly in developing countries and crops are mainly sold to the USA, Japan and Europe. This industry suffers from development problems marked by crop failures, due to environment degradation and diseases affecting reared shrimps. Research efforts in genetics and pathology, as well as to better estimate the activity's impact on the environment and the socio-economy, should help towards a more sustainable development in the future.

1. Introduction

Shrimp farming remains a new activity with a takeoff as recent as in the early 80s. Nowadays, farmed shrimp's market represents annually 6 billions US$, without taking into account the induced activities (feed, chemicals, and equipment manufacturers). With 700 000 mt (metric ton) produced per year, farmed shrimp represents about 27% of the world shrimp production, including fisheries, which tends to be stabilized at 2 million mt per year.

Shrimp farming is based on a few species, all selected in the peneidae family for their good reproductive and growth potential. Research allowed Japan, in the early 1960s, to set up a larval rearing technique for *P. japonicus*. Therefore, in the 1970s, research lead by France, USA, China, and Taiwan was able to complete the entire rearing cycle for the main species actually produced in aquaculture. Shrimp farming now relies on a technology, which allows a complete independence from wild juveniles and brood stock.

Post-larvae production takes place in artisanal and industrial hatcheries with an annual output capacity ranging from a few millions to 800 millions larvae. Grow-out is mainly conducted in earthen ponds with different yields (from 0.5 mt to 50 mt per hectare per year) depending on rearing technology and the level of input.

The most interesting shrimp species for aquaculture are tropical shrimp, therefore shrimp farming quickly expends in inter-tropical areas, mainly involving developing countries. Shrimps were a good opportunity for those countries to earn strong currencies through exportation of high added-value product to Japan, USA, and Europe. Shrimp farming manages to deal with these markets by selling a range of product adapted to each country's taste.

Economic interest in making quick money was the main driving force in the first decade of shrimp farming development. Financial institutions loaned large amounts of money knowing that the refunding was very fast. These conditions favored an extremely quick growth of this activity, and in most cases considering neither the social nor the

environmental aspect. Indeed, this rapid development has led, in some producing countries, to crop failures and major social and/or economical problems.

The big expansion of shrimp farming is now over and the actual trend for its development is to produce higher quality. This way to a sustainable development should rely on a strong research activity in different domains such as genetics, pathology, environment, social, and economic. Therefore, two aspects should be considered: first to stabilize existing facilities by seeking solutions for environmentally acceptable production, secondly to base development of new projects on feasibility studies, which will integrate evaluation of social and ecological impacts. Finally, it will be useful to test alternative farming techniques with a better adaptation and integration to the development process of coastal areas with particular background.

2. Penaeid Biology

2.1 Adult Shrimp

Like all crustaceans, shrimps for the Peneidae family are characterized by their body's segmentation. Segments or metamers are grouped in specialized areas: Head (or acron), thorax (or perion), and abdomen (or pleon). The thorax bears 6 pairs of legs called periopods, used for walking, while the abdomen holds the pleopods for swimming.

Figure 1. Child holding a *P. monodon* breeder (picture M. Autrand).

Average females' size is bigger than the males'. Females display a sexual external differentiation called thelycum or seminal receptacle between the bases of the 5th pairs of periopods. In some species *P. monodon*, *P. indicus*, *P. japonicus*, and *P. kerathurus*, this thelycum is closed; where in others *P. stylirostris* and *P. vannamei* it is open. During mating males transfer their spermatophores, which contain spermatozoa, to the female's thelycum.

Among all species in the Penaeid family, the one selected for farming are relatively large prawn. For instance, the shrimp *P. monodon* (see Figure 1), commonly farmed in Asia, have a maximum size and weight that can reach 336 mm. and 270 g. respectively. The two species farmed in Latin America *P. vannamei* and *P. stylirostris* can measure respectively 230 mm. and 260 mm.

2.2 Natural Distribution

On the Pacific coast of Latin America, there are two native penaeid species of commercial interest: *P. vannamei* (white legs shrimp) and *P. stylirostris* (the blue shrimp). Those two species occur from Northern Mexico to the North of Peru.

In Asia the main farmed shrimp and the biggest one is *P. monodon* (see Figure 1). Its distribution covers the Indo-west Pacific from East and South East Africa to Japan, the Malay Archipelago, and Northern Australia. The second species, *P. orientalis*, a sub-tropical shrimp, is mainly observed in the China Sea from the Bohai Sea to Hong-Kong. Another sub-tropical species, *P. japonicus*, is widely distributed in the Indo-West Pacific from the Red Sea and Eastern Africa to Japan, Korea, and the Malay Archipelago, and is also reported in Fiji.

