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SOME ADVANCES ATTAINED IN SHRIMP FARMING RESEARCH AND MANAGEMENT PRACTICES: INSIGHTS TO FUTURE PROSPECTS FOR EXPANSION OF PRODUCTION

by

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ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project
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By
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FOREWORD

Inquiries to the ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project on management techniques, hatchery operations, feeds, diseases and related aspects of shrimp farming has been increasing. Publications of the Project retained in the library have become out of print due to high demand within and outside the region. Reproduction of pieces of information concerning shrimp farming becomes a tedious and repetitious work for a one-man library. In view of this situation, it was thought that available information from different sources compiled into a single document would be of great benefit to shrimp farmers, the research workers, students and administrators in government in their pursuit or technical information for shrimp farming development. The preparation of this document is part of the information dissemination of the Project to provide the ASEAN countries with essential technical information. This material is not complete in itself, but relevant technical information at the time of preparation were used.

1. INTRODUCTION

There are seven major shrimp species of interest in the Indo-Pacific region, namely:

Species	English/vernacular names
Penaeus monodon	Giant tiger shrimp (sugpo)
Penaeus semisulcntus	Green tiger shrimp (bulik)
Penaeus japonicus	Kuruma shrimp (bulik)
Penaeus merguiensis	Banana or white shrimp (hipon puti)
Penaeus indicus	Indian white shrimp (hipon puti)
Penaeus orientalis	Fleshy shrimp
Metapenaeus spp.	Greasyback shrimp (suahe)

Of these species, *Penaeus monodon* is the most widely cultivated species due to its fairly fast growth rate under various pond management systems (Figure 1); it tolerates wider salinity level fluctuation of environment and lends itself to domestication; its foreign market is well established. The expansion of shrimp farming in Southeast Asia is triggered by the increased international market demand and the break-through made on seed production and intensive shrimp culture.

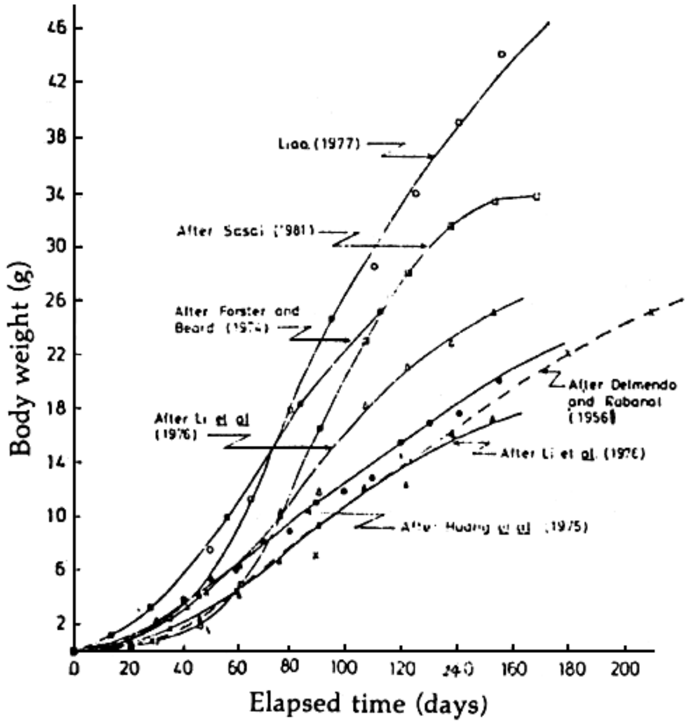

Figure 1. Growth curves of grass prawn,
Penaeus monodon
(Source: Liao,1986)

Of the cultured marine shrimp species, *Penaeus monodon* accounts for 40.9 percent; P. *merguiensis* and P. *indicus,* 23.3 percent; P. *orientalis,* 17.1 percent; P. *japonicus,* 1.2 percent; other penaeids, 3.6 percent; and *Metapenaeus* sp., 9.7 percent. Prawns account for 2.9 percent and swamp crab and *Portunus* sp. constitute 1.3 percent of all the crustaceans framed in the Indo-Pacific region (Csavas, 1988).

The world aquaculture production of crustaceans during 1975-1985 increased from 29 700 mt to 265 700 mt. The share of Asia increased from 22 700 tons to 198 500 tons which is equivalent to over . 70 percent of the world total production (Table 1).

By country, the People's Republic of China has the highest production; this is followed by Taiwan, Indonesia, Philippines, Thailand, India, Vietnam and Bangladesh in the order of production (Figure 2).

The farming of shrimps used to be secondary to milkfish until in 1968 Taiwan revolutionized its technology of production through artificial spawning. With this technological breakthrough, shrimp farming no longer depended on wild-caught fry; hatchery reared seeds became available which enabled shrimp farmers to intensify production. The technique of growing shrimps from juvenile stage to marketable size has been an extensive practice and farmers do not seem to have any problem raising them. However, the lack of seeds had been the bottleneck all along which hampered intensification of production.

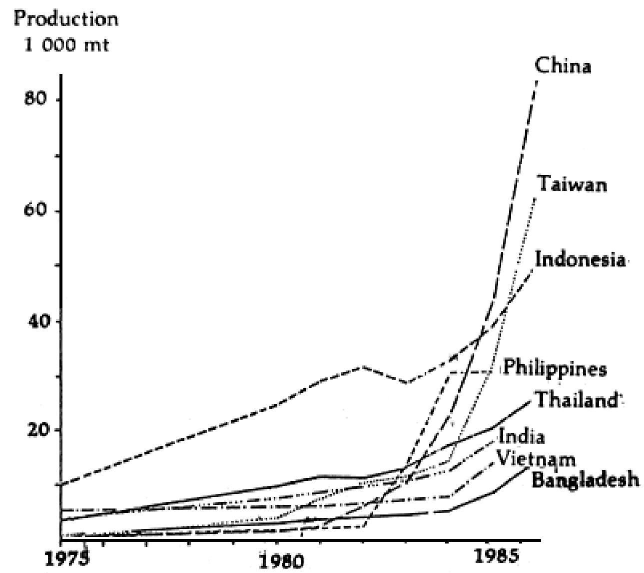

Figure 2. Cultured crustacean production in Asia
Source: Csavas, 1988

Now, the lack of seedlings has been met by hatchery operations. As of May 1989 there were 325 units of hatcheries in the Philippines; in Taiwan, there were 1 800 hatcheries in 1986 which produced 10 billion shrimp larvae. No information is available in the Philippines as to how much shrimp fry were produced in the same period as this is a guarded secret of private operators. Suffice it to say that there has been a rapid expansion of shrimp farming in this country despite multifarious technical problems and losses incurred by some newcomers in the hatchery business. The successful ones would keep their secrets more zealously while the losers would probably try some more or completely get out of the business. There are some large hatchery facilities that are not working well and lying idle.

Table 1. Global production of cultured crustaceans

Unit: 1 000 metric tons

Continent	1975	1980	1985	Annual growth (%/year)
Africa	—	—	0.1	—
America, North	5.8	8.3	33.8	48.3
America, South	1.2	6.0	32.9	264.1
Asia	22.7	60.7	198.5	77.4
Europe	0.0	0.0	0.4	423.0
Oceania	—	—	0.0	
World total	29.7	75.0	265.7	80.6
Percent share of Asia (%)	76.6	80.9	74.7	—

Souce: Csavas (1988)

For the benefit of newcomers in shrimp farming and the traditional practitioners, this compilation is an attempt to put together essential technical information relevant to shrimp farming activities including hatchery development and techniques which could further improve present practices and perhaps help modify existing management techniques both on seeds production and grow-out of shrimps. The technical problems which require solution should be given appropriate attention by government administrators and research institutions.

[1]Paper delivered in the Technician-Clientele Seminar on Shrimp Farming organized by Region XI, Davao City, 24-26 May 1989, Department of Agriculture

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2. SEED PRODUCTION

2.1 Broodstocks quality

Intensification of shrimp culture production is limited by seed supply. On the other hand, the production of seeds in hatcheries depends on availability of broodstocks and quality of spawners. A healthy spawner is described with illustration in Figure 3.

Shrimp hatcheries still depend on broodstocks obtained from the wild although eye-stalk ablation technique to induce maturation of shrimp has been found to work very well. However, it has been reported to be more expensive to raise breeders in captivity than to buy the wild mature shrimps from the sea. Furthermore, it was found that the ablated shrimps are not good which results to low rate of survival. Fry produced from pond-grown ablated broodstocks are not as hardy as those from spawners obtained from the sea. This may be due to a combination of many factors such as nutrition, genetics and environment (Liao, 1986). More research in these problem areas are necessary.

In Taiwan, this problem is being solved by "sea ranching". Pond-grown shrimps are released in suitable sites that are protected and recaptured after several months when they are mature. A recovery rate of about 15 percent was considered high enough to be profitable. In the Philippines, perhaps keeping them in enclosures at sea would provide higher recovery rate. This would ensure the supply of shrimp brood-stocks all year round, thus, also ensure seed supply of better quality.

