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Shrimp culture: a global overview

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Shrimp culture: a global overview

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Showing signs of peaking

Greenpeace and whitespots notwithstanding, the six billion dollar shrimp farming industry manages to hover at the close to one million metric ton production level it has been at since 1995. After a spectacular 26.4% average annual growth between 1984 to 1991, the industry managed to squeak by with a 2.2% average annual growth between 1991 to 1997. The industry appears to have reached its plateau since 1992. Although there are signs of decline, don't bet on it — the 1997 contraction was less than 1%. Meanwhile new players continue to come in and may just boost total production.

As industries go, shrimp farming is relatively new. Not counting the pioneering research work of Dr. Hudinaga in the 1930s which eventually led to the development of shrimp hatchery technology, and the extensive cultures using wild seedstock, shrimp culture as an industry can be traced back only to the early 1970s. That was when interest in its culture started to perk up outside the traditional growers in Southeast Asia in their age-old earthen ponds. Despite its relative newness, close to a third of world shrimp landings is now made up of farmed shrimp (Figure 1).

If the production of the major farmed species are compared with the same species from capture fisheries then the contribution of aquaculture is considerably higher. As shown in Figure 2, of the six major species being farmed only the Kuruma prawn, *Marsupenaeus japonicus* still relies more on capture fisheries than on aquaculture. On the other hand there are no entries at all of landings from capture fisheries in the FAO Fisheries Statistics of the blue shrimp, *Litopenaeus stylirostris*.

Figure 1. World production of shrimps from capture and culture showing percentage of farmed shrimps to total, 1984-1997 (Source: FAO Aquaculture Statistics)

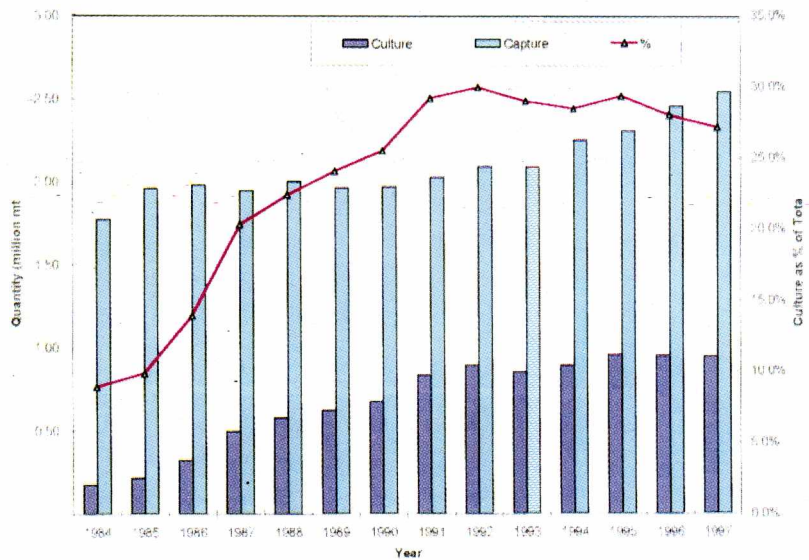
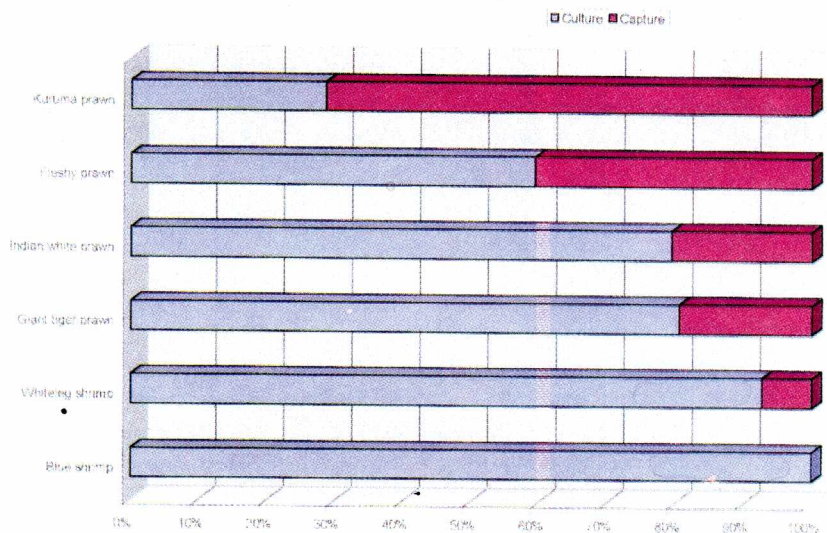


Figure 2. Percentage contribution of aquaculture and capture fisheries to the production of major penaeid shrimp species



As for the other species, farmed shrimps make up 92.6% of the total world production of whiteleg shrimps, *Litopenaeus vannamei*, 80.6% of the giant tiger prawn, *Penaeus monodon*; 79.5% of Indian white shrimps, *Fenneropenaeus indicus*, and 59.4% of the fleshy shrimps, *Fenneropenaeus chinensis*.