2.3 Ecology and Life History

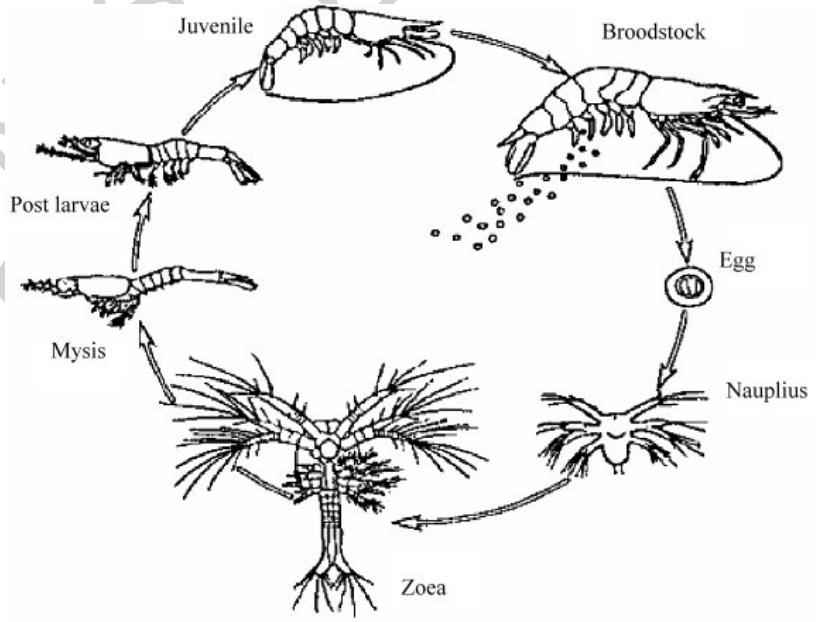

Figure 2. Life cycle of Penaeid shrimps.

Penaeid shrimps are usually marine and coastal crustaceans. *P. monodon* lives in estuarine and marine waters on muddy and sandy bottom, and is found down to a depth of until 100 m. depth. *P. vannamei* inhabits estuarine and marine waters down to about 70 m deep. *P. stylirostris* is found in estuarine waters down to about 30 Meters. The *P. orientalis* habitat depth is 90 to 180 m.

The lifecycle (see Figure 2) of penaeid shrimp is divided in 4 successive stages: larvae, post-larvae, juvenile, and adult during which, morphological, behavioral, feeding, and habitat changes occur. It starts in open sea, where male and female mate. Spawning takes place at night, the female releases the eggs and at the same time the spermatozoa, within spermatophores, are discharged. The fertilization process is completed in the sea. According to species and female size, one spawn gives between 100 000 and 1 000 000 eggs. The eggs diameter averages 250–300µm. Depending on temperature the eggs hatch between 12 and 16 hours after fertilization, in Nauplii larvae. At this stage larvae are vitellotroph: they feed on their own yolk (vitellus). Nauplii look more like tiny aquatic spiders than shrimps.

Then they metamorphose into Zoeae larvae, which have feathery appendages and elongated bodies. The zoeae shape is still far away from the adult shrimp. It lasts six days, feeds on micro-algae and then metamorphoses into Mysis larvae. Mysis have many of the characteristics of adult the shrimp, like segmented body, stalked eyes, and shrimp-like tails. They feed on phytoplankton and zooplankton. This stage lasts another three days, and then the Mysis metamorphoses into post-larvae. Post-larvae look like juveniles and adults. After metamorphosing into post-larvae, the shrimp migrates from the open sea, where they had a planktonic life, to bay or inland sea of lower salinity, by means of oceanic and tidal currents. Then, post-larvae settle down on the sea-bed and begin their benthic life. During this stage, shrimps feed on small benthos, detritus, and algae. Then shrimps gradually migrate back from the shallow sea to the open sea where, at one year old, they will be mature and breed.

3. History of Shrimp Farming and its World Production

Shrimp culture started up in Asia in extensive tidal fishpond, which yielded a mix of fish and crustacean species. Juvenile shrimps entered with the tidal flow into the pond where they were kept. Shrimp grew only on natural productivity, grazing on the benthos and organic material available in the pond. This technique was quickly improved, by stocking the pond with juvenile shrimps collected along the seashore, which allowed Thailand in 1969 to produce nearly 3500 mt of shrimps from about 8000 hectares of ponds.

