are many opportunities for assistance and investment. Ideas and partnership are certainly welcome!

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The successful development of backyard hatcheries for crustaceans in Thailand

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One of the important milestones in freshwater prawn farming occurred in the late 1970s when the United Nations Development Programme decided to fund a three-year FAO-executed project, named ‘Expansion of Freshwater Prawn Farming’, in Thailand (New, 2000). This project built on the earlier work of the Thai Department of Fisheries (DOF), led by Somsak Singholka and his team at the Chacheongsao Coastal Fisheries Research and Development Centre (former Chacheongsao Fisheries Station) in Bangpakong, Chacheongsao Province. At first it was assisted by one of the pioneers of global *Macrobrachium* culture, Takuji Fujimura, together with visiting FAO project manager, Herminio Rabanal. Michael New was appointed by FAO in 1979 and he and Somsak Singholka co-managed this project until 1981, after which the Thai government continued this initiative. As a result of these efforts, farmed freshwater prawn production expanded from less than 5 t/yr before the project began (1976) to an estimated 400 t by the time it ended in 1981 (Boonyaratpalin & Vorasayan 1983). Soon afterwards (1984), the DOF was reporting to FAO that Thai production had exceeded 3,000 t/yr (FAO 1989), a very rapid expansion indeed.

This DOF-FAO project not only enabled the establishment of a significant aquaculture sector in Thailand but also benefited the development of freshwater prawn farming globally. One output was the publication of a technical manual on the topic (New & Singholka, 1985; New, 2002) that was translated into many languages. In addition, the Thai Department of Fisheries hosted ‘Giant Prawn 1980, the first international aquaculture conference ever held in Thailand (New 1982), which was attended by 159 international participants from 33 countries and 200 local farmers. Many Thai experts later advised *Macrobrachium* projects and ventures elsewhere in Asia. By 2005, the aquaculture production of *Macrobrachium rosenbergii* in Thailand had risen to 30,000 t/yr (valued at US$ 79 million) and to more than 205,000 t/yr globally (FAO, 2007). In addition, a similar quantity of a related species, *M. nipponense*, was produced in China in 2007. In total, the global farm-gate value of freshwater prawn farming had reached almost US$ 1.84 billion/yr by 2007.

Concrete tanks for nursing PL.

Though there was no seawater avaiable, the Bangkok Marine Laboratory which has now been allocated by DOF to the Bangkok Fish Market, successfully cultured to post-larvae stage *Penaeus merguiensis*, *P. semisulcatus*, *P. latissulcatus*, *Metapenaeus monoceros* and *M. intermedius* in 1972 (Cook 1973). Seawater had to be brought from offshore by boat. All gravid female shrimp were captured in the Gulf of Thailand. Experiments on pond culture of artificially bred seed were carried out at private shrimp farms in Samutsakorn Province and Bangpoo, Samutprakarn Province but the results were not satisfactory.

In 1973, the Phuket Coastal Fisheries Research and Development Centre (former Phuket Marine Fisheries Station) sucessfully bred *P. monodon* by induced spawning from broodstock caught from Andaman Sea. Postlarvae of the early batches were stocked in semi-intensive ponds in Bangkrachai, Chantaburi Province, Klongdaan, Samutprakarn Province and Klong-sahakorn, Samutsakorn Province. This brought shrimp farming the much needed technique that enabled the farmers to have better control of their crop and sustainable production, instead of reliance only on wild seed for stocking as an extensive culture system. This important research later led to the highest peak of *P. monodon* production of 304,988 mt in 2000 (Kongkeo, 2006) before substitution by *P. vannamei*.

Hatchery production of crustacean postlarvae

The major extension thrust in the DOF-FAO project was the provision not only of technical advice but also of free *M. rosenbergii* postlarvae (PL) for stocking the initial grow-out operations on each farm. Freshwater prawns were distributed by road and rail all over Thailand. Large quantities of PL were produced for this purpose in a series of huge concrete tanks sited at the fisheries station in Bangpakong. However, many of its technical staff also began to produce PL successfully in other, less conventional and smaller containers, such as the ‘klong pots’ used for storing potable water. Before long, some of the stilted houses on the site had small production units underneath their living quarters. Even non-scientific staff learned the neces-sary techniques quickly. Soon, the first commercial ‘backyard hatcheries’ began to spring up in nearby areas of Chacheongsao Province. One of the reasons why these backyard hatcheries were to prove so successful was the ability of Thai entrepreneurs to follow changing market requirements. Unlike the massive species-specific hatcheries that were set up in the 1970s and 1980s for fish and crustacean species else-where, which were almost impossible to modify, many of these simple backyard hatcheries could easily and cheaply adapt themselves to produce marine shrimp PL (*P. monodon*) and seabass fingerlings (*Lates calcarifer*) according to demand.