P. monodon still dominates

The giant tiger prawn, which is known in international trade as black tiger, has been and continues to be the leading cultured species. As shown in Figure 3 some 52%, or 490,195 mt of the world's farmed shrimps consist of the giant tiger prawns. Coming a distant second is the whiteleg shrimp *L. vanamei* with 17.9% followed by the fleshy shrimp, *F. chinensis* with 11.1%. The fleshy shrimp used to be the second most important species after the jumbo tiger. With the collapse of the industry in China which produced 95% of the species, the fleshy shrimp was overtaken by the whitelegs in 1995. The banana shrimps, *F. merguensis*, constitute only 5.5% and the Indian white, *F. indicus*, only 0.5%. In spite of its very high price, especially when live, there is very little aquaculture of Kuruma shrimp, *M. japonicus* which makes up only 0.3% of the total shrimp produced from aquaculture.

It should be noted that the top three culture species, namely *P. monodon*, *L. vanamei* and *F. chinensis* are also endemic to the respective regions or countries where they are mostly produced. For sure there have been several attempts to introduce a species to a country where it is not endemic. There has been some limited success such as for instance the introduction of various penaeid species to French Polynesia where they are not native to, but no country has ever become a major producer out of such introduction.

Asia leads in shrimp production

During the last 14 years from 1984 to 1997 some 63 countries are listed in the FAO

next page

A short note on the scientific names

Many readers may be bewildered by the unfamiliar genus attached to familiar species name. These "new" generic names are not exactly new. They had always been there but only as subgenera, which are rarely used. Taxonomists have always known that the group of shrimps and prawns familiar to everyone as belonging to the genus *Penaeus* actually consists of different distinct groups based on their reproductive morphology and biology but hesitated to split it up due to the confusion that may ensue since everybody was already familiar and comfortable with *Penaeus*. Very recently, Perez-Farfante & Kensley (1997) took the bold step of placing the different penaeid shrimps in their proper "taxonomic bincards" by elevating the former subgenera to the level of full genera.

The black tiger and the green tiger shrimps remain under genus *Penaeus* so they are still *P. monodon* and *P. semisulcatus* respectively. The Indian white shrimp (*P. indicus*), the banana shrimp (*P. merguensis*), and the Chinese fleshy shrimp (*P. chinensis*) now belong to the genus *Fenneropenaeus*. The South American whiteleg and the blue shrimp should now be referred to as *Litopenaeus vanamei* and *Litopenaeus stylirostris* respectively. The kuruma shrimp (*P. japonicus*) is now *Marsupenaeus japonicus*. It should be noted that the specific names remain the same.

It will take time for these new generic names to be widely used. There may be some initial resistance. But then judging at how wide and how fast the acceptance has been when taxonomists reclassified the Nile tilapia and the Mozambique tilapia from plain old *Tilapia* to the jawbreaking *Sarotherodon* and finally to the currently used tongue-twister, *Oreochromis* within less than ten years, resistance to the changeover from plain old *Penaeus* to their respective "qualified-penaeus", may be futile. - - WGY

Perez-Farfante, I. and B. Kensley. 1997. Penaeoid and Sergestoid Shrimps and Prawns of the World Keys and Diagnoses for the Families and Genera. Memoire du Musee National D'Histoire Naturelle. Paris, France. 233 pp

Figure 3. Percentage composition of world production of farmed shrimp by species, "nei" means not elsewhere included (Source: FAO Aquaculture Statistics)