HOW TO TELL A HEALTHY P MONODON

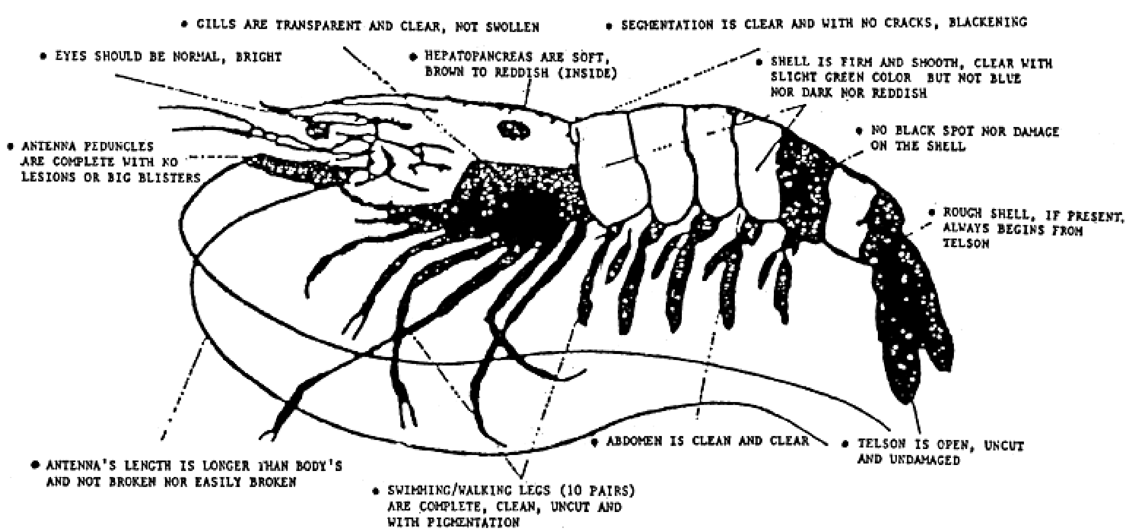


Figure 3. Illustration of a healthy spawner
Source: Tong Kuwan Aqua Development Co., Ltd. RM 4 5F 218 TA Shun 3 Rd, Kaohsiung, Taiwan, Province of China

Shrimp ranching has been done in Japan, particularly in Hamana-ko Lagoon. Post-larvae of P. *japonicus* were released in the lagoon in 1978. For a five-year period, a total of 17.6 million postlarvae were released. This programme has become an extensive programme reaching a total of over 300 million postlarvae released. The main sites of releases were inlets, open or semi-open waters (Figure 4). The result of this programme showed that shrimp production in the area was 2.4 times greater than natural catches in open waters.

The advantages of shrimp ranching are (Uno, 1985):

a) Increased supply of shrimp breeders and increased shrimp production

b) stabilized production through adjustment of the time in releasing the post-larvae

c) additional recruitment to the natural population of shrimp not caught for breeding purposes

Hatchery technique of seed production of P. m*onodon* is known and the application of shrimp ranching under Philippine condition could well be made. The use of sea enclosures like the fishpen would be a good approach to solve shrimp broodstock availability. Juveniles of shrimps produced from hatcheries could be released in coastal waters. However, the government should initiate the programme and set up specific areas for the purpose. Shrimp ranching could be allocated to small fishermen cooperatives in selected areas only. Otherwise, installation of enclosures at sea would also proliferate if not properly controlled. Guidelines for this purpose should be made; releases and recapture of juveniles should also be monitored.

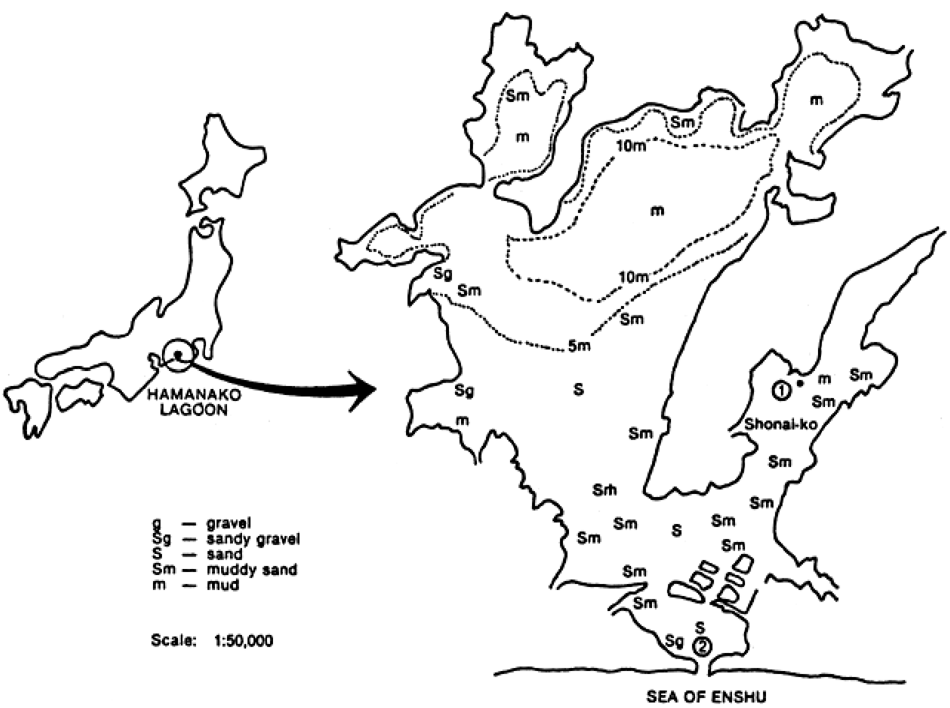


Figure 4. Topography of Hamana-ko Lagoon showing bottom conditions and depth. (1) site of enclosure for nursery culture; (2) mouth of lagoon (Imakiriguchi)
Source: Uno, 1985

2.2 Shrimp hatchery operations

The development of shrimp hatcheries in the Philippines is quite haphazard in the sense that many hatchery facilities sprang up without *adequate* technical guidance. This was a result of private sector interest and enthusiasm in getting the profits quickly and be ahead of the rat race for money-making. As a consequence, several hatcheries, especially the big ones end up losing money for not being able to operate them viably for several reasons

Further refinement in hatchery management technique for P. *monodon* should be made as it is not well established compared to that of P. *japoncus* in Japan. The research programme on hatchery techniques on P. *monodon* lacks sustained support and coordination of efforts. Thus, the private sector has been left alone to hit-and-miss affair in their operations. The interest of the private sector is a healthy sign of willingness to take risks. However, capital resources are wasted if the operations do not succeed and the blame almost always go to the inefficiency of the government in providing the right technical assistance and guidance.

Hatchery operations require the following conditions to become successful:

a) Appropriate design of hatchery facility particularly with respect to quality of water and availability

b) Supply of healthy spawners

c) Experienced and knowledgeable technicians conversant with the behavior and feed requirement of shrimp larvae at certain stage of its life cycle