But the real take off of modern shrimp farming had to wait for the set up of the mass larval rearing technique, that was going to supply shrimp juveniles in quantity and quality, and stop expose farmers to natural recruitment variations. The history started in Japan in 1934 when Dr Motosaku Fujinaga managed to master the larval rearing technique of the shrimp *Penaeus japonicus*. In 1964 it became possible to produce shrimp post-larvae, artificially and in huge quantities, from gravid females captured out at sea. The mass production of juveniles allowed the commercial development of farmed shrimps to proceed in Japan that year.

During the 1970s other countries like France, USA, China, and Taiwan began to investigate the potential of shrimp farming. The results of these researches permitted to define, for many shrimp species of economic interest, their rearing conditions from brood stock to larvae, up to commercial size animals.

Hatchery technology developed in France and the United States have spread out especially to Latin America (Ecuador, Colombia, and Cuba), Africa (Guinea, Madagascar) and, to a lesser extent, Asia (Thailand, Indonesia, and India). In the meantime, the technologies developed by Japan, Taiwan, and China would find their way —mainly in the Asian countries.

In the mid 1970s, when the juvenile shrimp became available to farmers, farmed shrimp production started to increase drastically. World production extended from 50 000 mt to nearly 200 000 mt from 1975 to 1985. Then from 1985 to 1988 (see Figure 3) it increased again more than 125% to reach about 450 000 mt. In the same time, between 1987 and 1989, Taiwan, that was the main producing country, experienced heavy mortality in the grow-out ponds: in one year production dropped 80% from about 100 000 mt to 20 000 mt.

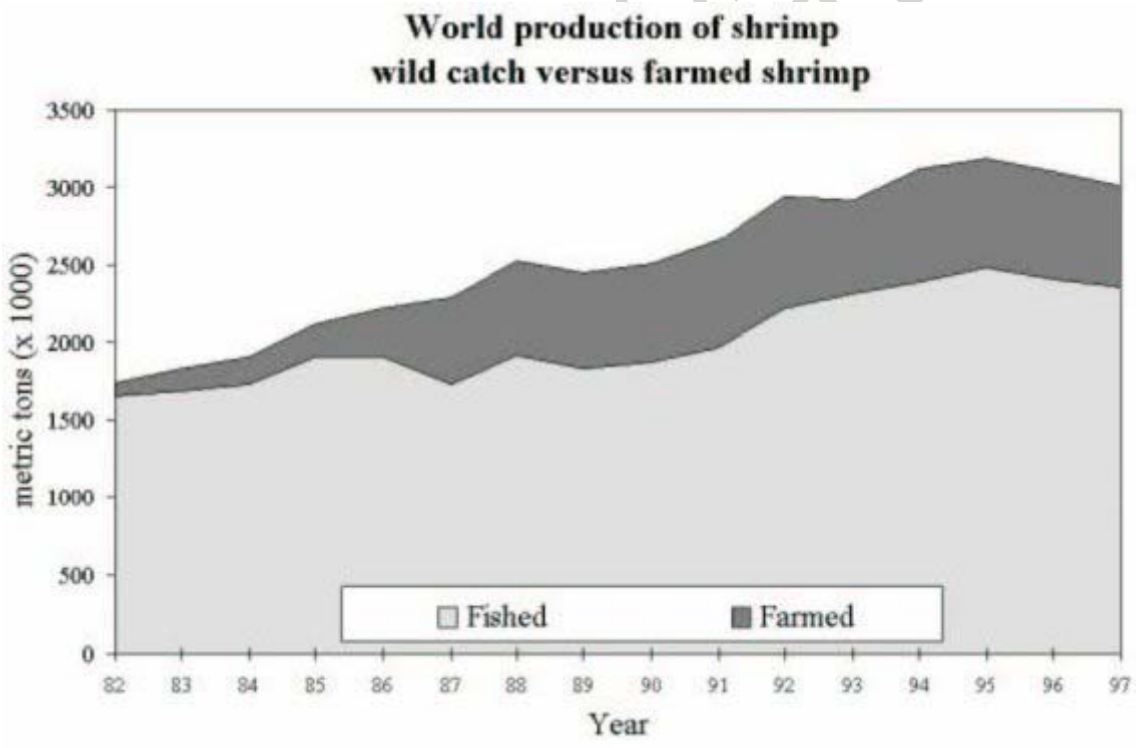

Figure 3. World shrimp production for reared and fished shrimps
(based on data from Shrimp News International).

Between 1988 and 1993, the world farmed shrimp production continued to grow, reaching around 700000 mt owing to China, which doubled its output from 100 000 mt to about 200 000mt. Then China experienced, between 1993 and 1994, the same problem that occurred in Taiwan a few years before, and saw it's annual production

crashing down to about 50 000 mt. A virus seems to have been the cause, but an environmental component was probably involved too.