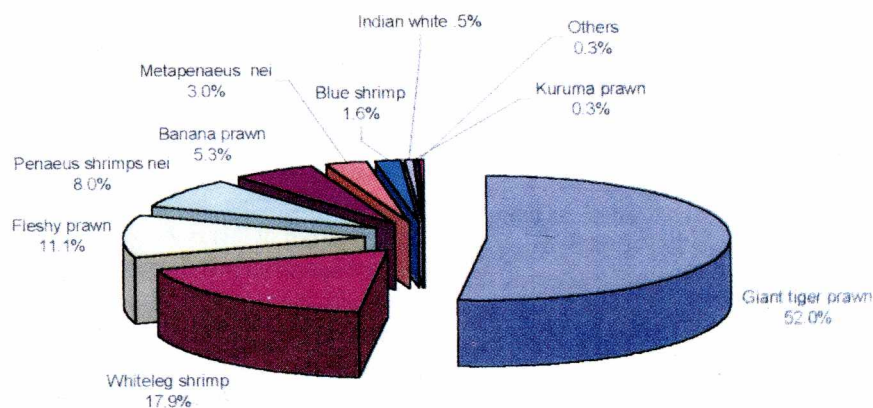
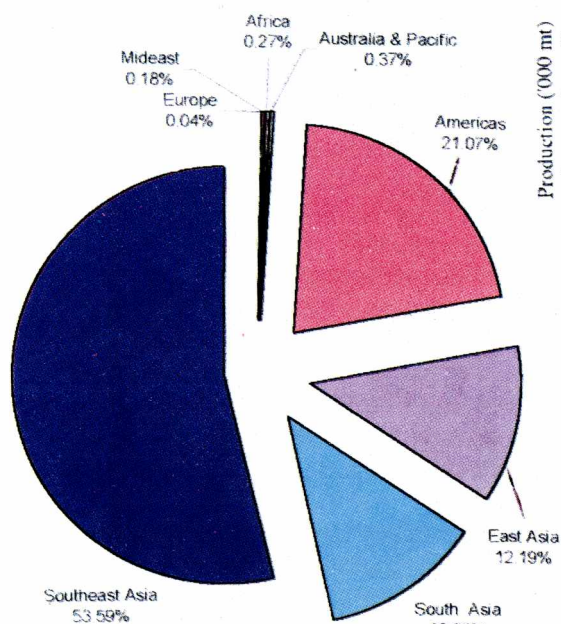
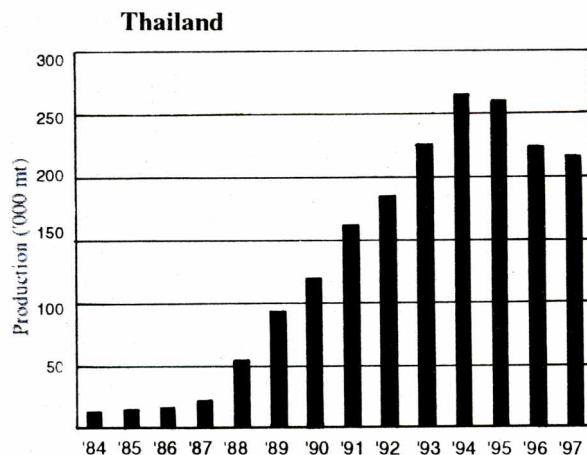


Figure 4. Percentage contribution of various regions to total world shrimp production of 941,814 mt in 1997 (Source: FAO Aquaculture Statistics)



aquaculture statistics as having produced shrimps at one time or another. In 1997, nine of these countries did not have any production reported. This leaves 54 shrimp producing countries. In 1984 only 29 countries had any shrimp production report. The producing countries are found in all regions including Europe and the Mid-East. One of the newest entry to the shrimp culture club is Albania which reported a 10 mt production of kuruma shrimp in 1997.

If grouped according to major regions, Southeast Asia is still the leading shrimp producing region with 506,035 mt or 53.7% of the total. If all of Asia is considered together as one region then it contributes 737,380 mt or 78% of the world's farmed shrimp with the Americas contributing 198,925 mt or 21%. The remaining one percent is distributed among all the other regions. In the Americas, the producing countries are all part of Latin America with the exception of the United States which managed to produce 1,200 mt despite stringent environmental laws and high labor cost.



By country, Thailand is the leading producer in 1997 with 215,000 mt, a position it has maintained since 1993. Thailand's 1997 production is already 19% lower than its peak production of 265,524 mt in 1994. Like all other countries in Asia, Thailand also suffers from disease and environmental problems not the

least of which is the WSSV or White Spot Syndrome Virus. That Thailand managed to remain on top has been attributed to, among others, the fact that 80% of the 12,500 intensive culture farms are owned by small-scale farmers operating 1-2 ponds, each ranging in size from 0.16 – 1.6 ha. These farms produce 80% of Thailand's *P. monodon*. No big shrimp farms with high investment and large overheads have been able to survive. Kongkeo attributes the failure of the large farms to "insufficient care in farm management." Simply put, it means hired technicians and workers in large outfits cannot match the attention lavished by small shrimp farmers on their own farms.