d) Availability of the appropriate typeof feeds

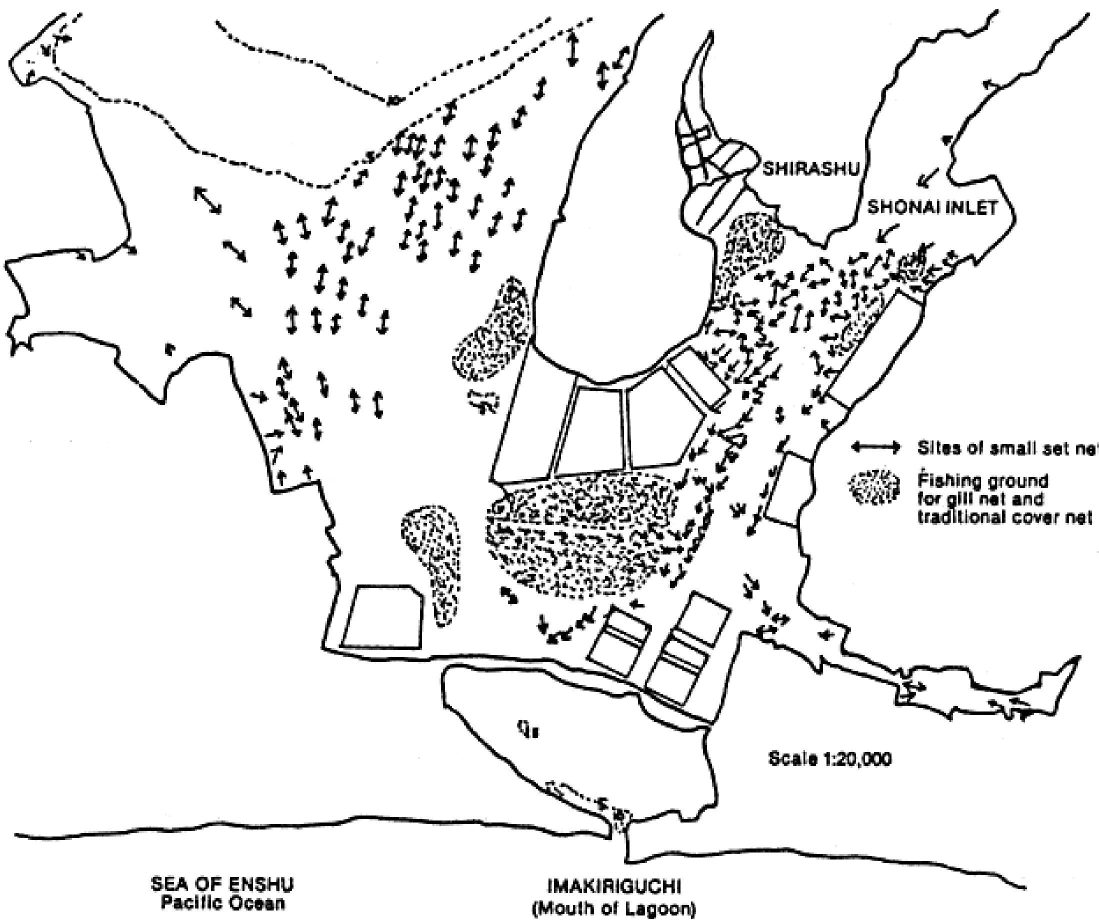


Figure 4a. Fishing grounds of kuruma shrimp, *Penaeus japonicus,* in Hamana-ko Lagoon. Figures denote depth in m.
Source: Uno, 1985

In view of the different stages of larval development of the shrimp, specialization of production would perhaps be better to maximize the use of available skills and provide more efficiency in the chain of seed production. This situation has developed in Taiwan as well as in Thailand although in a different context. In Taiwan, several specialized sub-businesses related to shrimp seed production include: (a) spawner supplier; (b) nauplius producer; (c) nauplius broker; (d) early stage postlarvae producer (PL10-PL12); (e) late stage postlarvae producer (PL20-PL35); and (f) postlarvae (PL10-PL35) broker. Figure 5 illustrates the specialized sub-businesses of the prawn industry in Taiwan. A firm or family business enterprise raises its crop to a certain stage of maturity and. sell the crop to the customers with the skill and capacity to raise the larvae to the next higher level of maturity (Liao, 1987). This avoids a total failure of operation of a hatchery if the facility cannot completely produce shrimp post-larvae or juveniles for grow-out use. Specialization also strengthens the seed production base of the shrimp culture industry. This is seen in the Philippine milkfish fry industry where there are the fry gatherers, the brokers and the milkfish nursery operators.

In Thailand, on the other hand, specialization came about as a consequence of overproduction of prawn fry resulting in very low prices. The existing hatchery facilities, particularly the backyard prawn hatcheries went into shrimp larvae rearing and live food organism culture. The prawn hatchery operators learned to diversify the use of their facilities for the production of shrimp and marine fish larvae such as P. *monodon, P. merguiensis,* seabass and grouper according to season and demand. At present there are over 800 backyard prawn hatcheries which specialize in nauplii, postlarvae and food organisms (Csavas, 1988).

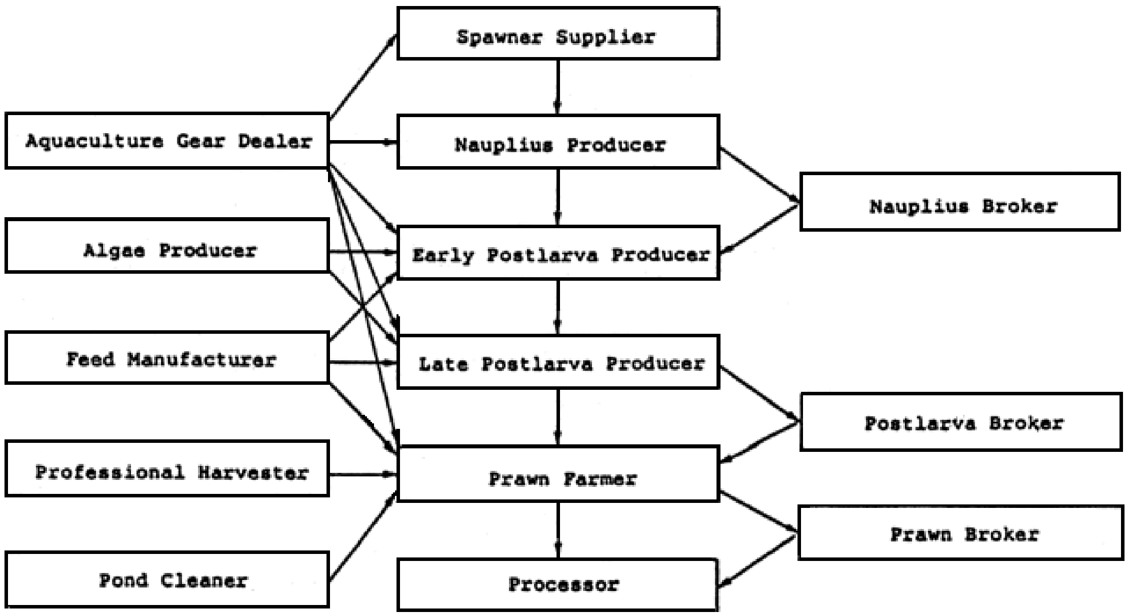


Figure 5. Specialized sub-businesses in the Taiwanese prawn culture industry
Source: Liao, 1988

The same situation has not yet occurred in the Philippines. There are a number of hatchery facilities already lying idle due to failures in hatchery operations not because of overproduction but more on failure in design of hatchery facilities and the lack of skills in hatchery management.

For information on stages of the life history of P. *monodon,* Table 2 shows the duration in each stage. Figure 6 illustrates the larval stages of the shrimp.

The most difficult stage of the shrimp larvae is the transformation from zoea to mysis stages. Each stage of larval development requires different kind of food. Table 3 summarizes the kinds of food of shrimp larvae from zoea to postlarvae. The feeding regimes during the developmental stages of penaeid shrimp is illustrated in Figure 7.

Table 2. Life history phases of the giant tiger prawn, *Penaeus monodon*

Phase	Begins at	Duration	Carapace length (mm) Male	Carapace length (mm) Female	Mode of life	Habitat
Embryo	Fertilization	12 hours	0.26[1]		Planktonic	Outer littoral area
Larvae	Hatching	20 days	0.5-2.2		Planktonic	Outer/inner littoral area
Juvenile	Completion of gill system	15 days	2.2-11.0		Benthic	Estuarine area
Adolescent	Stability of body proportion, development of outer genitalia	4 months	11-30[2]	11-37[3]	Benthic	Estuarine area
Sub-adult	Commencement of sexual maturity, first copulation	4 months	30-37[4]	37-47[5]	Benthic	Inner/outer littoral area
Adult	Completion of sexual maturity	10 months	37-71[6]	47-81[6]	Benthic	Outer littoral area

[1]Egg diameter
[2]Minimum size with jointed petasma
[3]Minimum size with adult-like thelycum
[4]Minimum size with spermatozoa in terminal ampoules
[5]Minimum size with spermatozoa with thelycum
[6]Maximum size ever found
Source: Motoh, 1985