Backyard hatcheies are generally managed with simple but efficient technology mainly by farmers with little education. The technology which was originally developed for *M. rosenbergii*, can easily be switched to *P. monodon*, *P. vannamei* or nursery of seabass and grouper fingerling if prices of existing species drop or disease problems occur. The initial investment for land, construction and equipment, as well as operation costs, is very low because of the simple techniques used. Fortunately, Thai farmers have had a long experi-ence and tradition of aquaculture and crop production. They are also enthu-siastic to learn and practise advanced technologies which have been successfully done on a research scale in government institutions or by large scale entrepreneurs. They always have new ideas for development or modifica-tion to suit with local conditions and are eager to experiment on their own. Sometime, they start to experiment on new culture techniques by themselves and learn by mistakes from the results. The present success of Thailand in shrimp and prawn industry is testimony to the persistence and ingenuity of Thai farmers in utilising applied science to its utmost potential. It is a good example of blending research work done by government with farmers’ enthusiasm in adoption of new technology.

Due to the long distance of hatcheries from the sea, hypersaline water from salt farms is transported by truck and subsequently diluted to the desired salinity with disinfected freshwater. This hypersaline water is pathogen-free and virus carrier-free due to its high salinity. These hatcheries purchase *P. monodon* or *P. vannamei* nauplii from nauplii producers who are located near the open sea areas for better water quality and circulation needed in the maturation process. For *Macrobrachium*, hatchery operators use spawners both from grow-out farms and from the wild. Small hatcheries run by owners and families are more efficient than big hatcheries which are run by paid workers due to sense of belonging. The decrease in price of shrimp fry caused by the spread of these backyard hatcheries also helped to stimulate the rapid expansion of grow-out ponds.

When problems occur, production can be discontinued, even for a long periods, without undue expense. This family business is in contrast to large scale sophisticated hatcheries, in which the cost of wages, power supply, supporting facilities and other overheads still has to be borne during the closure. Periodic discontinuation of operations is, in fact, necessary for both hatchery and grow-out in order

to facilitate reconditioning, drying and disinfection of tanks, ponds, aeration and water systems.

This is similar to the success of small-scale intensive ponds which spread all over the country. More than 80% of Thai marine shrimp production come from approximately 12,500 intensive farms with total production area of 27,000 ha (Kongkeo, 1995). These small operators typically run 1-2 ponds, each ranging in size from 0.16-1.6 ha. However, during the early stage of development large scale operators are always required to pioneer research work by their own or by adaptation of new technogies from government or overseas to serve as a prototype for further development by small-scale operators. The income from operations has also provided considerable socio-economic benefits to these small-scale operators who mainly live in coastal regions. Thus local communities directly gain these benefits.

After being developed in Thailand, this technology has been transferred through assistance of FAO, NACA, UNDP, Thai Government, the private sector and feed manufacturers and successfully adapted in Indonesia, Vietnam, India, Bangladesh, and Myanmar. Some countries modified the technology by using direct seawater because they have better seawater supply sources.

There are more than 2,000 small scale hatcheries in Thailand including in Chacheongsao, Chonburi and Phuket provinces where they generate significant production of more than 80 billion (90% of total) marine shrimp postlarvae per year. They have had sustainable production and survived the many shrimp crises that have occurred during the past 20 years. Unfortunately, they are now suffering from competition with SPF postlarvae supplies by large scale hatcheries which have introduced high technologies such as SPF and disease resistant strains, biosecure systems, raceways etc from overseas. To cover their high investment costs, these large scale hatcheries are under pressure to increase their margin by selling postlarvae direclty to grow out farms instead of selling nauplii to backyard hatcheries as they had formerly done. Tracebility of broodstock and certification, an issue usually raised by developed countries, are also problems for these backyard hatcheries because they purchase nauplii from external suppliers. Although nauplii producers can issue PCR negative certificates, it is difficult for them to sort out the source of origin for particular backyard hatcheries. Producers usually mix nauplii from various sources for easy distribution and economic reasons.