It also helps that the government provides considerable assistance to the industry. Proof of this is the development of a Seawater Irrigation System (SIS) which brings in clean seawater that individual shrimp farms can tap. The SIS incorporates pre- and post water treatment using mechanical and biological treatment measures (Tookwinas & Yindcharoen 1999). A good system of shrimp disease diagnosis

in place, using the latest PCR technique, helps minimize the risk for Thai shrimp farmers by avoiding the use of WSSV-infected postlarvae and/or spawners.

Thai shrimp farmers have been very fast in expanding to new areas. When the original shrimp producing area in the eastern coast started having problems, production shifted to the southern

coast. Now Thailand has expanded its production area 50 to 60 km inland, by using mainly freshwater. Estimates of the total area used range from 5,000 to 8,000 ha. Saltwater is trucked in and used only in the beginning and is diluted to very low salinity. Since it still uses some amount of saltwater, the practice has become controversial due to its impact on neighboring rice fields. This has forced the government to restrict any further expansion and to limit its practice to coastal provinces only.

Indonesia

The distinction of being the top farmed-shrimp producer has somehow always eluded Indonesia. Between 1988 to 1989 it was second only to China. Thailand dislodged Indonesia in 1990 and Indonesia slipped to the third position. This was to be so until 1992. The next year China suffered a catastrophic production failure and Thailand became the leading farmed-shrimp producer. Indonesia rose up to become the second largest producer, a position it has maintained up to the present.

Indonesia produced 159,480 mt in 1997, its highest ever. Like many other places in Asia, shrimp farms in the main island of Java are also struggling against diseases brought about by unbridled intensification in the past. Unlike most other countries in Asia however, Indonesia still has large undeveloped lands in the outer islands particularly in Sumatra and therefore has the potential to later become the world's largest farmed shrimp producer.

In the province of Lampung which is located in southern Sumatra, one of the world's largest, or most likely the largest, shrimp farm under the control and management of one company can be found. Here the P.T. Dipasena Citra Darmaja has established 18,000 individual plastic-lined culture ponds covering some 4,500 ha in a 16,000 ha site. It also has obtained the rights to develop at least 50,000 ha of land which used to be under Wahyuni, a sister company. Most of the ponds measure 2,500 m² gross area with a few measuring half a hectare. As provided for under Indonesian law, any aquaculture development over 30 ha in Java and 50 ha in islands outside Java has to be developed under the *Tambak Inti Rakyat* (TIR) or nucleus-estate concept. Dipasena is owned by the family who owns the tire-manufacturing company Gadjah Tunggal and also used to own the Bank Central Asia until the Asian currency crisis virtually brought a large portion of the Indonesian banking industry down.

The nucleus of the TIR, to be operated by the developer, consist of the water supply system including the central pumping station, hatcheries for the production of seedstock; possibly a feedmill; processing, packing and marketing facilities as well as a corps of extension technicians. The "plasma" consist of the grow-out ponds which are to be distributed to individual growers who qualify under the program. In the case of the Dipasena mega-shrimp farm, the beneficiaries are migrants from the densely populated island of Java who are encouraged to migrate to the sparsely populated outer islands under the Indonesian government's transmigrasi program. The family of such migrants are provided transportation to the island they intend to move into, farmland and shelter, and the means to get started, such as working animal and farm implement. In Lampung, the farmlands are ready-to-operate shrimp farm. Each shrimp farm consists of two grow-out ponds each measuring 2,500 m² gross or in some instances one unit of 5,000 m² pond.

With half a hectare per family, one

can see that 4,500 ha of ponds will have close to 10,000 beneficiary-families. With an average of 4 persons per family, the whole shrimp farm estate is a town in itself complete with schools, shops, mosques, a hospital and other amenities. The site runs for more than one hundred kilometers along the coast and has a total of more than 1,000 km of supply and discharge canals. The drainage canal is used as a main transport channel for both people and cargo.