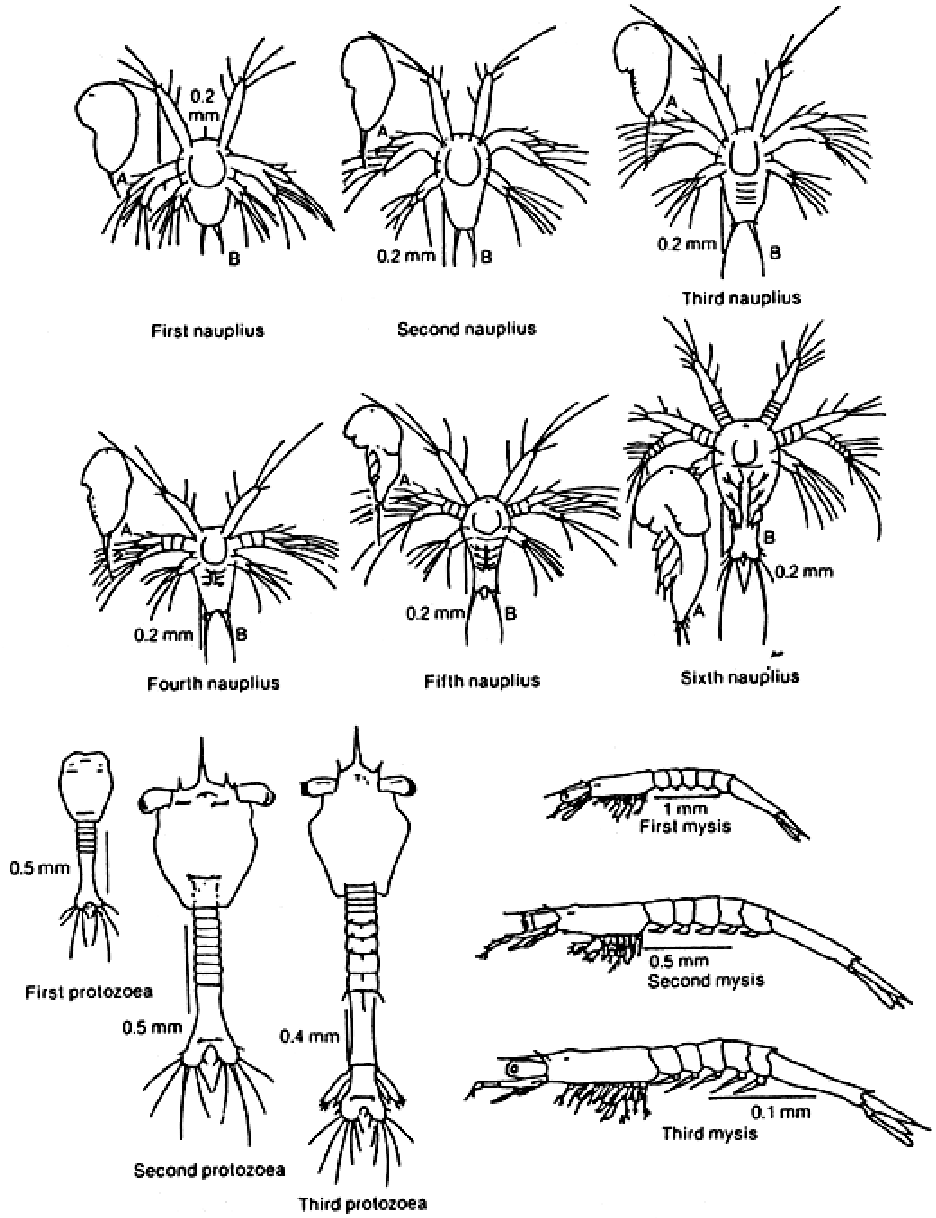
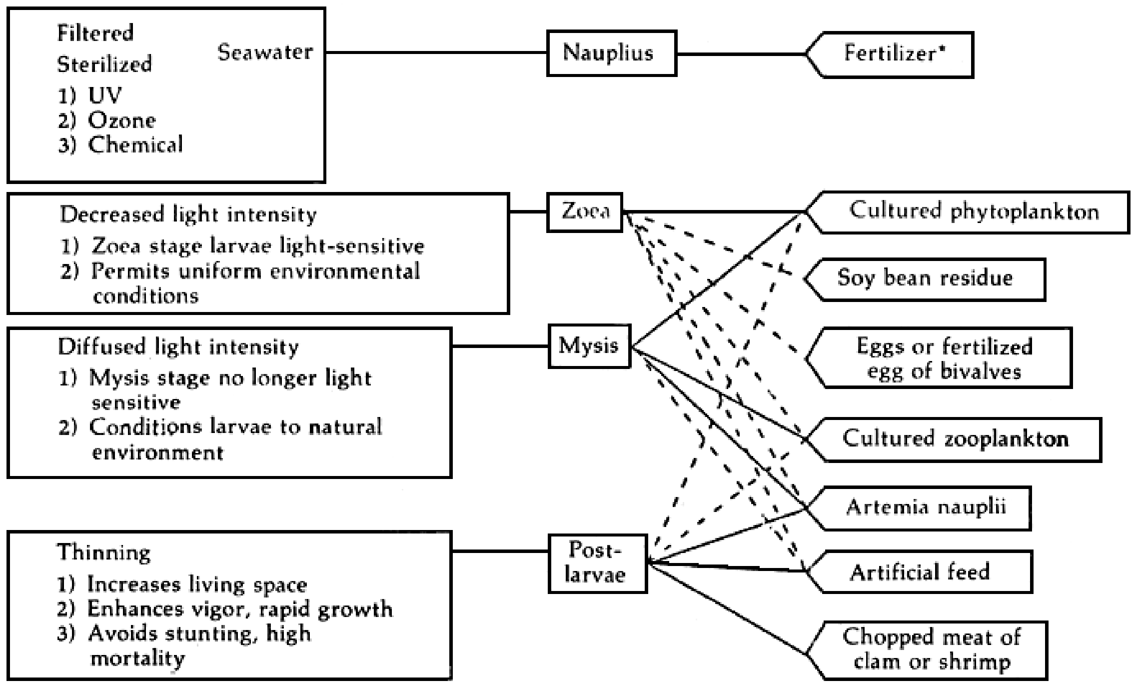


Figure 6. Larval stages of *Penaeus monodon* A — lateral view; B— ventral view (Source: Motoh, 1985)

Table 3. Feed materials used for shrimp larval stages

Kinds	Zoea	Mysis	Postlarvae (Early: P1-P1O)	Postlarvae (Later: P11-P25)	References
VEGETABLE SOURCES					
Skektonema sp.	++	++			Hudinaga, 194
Tetraselmis sp.	+	+			Beard, et. al.
Isochrysis sp.	+	+			Beard and Wicki
Chaetoceras sp.	+	+			Hirata, et. al.
Dunaiiclla sp.	—	—			SEAFDEC, 1981
Spirulina sp. -	—	—			Tang, 1977
Chlamydomonas sp.	—	—			Hudinaga and Kittaka, 1975
Marine chlorella	—	—			Hudinaga and Kittaka, 1975
Soy bean residue	+	+			Hirata, et. al., 1975
ANIMAL SOURCES					
Eggs or fertilized					Liao, 1969
eggs of oyster	++	++			
Eggs of Mytilus	++	++			Kittaka, 1975
Rotifer	++	++			Liao, 1969
Artemia salina	++	++			Hudinaga, 1969
Brine shrimp flakes	++	++			Unknown*
Moina sp.			—		Kittaka, 1975
Copepoda			++	++	Shigueno, 1968
Gammmarus sp.			—	++	Kittaka, 1975
Balanus sp.			++	+ +	Kittaka, 1975
Nematoda			—	—	Liao, 1969
Annelida				++	Liao, 1969
Clam meat				++	Liao, 1969
Shrimp meat				++	Liao, 1969
Fish meat				+	Liao, 1969
OTHER SOURCES					
Yeast	—				Furukawa, et. al., 1973
Milled feed		+	+	+	Shigueno, 1975
Sprayed dried feed		+	+	+	Shigueno, 1975
Microencapsulated diet		+	+	+	Johnes, et. al., 1979 a, b

NOTE: ,++ Good; + Available; — Poor
*Unknown — Origins presently being verified but cannot be substantiated at this time
Source: Liao, 1984



*Community culture method only

Solid lines (___) for most prominent feeding regime

Dashed lines (**….**) for occasional, less widely used regime

Figure 7. Schematic representation of feeding regimes for developmental stages of penaeid shrimp and related culture parameters
Source: Liao, 1984

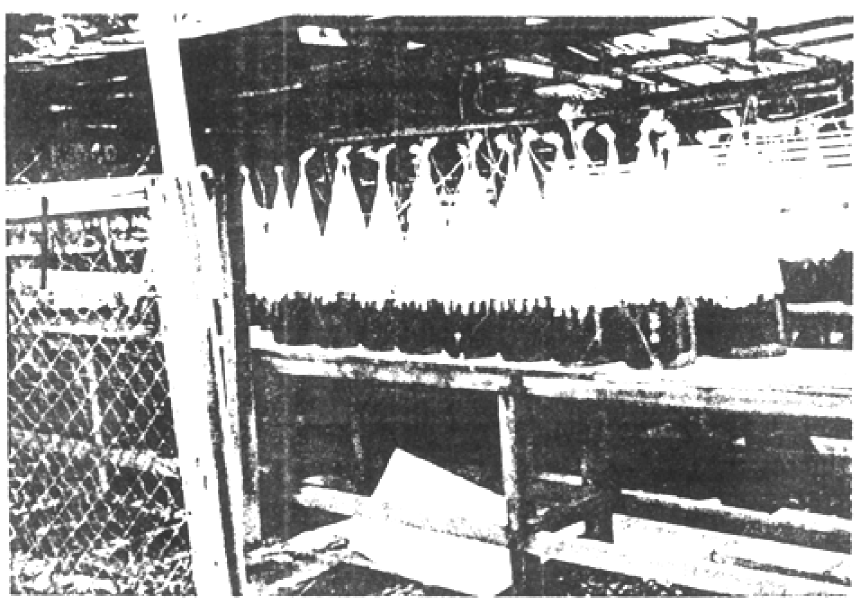


Figure 8. Algae culture using natural light

For larval rearing of *P. monodon,* some of the essential aspects of postlarvae production based on Taiwan experience and conditions are summarized in Table 4