From 1991 onwards, annual production of farmed shrimp leveled off at around 700 000 mt where about 80% and 20% came respectively from Asia and Latin America (see Table 1). Shrimp farming represented about 27% of world shrimps supplies, with fisheries producing around 2 000 000 mt. (see Figure 3).

Country	Production (Mt × 1000)	Fishery (%)	Aquaculture (%)
China	450	82	18
Thailand	280	43	57
India	341	79	21
Indonesia	240	63	38
U.S.A.	147	99	1
Vietnam	78	62	38
Ecuador	130	8	92
Greenland	73	100	0
Philippines	70	64	36
Mexico	80	85	15
Other	1030	96	4

Table 1. Details of 1996 World Shrimp Production by country (data from Shrimp News International, 1996).

The two main species produced are *Penaeus monodon* (or black tiger shrimp) and *Penaeus vannamei* (or white-leg shrimp) representing respectively around 60% and 20% of the world-farmed shrimp.

The black tiger is produced in Asia and Africa while the White-leg shrimp is farmed more exclusively in Latin America. The other farmed species are:

- *P. stylirostris* in Latin America, mainly Mexico and Ecuador, and in New Caledonia
- *P. japonicus* in Japan, Korea, China, Taiwan, and Australia
- P. orientalis in China
- *P. penicillatus* in China and Taiwan
- *P. merguiensis* and *P. indicus* in extensive farms throughout Southeast Asia
- *P. shmitti* in semi-intensive farms in Cuba

4. Culture Methods

Shrimp juveniles are either caught by fishermen near the seashore or artificially produced in hatcheries. Production of shrimp larvae starts in the hatchery with the brood stock. Breeders come either from the sea (wild brood stock) or from rearing in ponds (captive brood stock). When wild gravid females are caught, they are directly transferred to spawning tanks.

Post-larvae from the wild or produced in hatcheries are transported to the farm where they are reared in earthen ponds. In the farm there are two steps, a first nursery step that last 1-month and allows the post-larvae to grow up to an average weight of 1g.

A grow out step, that last between 4 and 5 months and allows the shrimp to grow up to commercial size. At the end of the grow-out period, the shrimps are harvested, and transported to the processing and packaging plant.

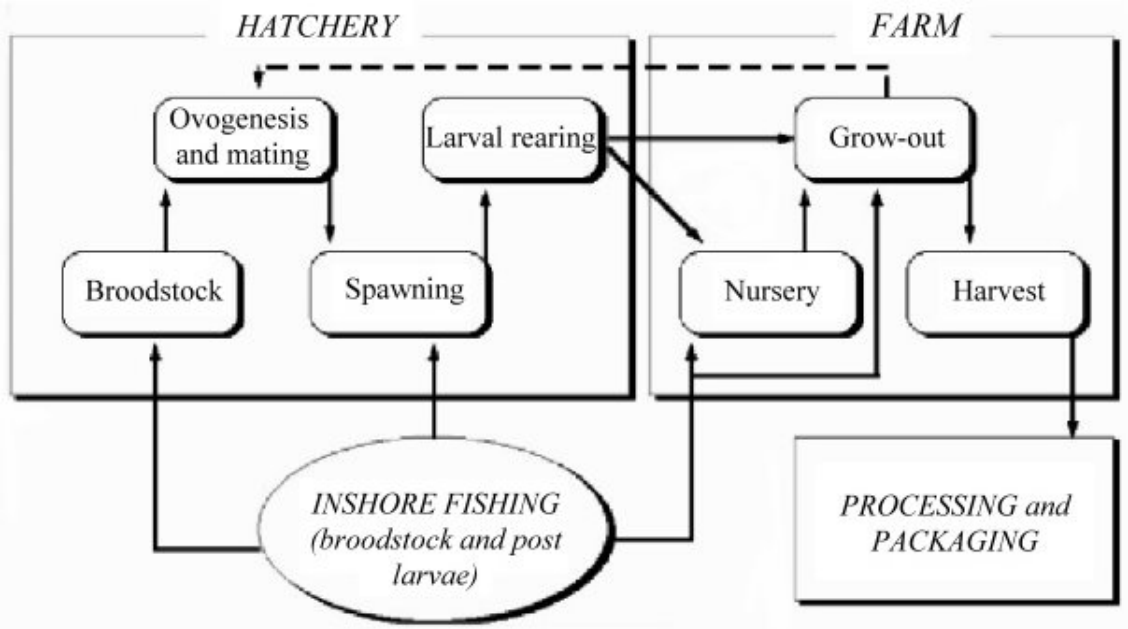

Figure 4. Main steps in peneidae shrimp farming.