In a scheme patterned after home financing programs, the developer, in this case P.T. Dipasena, is paid by the servicing bank the full development cost plus a pre-agreed profit margin once each half-hectare farm is turned over to a qualified beneficiary. Each beneficiary is then expected to pay the servicing bank the cost of the farm over a set period of time at a pre-set amortization schedule. The nucleus company then provides the shrimp fry, feeds and other inputs and buys the shrimp produced for processing and export. In theory it is a win-win arrangement. The small farmers gets to own a modern shrimp farm and is assured of inputs and a market for their produce. The developer makes money on the development and continues to make money by providing the fry and other inputs and in the processing and export of the shrimps. Between 1996 and 1998 Dipasena reportedly produced some 16,000 to 19,000 mt of shrimps per year.

The 1997 Asian currency crisis has hit Indonesia hard. The Indonesian currency plummeted from 2,800 Rupiah to the US dollar to as low as 15,000 Rupiah. It has now stabilized somewhat at the 7,500 to 8,000 Rupiah level. This has affected the shrimp industry in general and Dipasena in particular. Feed mills are having a hard time sourcing dollars to import essential feed ingredients. Dipasena found the rupiah cost of the imported plastic liners soaring beyond the farm development price that has been pre-agreed with the servicing bank. Reports indicate that the development pace has slowed down considerably and that the company is considering the development of 5 ha earthen

ponds for extensive culture for the additional 50,000 ha area. Just to provide a scale for comparison, the total brackishwater pond area said to be used for shrimp farming in the Philippines is only 54,000 ha.

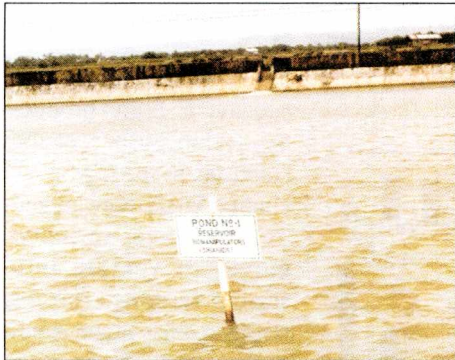
Before the Asian currency crisis and the political turmoil that came after it, the Indonesian Directorate General for Fisheries already had a plan to become the world's largest producer of farmed shrimps. This it intended to do by developing up to 250,000 ha of shrimp farm, with the government financing 30% of the cost, to produce one million tons of shrimps and earn up to US\$8 billion annually. It should be noted that this level of production is even greater than the 1997 world production of cultured shrimps. It is not known whether the government still has the political will and the financial capability to push through with such a large undertaking after all the troubles the country has been having.

China

As late as 1980, Chinese shrimp production from aquaculture was so insignificant it was often lumped together with "others." While aquaculture is said to have started in China this was centered on freshwater aquaculture and the country had no strong tradition for coastal saltwater aquaculture. Then it grew rapidly by leaps and bounds to reach 19,300 mt in 1984. After that, Chinese farmed shrimp production practically doubled itself every year during the succeeding three years to reach more than 153,272 mt in 1987. From the successive 100% annual growth, this slowed down somewhat to only 30% to reach 199,418 mt in 1988. Subsequently it suffered some minor setbacks between 1989 to 1990 but recovered somewhat in 1991 to exceed the 200,000 mt level. A minor decline in 1992 was followed by a catastrophic failure in 1993 which saw the production level fall from more than 200,000 to only 87,856 mt in 1993 and finally reached its nadir at 63,872 mt in 1994. It has since slowly re-



Environment-friendly culture ... p 26



culation and can turn over the water for better penetration of sunlight to maintain the desired plankton level.

Low salinity

Low salinity is maintained at 22 ppt from initial stocking and to be gradually reduced to 16 ppt after 60 days from the start of the culture period, then at 15 ppt after 90 days until the desired salinity of 8 ppt at 150 days of culture.

Bioaugmentation

Microbial inoculants were introduced to counter the dominance of non-beneficial or pathogenic microbes. Intensive monitoring of bacterial and phytoplankton levels were done to prevent outbreak of diseases.

Use of reservoirs

Two reservoirs are used in the scheme. Water pumped in from the river is allowed to settle for at least one day before it is used to replenish the grow-out ponds.

Result of the study at 55 days of culture

Scheme B pond yielded shrimp weighing 3.0 g with estimated survival of 85% while in Scheme A, shrimp weighed 3.5 g with estimated survival of 70%. "The initial result is very encouraging," says Mr. Baliao. "But we need to do further runs. If we get consistent results, then maybe we can say 'this is it'." At least, he said, this will convince the prawn growers that SEAFDEC is really doing its best to help them. ###

Shrimp/global overview ... from p 21

covered with production already exceeding 100,000 mt in 1997.