Table 4. Some aspects concerning larvae rearing of *Penaeus monodon* in Taiwan

Sources of spawner	It is difficult to guarantee source of spawner. Fortunately with unilateral eyestalk ablation technique some 5-10 percent additional spawners can be provided; 20-40 percent depend on. importation and 55-70 percent on wild spawner. Season to capture spawners is from March to November. In the other months spawners supplemented from Southeast Asia.
Number of eggs from one spawner	Around 20-60 x 10^4
Size of rearing tank for spawning and hatching	Large tanks are usually not suitable for spawning due to difficulty in collecting large numbers of spawners at any one time; 0.5-1.0 ton small round tanks adequate to hold 1-3 spawners are used. Spawning and hatching in the same tank take place where larvae are reared to mysis stage. Before transfer to larger pond, 30-50 thousand larvae are stocked in each small tank. Larger concrete tanks of 20 tons are used in case more spawners are available.
Sensitivity to light	Zoea stage should be kept in comparatively dark shaded area because of high sensitivity to light. After mysis III, larvae become adaptable to light.
Optimal temperature and salinity	Suggested water temperature 28-31°C. Salinity for nauplius, zoca stage, 31-33 o/oo after mysis stage, below 30 o/oo.
Recommended method for rearing	"Monoculture method" recommended. Zoea feed mainly on *Skelctonema;* mysis on rotifera and *Artemia nauplii* and post-larvae on *Artcmia nauplii,* minced trash fish or shrimp.
Diseases	Mass mortality in zoea and mysis stages resulting from unknown causes, while in postlarval stage may be infected by *Epistylis* sp. Recently the phenomena of regional and seasonal mass mortality have been reported.
Survival rate	Usually P12-15 sold to nursery farmers who raise them to P30-40 averaging 0.02 g before delivery to farmers, from nauplius stage to P12-15, surviv.il rates average 40 percent.
Prices of juvenile	NT$300-900/l 000 juveniles (US$7.9-23.7/ 1 000 juveniles)

Source: Liao, 1984

Significant contributions of research to the shrimp hatchery industry has been done elsewhere, mostly in developed countries. These include the identification of nutritionally good species of algae and strains of *Artemia* as food organisms of shrimp larvae and the means by which the biochemical composition of algae, rotifers and *Artemia* may be enhanced by altering their nutrient source and rearing conditions. The development of a technique of disinfection and decapsulation of *Artemia* cyst during hatching has reduced fouling and contamination prior to hatching. The development of microencapsulated feeds for shrimp larvae is a breakthrough in hatchery technology (Wickins, 1986). The use of these imported feed materials are however, costly and small fish farmers are not able to procure them. Techniques of food organism culture have also been developed. Algae or zooplankton culture need not be indoors with sophisticated facilities. The use of plastic bags containing the culture media under a shed outdoors is not difficult to set up as shown in Figure 8. Asia is blessed with adequate sunlight the ye ar round to promote algae culture.

A hatchery design should provide efficiency of water use and conveyance such as a ladder type of hatchery taking advantage of gravity system as shown in Figure 9. Engineering considerations for disease and stress prevention in shrimp hatcheries and grow-out ponds were studied by Gacutan and Vizcarra (1988) which are now being adapted in recent construction of shrimp hatcheries and pond renovations in the Philippines (Appendix 1).

There are three major sizes of hatcheries, namely; large, medium and small. The characteristics of such hatcheries are summarized in Table 5.

Most of the complaints of hatchery operators concern about low survival and disease infections. The low rate of survival may be due to eyestalk ablation. It has been reported that a maximum of 2-3 or 4-5 spawnings are obtained after each process of ablation. Consequently, the health conditions of larvae obtained from the later spawnings are claimed to be poorer than those obtained in earlier spawnings; shrimp larvae obtained from spawners by eyestalk ablation are weaker, hence, lower rates of survival than those obtained from spawners caught from the wild or non-ablated individuals. These observations, however, need confirmation through scientific research to determine the causes of low survival of larvae from ablated spawners (Liao, 1984).

Diseases often result to high losses of hatchery operators. Some of the common diseases encountered in shrimp hatcheries, the symptoms and treatment are summarized in Table 6.

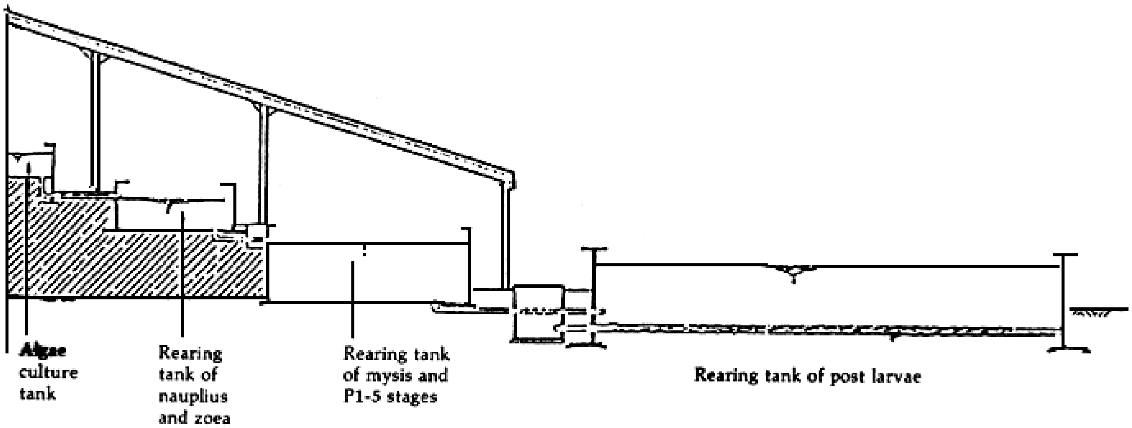


Figure 9. A ladder system hatchery taking advantage of ground slope and water levels
Source: Liao, 1984

Table 5. Distinctive characteristics of three major sizes of hatcheries

Size	Large	Medium	Small
Ownership	Company	Family or partner	Family
Personnel	Consultant, supervisor, technicians and workers	Owner and experienced workers	Owner and worker
Size (unit of pond)	600-800 m^2 plus excessary tanks (40-60 tons)	(1-20 tons)	(1-5 tons)
Electricity (generator power)	100 KW	50 KW	5 KW
Water storage	600 tons	200 tons	10-50 tons
Water treatment	Filtered at the source or UV light treated	Filtered at the source or UV light treated	Filtered at the hatchery
Number of spawners/yr	500 spawners	200-300 spawners	40-50 spawners
Sources of spawners	Private shrimp trawler or broker	Fishermen or broker	Fishermen or broker
Length of active operation (mo/yr)	11	10-11	6-8
Maximum capacity (fry/yr)	10 000 000	5 000 000	1 000 000
Nursery	Necessary	Necessary	Not necessary
Shipping	Airplane, truck or exfarm	Truck or exfarm	

Source: Liao, 1984

Table 6. Diseases found in the developmental stages of penaeid prawn larvae and their control methods

Diseases	Affected parts	Symptoms	Treatment		Life stages affected*	References
Bacteria:						
Bacterial necrosis	Appendages	Appearing as localized necrosis or discoloration on any appendage, causing high mortality of zoea and mysis stages, affects post-larvae to a lesser extent.	Furanaee Erylhromycin Achromycin	1.1 ppm 1.5 ppm 1.2 ppm	Z M PL	Tareen, 1982 Lightner, 1983
Vibrio infection	Hemolymph, midgut gland	In initial stages of one form, some larvae will show yellow-vermillion and red color permeating entire nervous system. Another form exhibits "white-turbid liver",where the midgut gland of the larvae becomes generally white-turbid. Turbidity becomes more apparent and well-defined as the disease progresses.	Furazolidone Terramycin Furanace	2.0 ppm 450 mg/kg biomass 1.3 ppm	PL	Niekelson and Vanderzant, 1971 Lewis, 1973 Shigueno, 1975 Lightner, 1977 Johnson, 1983 Cipriani, et. al., 1980 Tareen, 1982 Lightner, 1983
Filamentous bacteria	Gills, pleopods	Commonly found attached to the gill filaments and the pleopods, turning blackish when bacteria mix with dirt. If everely affected, the respiratory function of the gill suffers damage.	Cutrine plus Malachite green Potassium permanganate Cuprous chloride	0.5 ppm 10 ppm 8.5 ppm 1.0 ppm	PL	Delves-Broughton and Poupard, 1976 Streenbergen and Schapiro, 1976 Johnson, 1978 Solangi, et. al., 1979 Lightner, et. al., 1980 Tareen, 1982 Lightner, 1983