The Thai DOF has tried very hard to solve the problems of small scale operators. A farm registration system and CoC and GAP certification systems have been implemented since 2003. At the moment, 98 and 727 hatcheries, including some backyard hatcheries, have been certified with CoC and GAP standards, respectively. Furthermore, the use of the “Movement Document” and traceability system at grow-out farm level have been recently implemented and are expected to be functioning properly and to cover the hatchery level in the next few years. As the fact that overseas SPF technology assuring the organism is free of specific disease only in its specific environement, its popularity may decrease if there is more evidence of disease infection similar to cases in Indonesia. At that time, the opportunity of the backyard hatcheries may again resurface, if they are all certified and operate under a traceability system.

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Alternate carp species for diversification in freshwater aquaculture in India

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Indian fisheries has made great strides during last five decades with the production levels increasing from 750,000 tonnes of fish in 1950-51 to 6.4 million tons in 2005-2006, of which the contribution from the inland sector is around 3.3 million tons (51.6 % of the total) compared to 3.10 million tons (48.4 %) from the marine sector. The contribution of fisheries to the gross domestic product (GDP) and agriculture GDP has been estimated to be 1.2 and 4.2 %, respectively. India ranks second in world inland fish production, next to China. The growth rate of inland and marine sector at present is 6.6 and 2.2%, respectively. The anticipated growth rate during the tenth five-year plan (2002-2007) for inland and marine fisheries are 8.0% and 2.5 %, respectively.

Indian freshwater aquaculture has evolved itself from the stage of a domestic activity in the Eastern States of West Bengal and Orissa to that of industry and has become an important component of Indian fisheries contributing about one third of total fish production of the country and share about 95% of the total aquaculture production. The mean national fish production levels from tanks and ponds have increased significantly from 600 kg/ha during the 1970's to 2,200 kg/ha in the 1990s. In some areas such as the states of Andhra Pradesh, West Bengal, Punjab and Haryana yield has increased even to 8,000-10,000 kg/ha. Demonstrations on intensive composite carp culture practices had shown a maximum production of 15,000 kg/ha at Central Institute of Freshwater Aquaculture, Bhubaneswar (Jana and Jena, 2004).

Carps are the backbone of Indian freshwater aquaculture, comprising around 85% of the total freshwater production. Carp culture in India is largely limited to six species; the three Indian 'major carps' catla, rohu and mrigal; and three exotic or 'Chinese carps', grass carp, silver carp and common carp. Again, Indian major carps contribute the lion's share of freshwater aquaculture production, around 80% by volume. Among Indian major carp production, the contribution of rohu alone is about 35%.

India is regarded as a 'carp country' due to its rich diversity of carps in its freshwater ecosystems. About 2,070 species of carps (family Cyprinidae) are available in Indian waters. Though many of the carp species like minor barbs and minnows are not economical from the commercial culture point of view, the country is blessed with at least 15-20 varieties of minor and medium carps that have a high potential for freshwater aquaculture, which has yet to be exploited. These carp species can be considered as alternatives to the major cultured carp species, for diversification in freshwater aquaculture. The systematic classification, geographical distribution, biology, age at sexual maturity, breeding behaviour, consumer preference, present culture status, problems and prospects of culture along with the suggestions for conservation of these species are detailed below.

Labeo calbasu

Commonly called 'kalbasu', or 'black rohu' in some areas, it is a carp of medium economic significance, though some authors categorized it as major carp. It belongs to the sub-family Cyprininae. *Labeo calbasu* is widely distributed in India. It is a highly preferred food fish. It is also considered as a game fish. It can be domesticated in tanks and is suitable for composite fish culture with other carp species. It thrives well in tanks, lakes and other forms of stagnant water bodies. It is an 'illiophage', predominantly herbivorous, feeding on the bottom. Kalbasu competes with mrigal, frimbritus and bata in culture environments. Its feed mainly consists of organic detritus, diatoms and green algae along with zooplankton. Kalbasu has comparatively few inter-muscular bones than the major carps. It is a seasonal breeder and spawns once per year in lotic environments during the monsoon. It can be induced to breed by hypophysation. The relative fecundity of Kalbasu is highest among all major carps, ranging from 90,000 in first year group to over 500,000 in seventh year class. It can reach a maximum length of around 100 cm, but grows to around 20cm and 800 g in the first year. Sexual dimorphism is more prominent during breeding season. Like major carps, the male develops roughness on the pectoral fin and a sandy texture on scales and milt oozes with slight pressure on abdomen. In the case of females, the pectoral fins and scales are found to be smooth, abdomen bulges and the vent appears reddish and protrudes outside. Using induced breeding techniques, Kalbasu