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Bibliography

AQUACOP (1982). Penaeid larval rearing in the centre oceanologique du pacifique. In *Handbook of Mariculture*, Vol. 1: *Crustacean Aquaculture*. Boca Raton, FL: CRC Press. [This article gives detailed larval rearing techniques in "clear water."]

Barg U. C. (1992). *Guidelines for the Promotion of Environmental Management of Coastal Aquaculture Development*. FAO Fisheries Technical Paper No 328, 122 pp. Rome: FAO. [This paper examines environmental problems in relation with aquaculture development, especially with shrimp farming.]

Browdy C. L. and Hopkins J. S., eds. (1995). *Swimming Through Troubled Water*, Proceedings Of the Special Session on Shrimp Farming. Aquaculture '95. 251 pp. Baton Rouge, LA: World Aquaculture Society. [This publication presents papers dealing with shrimp biology and farming.]

Gall G. A. E., Quinitio E. T, and Primavera J. H, eds. (1998). *Special Issue: Culture Of Penaeid Prawns and Shrimps*, 374pp. Aquaculture. Vol. 164. [This publication reviews papers on shrimp biology and farming as well as original works such as rearing shrimps in floating cages.]

Rosenberry B. (1998). *World Shrimp Farming 1997*. San Diego, CA: Shrimp News International. [This annual publication gives statistics on shrimp world production and state of this activity.]

Shigueno K. (1975). *Shrimp Culture in Japan*, 153 pp. Tokyo: Association for International Technical Promotion. [This book deal in details with the larval rearing technique called "green water," which was settled in Japan. Grow-out techniques carried out in Japan are also described.]

Tacon A. G. J. (1994). Dependence of intensive aquaculture systems on fishmeal and other fishery resources—trends, and prospects. In *FAO Aquaculture Newsletter*, April 1994. Rome: FAO.]

Biographical Sketches

Liêt Chim was born in 1956 in France and graduated from Paris University in 1978. He received his Doctorate on animal physiology at the Paris Pierre et Marie University. Between 1983 and 1985 he has carried out researches on aquaculture nutrition in the laboratory of Professor Kanazawa (Japan). From 1985 to 1988 he has worked in shrimp production as expert for Ecuadorian companies in Guayaquil and for the Food Agriculture Organization in Cuba. In this frame, he has been involved in shrimp commercial hatcheries, farm and feed formulation and production. From 1988 to 1992, he was project manager for Sanofi Aquaculture and was in charge of grow-out shrimp feed development and marketing and as such has supervised several projects in Colombia, Thailand, Indonesia, Madagascar and New Caledonia. Since 1993, he works in the French Institute of Research for Marine Exploitation (IFREMER). From 1992 to 1996 he was a geographic manager in the International Relation and Co-operation Directorate. And from 1997 up to date he is in charge of research unit on shrimp eco physiology of the tropical aquaculture laboratory of IFREMER's Tahiti Center. His main research interest is shrimp physiology (osmoregulation, nutrition) with application to the farm production. He has published several scientific articles and technical reports.

Hervé Lucien-Brun was born in 1954 in France and graduated from Orsay University in 1981. In 1983, he received his degree of Project Manager in Aquaculture of the University of Montpellier, in this frame he had a one-year professional training course in Japan. From 1983 to 1985 he was project manager for Tilapia farming in warm effluent water of nuclear power plant (France) and in Maryut farming project (Egypt). From 1985 to 1988 he was technical manager of a commercial shrimp hatchery and farms for an Ecuadorian private company. From 1988 to 2001, he was executive in a French company (SEPIA) dealing with aquaculture. In this frame he has been Manager for a group of shrimp farms in Ecuador and for the starting up of an integrated shrimp farm and hatchery in Indonesia and Madagascar and several other countries in the intertropical area. He has been expert for implementation and technical audit of several shrimp hatcheries, farms and packing plants in Latin America, New Caledonia and Asia. His actual position with WORD France not only deals with all aspect of shrimp aquaculture but also with quality control and tracability of the products. He has published several articles and technical reports on shrimp farming.

Gilles Le Moullac was born in 1957 in France and graduated with a M.Sc. from EPHE in 1995. He has been worked as researcher at the French Institute of Research for Marine Exploitation (IFREMER) previously named CNEXO since 1979. Within the Institute, his work was first focused on the production system in shrimp aquaculture in reproduction and larval rearing. His professional experience has been used in technical assistance to industrial hatcheries especially in South America. A second step to his career turned him in basic research in physiology to study digestive physiology and then immunology in penaeid shrimp. In the last 8 years he has published 12 scientific articles and taken part in international conferences.