Shell disease	Exoskeleton, muscles	If infected by chitinoverous bacteria, the exoskeleton will display eroded blackened areas. The edges or tips of the exoskeleton parts are typically attacked.Also,bacteria can rapidly enter the body through surface breaks to cause internal damage.	Malachite green *and* Formalin combined	0.9 ppm 22 ppm	PL	Cook, 1973 Delves-Broughton
Black gill disease	Gills	In initial stages, gill color turns dull orange-yellow or light brown. When advanced, the area darkens until it is finally black.	Malachite green Methylene blue	3.0 ppm 8-10 ppm	PL	Shigueno, 1975 Tareen, 1982
Fungi:						
Lagenidium infection	Body cavity, appendages	Only thin-cuticled prawn can be infected, thus larval prawn are highly sensitive. The hyphae appearinside the body of zoea and continue into mysis stage,resulting in massive muscle destruction and heavy mortality of zoea and mysis.	Treflan[R] Malachite green	0.1 ppm 0.01 ppm	Z M	Hubschaman and Schmitt, 1969 Lightner and Fontaine, 1973 Lightner, 1977 Johnson, 1978 Gopalan, et. al.,1980 Tareen, 1982 Lightner, 1983

Ectocommensal protozoa:						
Ciliate infection (*Zoothamnium* sp. *Epistylis* sp.)	Gills, eyes, exoskeleton	Heavy infestation by *Zoothamnium* sp. on gills and eyes of larval prawn results in high mortality. *Epistylis* sp. seems to prefer exoskeleton as Attachment site and is less Harmful. When abundant on gill surface, both can cause hypoxia and death. Addiditionally, their bundant presence on general body surface of larvae may interfere with locomotion, feeding, molting, etc., Parasite burden increases until ecdysis provides relief.	Malachite green and Formalin combined Quinacrine hydrochloride Chloramine-T Methylene blue Saponin 10%	1.0 ppm 25 ppm 0.8 ppm 5.5 ppm 8.0 ppm 5.0 ppm	Z M PL	Johnson, et. al., 1973 Overstreet, 1973 Delves-Broughton and Poupard, 1976 Lightner, 1977 Liao, et. al., 1977 Johnson, 1978 Lightner, et. al., 1980 Tareen, 1982 Lightner, 1983
Viruses:						
Penaeid baculoviruses (BP, MBV,BMN)	Hepatopancreas, Anterior midgut	Penaeid baculoviruses infect epithelial cells of the hepatopancreas and. less commonly, anterior . midgut, causing high mortality in the post-larval stage.			PL	Johnson, 1978 Sano, et. al., 1981 Lightner, 1983 Lightner, et. al., 1983 Couch, 1974

Infectious hypodermal and hematopoietic necrosis (IHHN)	Hypodermin, hematopoietic organs	Prawn dying from acute IHHN show massive destruction of cuticular hypodermis and often of the hematopoietic organs,of glial cells in the nerve cord, and of loose connective tissues such as the subcutis and gul serosa. Only prawn within a size range of 0.05-1.0 g have been observed to have these epizootics, resulting in massive mortalities (often 80 to 90'percent withip two weeks of onset)	PL	Lightner, 1983
Miscellaneous diseases:				
Abnormal nauplii	Appendages	Occurs as a result of poor quality of spawner.	N	Tareen, 1982
Ameobasis of larvae	Subcutis, muscles	Invasion of muscles and subcuticular tissues located in the abdomen, cephalothorax, antenna and eyestalks, by unclassified amoeba.	Z	Laramore and Barkate, 1979 Lightner, 1983
Larval encrustation	Exoskeleton	Brown to black encrusted deposits which contained iron salts affect larvnl penaeids.	Z M PL	Lightner, 1983

***N = nauplius; Z = zoea; M = mysis; and PL = post-larva**

Source: Liao, 1985

3. SHRIMP GROW-OUT MANAGEMENT TECHNIQUES

The rearing of shrimps in the Philippines has been an old practice in brackishwater fishponds. The techniques of management, however, have been generally extensive. It was only after the development of shrimp hatchery operations which spilled out from Japan and Taiwan experience did intensification of shrimp farming come about. Approximately, 23 400 ha of brackishwater fishponds in the country have been converted to semi-intensive and intensive shrimp farming operations (IAC, 1989).

Expansion towards intensification of shrimp farming operations are also found in other ASEAN countries particularly in Thailand and Indonesia. This is boosted by government loans from the AsDB for shrimp farming development and technical assistance by government to the shrimp farming industry.

There are three different types of shrimp culture management systems in practice.

3.1 Extensive management system

This type of shrimp farming operation is the traditional practice of natural seeding of ponds with shrimps by tidal inflow or pumping. Seeds may be stocked but of low density (3 000-5 000/ha); rearing of shrimps depends on natural food. Production level is, therefore, very low, ranging from 50-200 kg/ha/yr. In the Philippines where shrimps used to be grown as a secondary crop with milkfish, the production level ranges from 100-250 kg/ha/yr by natural seeding. However, if in addition to natural seeding, shrimp fry are stocked in the ponds, production level increases to 500 kg/ ha/yr (Delmendo, 1970). Some farmers stock more shrimp fry than milkfish. It was reported that polyculture of shrimp and milkfish contribute to the control of insect larvae (Chironomid) population in fishponds (Apud, 1985). Extensive mono-culture of shrimps is now commonly practiced. Stocking density ranges from 10 000 to 30 000/ha.

The traditional practice of trapping-growing operation used to be a common method in Malaysia, Thailand, Philippines, Indonesia and Vietnam, wherein seeding.is entirely dependent on tidal water inflow. A mixture of shrimps are accumulated in the ponds and allow them to grow on natural food. In Malaysia, periodic cropping every two months is carried out during an annual cycle as observed in Johor Bahru, Malaysia which showed a total production of 4 000 to over 5 000 kgs of shrimps which is high compared to average output of extensive pond operation in most ASEAN countries (Table 7). The species of shrimps harvested in trapping ponds include tiger shrimp, white shrimp, red shrimp, other shrimps of medium and small sizes.

3.2 Semi-intensive management

Extensive pond operations could be shifted to semi-intensive management system. The main difference is the manner by which the ponds are prepared, seeded and the rearing regimen applied. Natural feeds are grown by application of inorganic and organic fertilizers; supplementary feeds are given to the shrimps during the culture period. Adequately prepared and well-managed ponds have high levels of production ranging from 2.5-7.0 tons/ha/yr or better (Rabanal, 1988). Compared with extensive management system, the ponds used for semi-intensive shrimp production are relatively smaller in area, 0.2-2.0 ha/ pond (Wickins, 1986) and also deeper, 1.0-1.5 m (Rabanal, 1988). Stock density ranges from 50 000-100 000 PL/ha. One culture period may last from

100-150 days depending on availability of postlarvae.

Under semi-intensive operations, water exchange at the rate of 30-40 percent is effected either by pumping or gravity flow. Supplementary aeration is also used.

3.3 Intensive management

This system of shrimp pond management requires a good design of grow-out facilities. Pond units are much smaller, 0.1 to 1.0 ha but the depth could be the same as semi-intensive ponds, 1.0-1.5 m. The water exchange is continuous with at least 30 percent daily is necessary. Stock density ranges from 100 000 to 200 000 PL or more per ha per crop. It is possible to produce two crops per year with output levels of 5-12 tons/ha/yr (Rabanal, 1988). Artificial feeds, aeration and water exchange are imperative under this type of management.

Table 7. Production of a trapping pond, Johor Bahru, Malaysia

	Quantity				Value			
	1980		1981		1980		1981	
	kg	%	kg	%	kg	%	kg	%
Total	4 527	100.0	5 375	100.0	34 855	100.0	41 923	100.0
Tiger shrimp	50	1.1	128	2.4	1 002	2.9	2 178	5.2
White shrimp	1 120	24.7	1 231	22.9	18 727	53.7	19 935	47.6
Medium-sized shrimp	332	7.3	328	6.1	3 189	9.2	3 183	*7.6*
Small-sized shrimp	1 311	29.0	1 549	28.8	7 801	22.4	11 015	26.3
Red shrimp	1.714	37.9	2 139	39.8	4 135	11.9	5 612	13.4

Source: Hirasawa, 1985

Table 8 shows some examples of shrimp production under different shrimp pond management systems in various countries.

A Philippine example of a water regime followed in intensive shrimp culture is as follows: (Stockwell and Williams, 1988).