The meteoric rise in the Chinese shrimp industry was made possible by a massive development program along the Bohai Bay coastline in the northeast all the way down to Fujian in the south. Every year, thousands of hectares were developed by the Chinese government, when it came to the realization that shrimp farming was the best way of making productive vast tracts of arid saline-alkaline coastal flat lands, provide employment and earn foreign exchange to boot.

If subjected to a standard feasibility study it is doubtful if any of the megafarms along the northeastern coast would have been found feasible. Most of the area is above 30° N latitude, about the same level as Los Angeles, California. Therefore, it has a narrow window of opportunity for shrimp farming. The ponds have to be stocked by July of each year at the latest and have to be harvested by November. The rest of the year it is too cold to do any aquaculture. The hatcheries operate only for a brief period from mid-spring to early summer and have to produce all the fry required for the year in a period of no more than 8 weeks.

But the Chinese government took a macro-economic approach to development. Without the shrimp farms the coastal flat lands were useless for anything else. Saline and highly alkaline and without any freshwater they cannot be used to grow crops. There was not enough economic activity to gainfully employ all the people. The government had to subsidize food, clothing and shelter. With the shrimp farms money which would have gone into subsidy went into shrimp farm development and provided employment to the people starting from the construction stage. To maximize employment all the construction works were done by manual labor. Machines were used very sparingly, if at all. Even the crushing of boulders into concrete aggregates was done by hand. Sand,

gravel, cement, bricks and other construction materials were hauled to the construction sites either by wheelbarrows, if the distance was only a few kilometers away or with bullock or donkey carts if the source of material was 50 km or more away. Cement mixing were all done manually. In that manner hundreds of thousands of people were gainfully employed to develop the shrimp farms.

The fall of the industry in 1993 has been attributed to over-stocking and the lack of provision for treating wastewater discharge. The heavy use of wet and fresh feedstuff such as small mollusks and brine shrimp biomass as feed exacerbated the build up of organic load in the water. With so many families depending on the industry the production failure must have hit the shrimp producing areas hard. The industry is now showing signs of recovery and with the hard lesson already learned the Chinese shrimp farmers like their counterparts everywhere are likely to be more cautious this time.

The rest of Asia

The case of Taiwan is already well known. From one of the top producers in 1986-87, Taiwan is now a net shrimp importer.

Philippine shrimp production continues to be sluggish due to widespread infection by the luminiscent *Vibrio* bacteria. At its peak in 1993, the Philippines produced 95,816 mt, of all species but mostly of the giant tiger prawns, based on official government statistics which is also the basis for the FAO figures. The total 1997 production was 41,610 mt. The 10,000 mt production level in the 1997 World Shrimp Farming published in the United States by Shrimp News International is even less than the export figure of 10,532 mt.

Unlike Indonesia or Thailand, the Philippine shrimp growers do not have the luxury of finding new areas for development. The Philippines have run out of new sites to develop. Shrimp growers in Negros Occ. which used to be the center of intensive shrimp farming are slowly and very