No water exchange for the first 20-30 days after seeding; 5 percent daily water exchange from day 30-50; from day 50-75 water exchange increases to *7.5* pecent daily, between day 75-90 water exchange increases to 10 percent daily; and from day 90 to just before harvest the rate of water exchange is 12.5 percent per day. The final water exchange may reach up to 100 percent which is undertaken about a week before harvest to induce molting. The hardening process is adequately completed in a period of one week after molting.

A qualitative and quantitative definition of shrimp culture management systems found in the Philippines is summarized below: (Young, 1987).

Table 8. Production examples from different types of prawn farm (data from various sources)

Culture type and country	Stocking density (no./m-²)	Yield tonnes (ha-¹/yr-¹)	Crops (no./yr¹)	Size of prawns (g)	Species
Extensive:					
Ecuador	1-10	0.72-4.8	3-4	19-22	P. *vannamei*
Panama	4-5	0.4 -0.9	1-3	20	*P. stylirostris*
Bangladesh	1-5	0.08-0.1	1-2		*P. monodon*
Indonesia	1-5	<0.2	1-2		*P. indicus*
Thailand	1-5	0.4	1-2		*P. merguiensis*
Philippines[1]	1-3/two m²	0.05-0.5	1-2		*P. monodon*
	1-5	0.5-1.5	1-2		*P. monodon*
Semi-intensive:					
Taiwan	10-15	4.2. -11.	1.5-2	30.40	*P. monodon*
USA, Hawaii	2-6	1.5-2	) Continuous	20-30)	
USA, S. Carolina	4-6	0.7-1.2	) harvesting	20-25)	*M. rosenbergii*
			) for 6 months		
Philippines[2]	5-10	2.5-7.0	2-3		P. *monodon*
Intensive:					
Taiwan	15-40	12.6-27.4	1.5-2	30-40	P. *monodon*
Philippines[2]	10.20	5-12	2		P, *monodon*
Super-intensive:					
Japan	100-250	4.5-24	1	17-20	*P. japonicus*
USA, Hawaii	?	25-70	2.5	?	*P. vannamei*

[1]Delmendo, 1970
[2]Rabanal, 1988
Source: Wickins, 1986

4. IMPORTANT CONSIDERATIONS FOR INTENSIFICATION OF SHRIMP FARMING MANAGEMENT TECHNIQUES

Perhaps shrimp farming has the most unprecedented phenomenon of rapid expansion worldwide, particularly with *Penaeus monodon.* This is mainly because *P. monodon* is a euryhaline species and it grows fast; hatchery techniques for seed production is also quite advanced compared to other tropical species of shrimps except the P. *japonicus.* Intensification of pond management techniques became popular.

The key factors to consider by shrimp farmers who intend to further intensify their management techniques are water exchange, feeds and feeding, and seeds supply which should be under the control of the operator. There are varying degrees of sophistication of techniques available to regulate these factors.

4.1 Water exchange

A vital factor influencing the high rate of productivity of intensive system is the capability to change water as often as possible within a short period of time. In Japan and Taiwan, it is necessary to effect a complete change of water in 2-3 hours. Sea-water and freshwater supply should, therefore, be available to provide the appropriate salinity level required by the shrimp at any stage of growth during the culture period. This capability requires an engineering design prepared by a knowledgeable and experienced aquaculture engineer. Figure 10 shows the relationship between productivity and water change in shrimp farming.

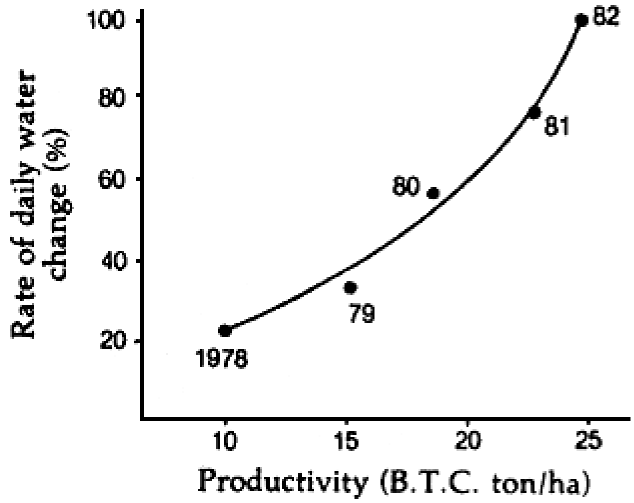


Figure 10. Relationship between productivity and rate of water change in shrimp culture ponds in Taiwan using black tiger conversion (B.T.C.) method Source: Hirasawa, 1985

	Traditional	Extensive	Semi-intensive	Intensive
Shape	Highly irregular	Irregular/rectangular	Rectangular	Rectangular/rectangular
Size	Very large, > 2 ha	1.5-2.0 ha	1.0-1.5 ha	1 ha and smaller
Construction	Excavated, below sea level	Excavated/ built up	Built up; above sea level	Built up; above sea level
Dikes	Earth	Earth	Earth/riprap	Earth/riprap/concrete
Pumps	No	No/yes	Yes	Yes
Salinity control	No	No/yes	Yes	Yes
Aeration	No	No/yes	Yes	Yes
Feeds	None	Natural/formulated	Formulated	Formulated
Feeding frequency/day	NA	1-3	4-5	5-8
Mono/polyculture	Polyculture	Monoculture	Monoculture	Monoculture
Stocking density	Less than 1/m^2	3-8/.m^2	8-18/m^2	18 above
Water exchange	Occasional	Regular	Often/very often	Very often
'Culture days	150-180	100-120	100-120	120-140

Source: Young, 1987.

The higher the rate of water change the higher the productivity. The reason for this is the removal of waste products in the culture facility and good aeration. Pumping of tidal water for this purpose has been found economical than relying on tidal inflow. Pump-fed ponds are more efficiently drained and also harvested completely; a 20 percent water change could be , effected daily in a .5-1.0 ha pond (Gedney, 1983). Tidal ponds could be renovated to provide better water exchange by constructing a pumping station that supplies water through a network of open canals on top of the pond dikes for water distribution in the various ponds. Water discharge is made through existing pond gates.

4.2 Feeds

Supplementary feeds are essential production inputs for semi-intensive and intensive shrimp farming operations. The quality, quantity of feeds and frequency of feeding are important considerations in pond culture management.

Feed formulations contain 11 percent water compared to trash fish which has 75 percent water. Feed conversion efficiency of trash fish is 4-5 kg to 1 kg formulated feed. Snails and clams are used as substitutes for trash fish but 10-12 kg of this material is equivalent to 1 kg of formulated feed (Kuo, 1986).

Artificial feeds formulated in ' Taiwan used for the culture of P. *monodon* has an average conversion ratio of 1.8 to 3.3:1. At a density of 15-20/m^2, a production level of 0.6 kg of shrimp per unit area (Liao, 1986) is obtained. The composition of this artificial feed is shown in Table 9.

The nutritional requirement of P. *monodon* is not fully known. There is no single formulation that is considered the best feed. Liao reported that P. *monodon* requires more animal protein in the early stages of growth but when it reaches a certain size, it gradually exhibits capability to consume plant proteins. This aspect requires thorough evaluation and study to develop appropriate feed formulations for use during the early and late stages of growth. Fish/shrimp nutrition scientists should look into this matter.

Feeds constitute a large percentage of production input. Therefore, feed conversion efficiency of formulated feeds and their costs are significant to shrimp farming. The quantity of feed increases when farming management system shift from semi-intensive to intensive management. Shrimp farmers have to use more feeds to compensate for the loss of natural productivity. This is exemplified in Taiwan as shown in Figure 11.

The frequency of feeding for PL stage is usually twice a day; forgrowers and finishers, 4-6 times a day. However, if the feed is not stable, the shrimps would feed more frequently. A feeding regime of 4-5 times a day should be enough provided this is done, from early morning staggered until midnight (Kuo, 1986). A generalized feeding schedule for marine shrimp larvae has been developed by AQUACOP (Figure 12).