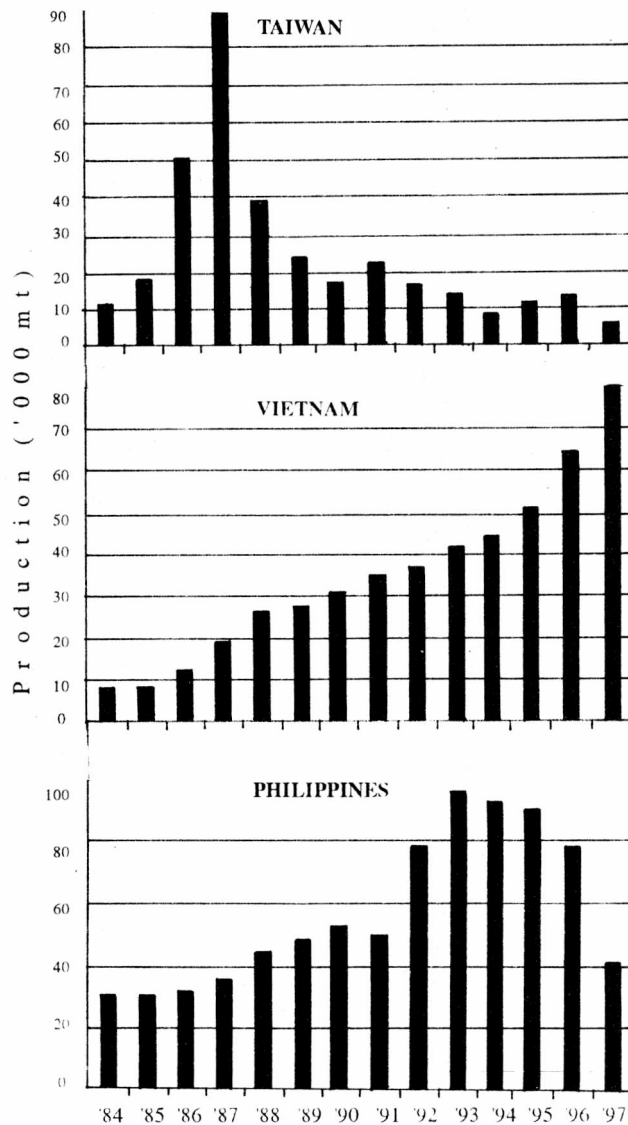
Shrimp/global overview ... from p 33

cautiously trying out lower densities, using probiotics, pond bio-remediation techniques and even enlisting the assistance of a heretofore shrimp pond enemy number one – the tilapia, to minimize the risk of *Vibrio* infection. Panguil Bay, which used to be the northern Mindanao equivalent of Negros Occ. is still a virtual disaster area as far as shrimp growing is concerned. Many of the shrimp growers have shifted to milkfish and lately to tilapia.

Vietnam is the country to watch. Vietnamese shrimp production has steadily increased from only 8,000 mt in 1985 to 80,000 in 1997 – a ten fold growth over 12 years. It now produces more than India which produced only 54,647 mt during the same year after attaining 97,539 mt in 1995. The Indian Supreme Court ruling in 1997 which practically banned intensive shrimp farming within 500 m from the coastline and 200 m from rivers, did little to dampen Indian interest in shrimp farming. However, the widespread occurrence of WSSV has put a damper on further development and on high stocking rates. Bangladesh is also slowly inching up and with 56,480 mt in 1997 already produces more than the Philippines.

Ecuador and the Americas

Ecuador stands out as an oddity among the major shrimp producing countries. It is the only country outside Asia. As early as 1984 it was already producing more than any of the major shrimp producing countries in Asia. Since it was dependent totally on wild fry the industry remained at almost the same level until 1987 and was overtaken by China and Indonesia in 1985. Production perked up only when hatcheries started to be put up. Production exceeded the 100,000 mt level for the first time in 1991 and reached a peak level of 113,137 mt in 1992. However by that time China, Thailand and Indonesia were already producing much more. So Ecuador fell to the fourth position.



Production dropped to 83,404 mt in 1993 due to the Taura syndrome but has since recovered to reach an all time record production of 132,709 mt in 1997. There was an initial controversy over the etiology of the Taura syndrome. At first it was widely believed to be caused by toxic agents in the environment. However it is now confirmed to be caused by a virus which has been designated Taura Syndrome Virus or TSV (Hasson *et al.* 1995)

Practically all the Latin American countries from Mexico to Peru have also started their respective shrimp culture industry. However except for Mexico which in 1997 produced 17,422 mt all the

rest produced less than 10,000 metric tons.

The Middle East

The Middle East with all its oil, is also striving to become a shrimp producing region. Many of the countries in the region including UAE, Kuwait and Yemen have initiated moves to venture into shrimp farming. So far however, serious and large-scale development have been taking place only in two countries: the Kingdom of Saudi Arabia and the Islamic Republic of Iran.

Shrimp culture in Saudi Arabia started way back in 1983 when a private company, the Al-Balaa Establishment developed a 20 ha pilot farm along the Red Sea, using largely Filipino consultants and technicians. This actually preceded whatever shrimp farming activity was carried out by the government's fish farming center. For more than 10 years the Al-Balaa operations at Al-Lith remained at the pilot level. It was only in the mid 1990s that family decided to expand its operation to 100 ha. Now it is developing what is reported to be a 1,000 ha farm.

The most remarkable aspects of the Saudi Arabian shrimp farming operation are the species and the salinity level. Who would have thought that *P. monodon* can grow normally in salinity above 40 ppt? The water of the Red Sea is already 40 ppt. Once in the supply canal the very dry air and the high temperature drives the salinity up to 42 to 45 ppt. The *P. monodon* spawners are caught mostly in the southern part of the Red Sea near Yemen. These prawns must have already adjusted to the



high salinity level of the area.

Saudi Arabia reported a production of 830 mt in 1997. It is not known how much of this is from the Al Balaa farm in Al Lith and how much from the newer Saudi Fisheries Company farm in Gizan province which has a series of circular ponds. The Al-Balaa farm in Al Lith reportedly suffered huge production failure in late 1998. MBV had previously been detected in the farm but this time around the animals reportedly tested positive for WSSV. The entire 100 ha farm as well as three hatchery are now on an extended dry out in an attempt to break the disease cycle.

Another company the Gizan Agricultural Development Co. (GAZADCO) already has a detailed engineering design for an initial 200 ha grow-out farms in a 500 ha site. It is now in the process of selecting the contractors and consulting engineers for the construction and development phase.

Iran is moving very fast after culture trials under a UNDP/FAO Project showed that it is possible to breed and grow local species found in the Persian Gulf which has an average salinity of 38 ppt. Initially two species were being farmed, *P. semisulcatus* and *F. indicus*. However due to slow growth of the former when farmers shifted to a locally milled feed, all the farms are now stocked with *F. indicus*.

The said Project also assisted Iran in the identification of sites suitable for shrimp culture development. Sites are now being developed all along the coast from the province of Khuzistan, which borders Iraq to Chabahar in the south, which borders Pakistan. Space does not permit a full report on the development status. But to provide an example, in Khuzistan a 5,000 ha site is being developed. Thus far 2,500 ha (gross area) has been completed although only 570 ha (net water area) has been stocked. All the three other provinces already have hundreds of hectares of ponds stocked and thousands of hectares still awaiting development.

Unlike Saudi Arabia where the development has been purely a private

sector initiative involving large companies albeit with generous government incentives, Iran is taking a directed development approach to benefit smallholders. The government is developing the sites into a shrimp farm park by providing basic infrastructures such as main supply and drainage canals, road network and electricity. The developed area is then subdivided into 20 ha lots, which are awarded to qualified individuals. Veterans of the Iran-Iraq war or the children of those who died in the war are given priority. The recipients then become eligible for a bank loan to develop the 20 ha lot awarded to them. Working capital loan is also provided.

Since everything is developed according to a master plan the drainage canal outlet is always located very far from the supply canal inlet. There is no possibility of one farm pumping in the neighbor's discharge. In the 3,000 ha site in Khuzistan, the main drainage canal is 7 kilometers long and has a telescoping width starting at 200 m and gradually expanding to reach 500 m at the mouth.

Like China the northern part of Iran also has a problem of cold winters. However in the southern provinces of Chabahar and Hormuzgan the winter may be short enough to allow two croppings a year. The hatcheries operate only between April and July. Spawners are still obtained from the wild. The lack of spawners is now a serious constraint. After the spring spawning, no sexually gravid shrimps can be found anymore. Landbased broodstock and maturation system is now being tried in Shilat's Kollahi experimental station where shrimp culture technology was first demonstrated.

Shilat, the Iranian Fisheries Organization is encouraging farmers to stock at no more than 20 fry/m². The aim is 50,000 mt annual production capability. With a 1997 production of 524 mt, it still has a long way to go.

Prospects for the future

Worldwide interest in shrimp farming remains strong though no longer in the same feverish mode which characterized

the rapid development during the 1980s. Production appears to have stabilized. The most serious issue facing the shrimp industry is sustainability. Environmental groups such as Greenpeace are convinced that shrimp farming as now practiced can never be sustainable. Its high value and marketability always tempt growers to stock more than what the natural environment can safely bear. In the meantime work on less polluting feed which also uses less fish meal continues to be undertaken. Beneficial bacteria to hasten decomposition of waste products as well as to exclude the entry of disease bacteria are increasingly being used. The role of the mangrove as a possible nutrient sink to purify discharge water is being explored. Mechanical means such as the use of ozone-generator to treat pond water are also being tried.

However, the most ecologically sound approach is likely to be the zero-discharge system where wastewater is treated using a combination of physical and biological processes and recycled. Once this system is fully worked out and shown to be financially viable shrimp farming can become more friendly to the environment. Then perhaps even shrimp farms can be viewed as green spots.

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