Table 9. Composition of artificial feed used in Taiwan for grass prawn, *P. monodon*

Stage or body weight of prawn	Shape of feeds	Size of feeds	Crude protein (%)	Crude lipid (%)	Crude ash (%)	Crude cellulose (%)	Residues (%)	Moisture (%)
P_{25} - 1 g	Broken granules	< ø 2 m/m	>40.0	>3.3	<18	<3	<1	<12
1-10 g	Granules	ø 2.5m/m x 2.5mm	>38.0	>3.0	<18	<3	<1	<12
10g	Rods	ø 3 m/m x 4 mm	>35.0	>2.8	<21.5	<3	<1	<12

Source: Liao, 1986

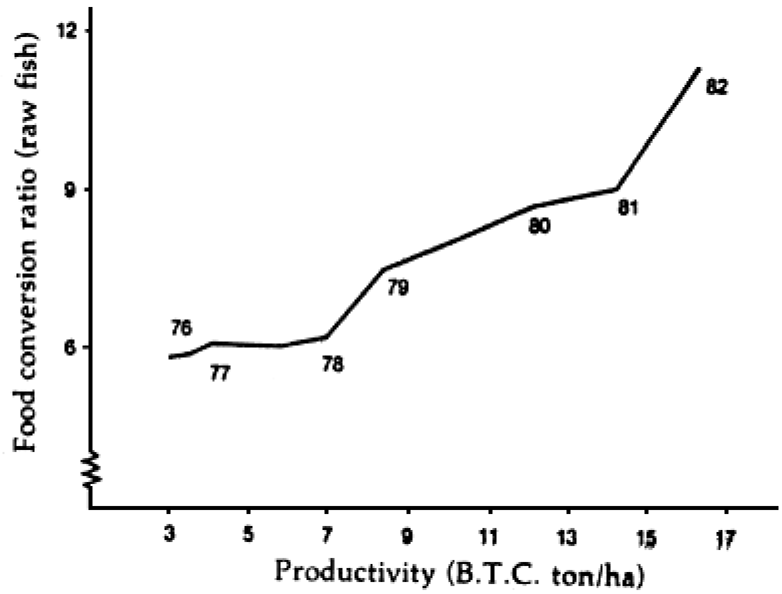


Figure 11. **Relationship between food conversion ratio and productivity (B.T.C. method) in Taiwan**
Source: Hirasawa, 1986

Intensive farms apply feeds at the rate 10-20 percent of shrimp biomass per day for shrimps less than 1 gram; for animals over 30 g, 2-4 percent of biomass is fed.

An example of feed application is shown below: (Stockwell and Williams, 1988).

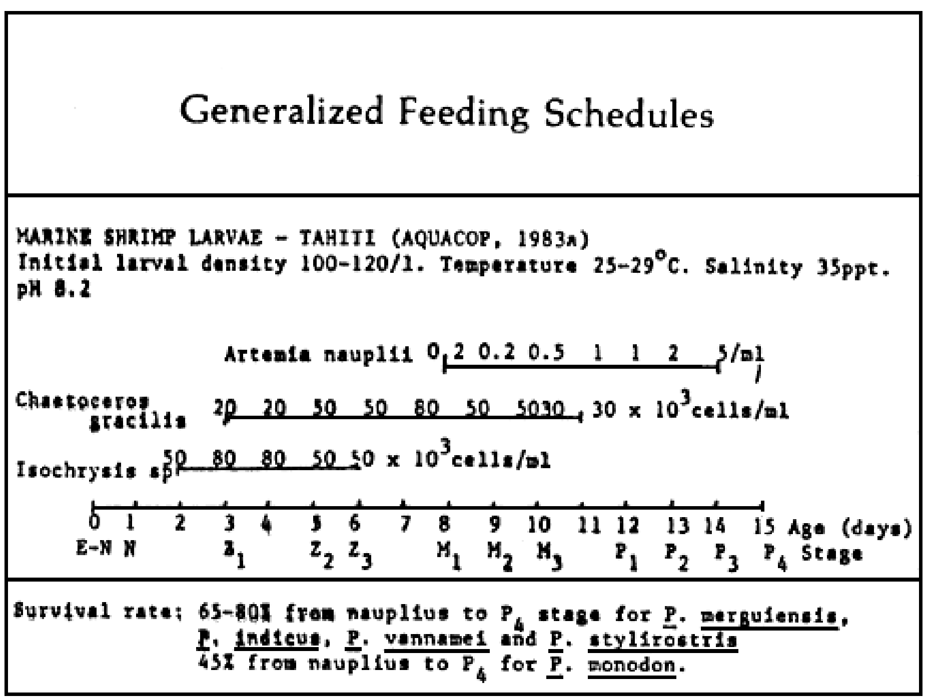


Figure 12. Generalized feeding schedule for marine shrimp culture
Source; Tacon, A. (1988)

Soybean levels greater than 10 percent can be used in feeds for shrimps and that the nutritional response to soybean meal in the diet of shrimps depends on the species of shrimp, size and the protein level in the feed, Research findings showed that soybean meal levels between 40 percent and 50 percent can be used to grow shrimp in the absence of natural food. It is possible that higher levels than 40-50 percent soybean in commercial feeds can be used for commercial shrimp production in ponds if micronutrients (vitamins and minerals) and semi-micronutrients are not limiting (Lawrence and Castillo, 1986). The ingredient composition of experimental diets used are summarized in Table 10.

Day after stocking	**Time of day** 0700	1100	1400	1700	2200
1-15	30%	—	—	70%	—
16-30	30%	—	40%	—	30%
31-45	20%	10%	— :	40%	30%
45-harvest	20%	10%	5%	40%	25%

Table 10. Ingredient composition of experimental feeds containing 25 percent protein and 35 percent protein levels used for tank studies

Feedstuffs	**Soybean content of experimental feeds**			
	Experimental feeds containing 25 percent protein			
	15	**30**	**45**	**53**
Soybean meal	15.0	30.0	45.0	52.7
Shrimp-head meal	15.8	9.6	3.3	0.0
Menhaden fish meal	15.8	9.6	3.3	0.0
Corn starch	38.2	33.2	28.7	25.9
Cellulose	1.4	1.5	1.5	1.6
Capelin fish oil	1.7	2.5	3.3	3.8
Minoral mix	3.6	5.1	6.7	7.5
	Experimental feeds containing 35 percent protein			
	30	**45**	**60**	***75***
Soybean meal	30.0	45.0	60.0	74.6
Shrimp-head meal	18.7	12.4	6.1	0.0
Menhaden fish meal	18.7	12.4	6.1	0.0
Corn starch	22.2	17.1	12.0	6.9
Cellulose	0.1	0.4	0.7	1.0
Capelin fish oil	0.4	1.2	2.0	2.0
Minoral mix	1.4	3.0	4.6	6.1

All values are percent of feed on an as fed basis.

All feeds contained 1 percent lecithin, 0.5 percent cholesterol, 2 percent vitamin mix, 2 percent sodium alginate, 1 percent sodium hexametaphosphate and 2 percent fish solubles.

Calculated composition of experimental feeds containing 25 percent protein was: 25 percent protein, 8 percent lipid, 39 percent carbohydrate, 13 percent ash, 5 percent fiber and 10 percent water.

Calculated composition of experimental feeds containing 35 percent protein was: 35 percent protein, 8 percent lipid, 29 percent carbohydrate, 13 percent ash, 5 percent fiber and 10 percent water.

Source: Lawrence, Addison L., et. al., 1986

Formulated shrimp diets tested and proven under intensive rearing condition is summarized in Appendix 2. How to formulate feeds for shrimps is in Appendix 3.

There has been no comparative study conducted on the efficiency and cost of various commercial shrimp feeds used in the Philippines. The shrimp farmers simply go by previous experience in the use of certain feed brands they have tried in the course of farming operations. The cheapest feed may not be the best choice but oftentimes, the supply and availability of feeds at the time of need spells the difference indecision-making of farmers with respect to the use of feeds. Intensive shrimp farming requires a steady supply of feeds. Feed companies that are able to supply farmers at reasonable cost and terms of payment are able to obtain a bigger share of the commercial feed market.

4.3 Seeds supply and rearing

Seeds supply is a critical factor in intensive shrimp farming operations. In the Philippines where supply of wild caught fry and hatchery seed production is still erratic, it is advantageous to have nursery pondsto keep adequate quantities of shrimp juveniles. The rearing of shrimp seeds is more complicated than the milkfish in the sense that shrimps molt and has different feed requirement during its larval stages of development. Keeping stunted juveniles may not have the same growth performance as the stunted milkfish fingerlings.

The cost of shrimp seeds is also high due to the unreliability of shrimp spawners. The full potential to produce shrimp juveniles is affected by several factors such as nutrition, diseases, water quality and skill of hatchery technicians. A shrimp hatchery has to have good facility and capability to hurdle all these limiting factors.

Regardless of size, hatcheries require two or more types of living food organisms for larvae rearing — such as unicellular algae or yeast for the protozeal stages; rotifers for the transitional stage from protozoea to mysis and postlarval stages of the shrimp fry. The manufacture of microencapsulated feeds using local feed ingredients should be made in order to simplify hatchery operations. This type of feed has been developed abroad and distributed in the Philippines and other ASEAN countries (FRIPAK). However, the high cost of this feed material does not encourage small hatchery operators to rely on this imported product although available in the commercial market.

Since the production and supply of shrimp juveniles is still highly fluctuating despite hatchery technology available in the Philippines, it is better to adjust the shrimp rearing management techniques according to prevailing conditions. Better use of rearing facilities such as the nursery and grow-out ponds would result to higher production.

5.INSIGHT TO THE FUTURE OF SHRIMP FARMING

The main purpose of intensification of farming management techniques is to increase productivity and obtain high profit. This has been the direction of shrimp farmers worldwide particularly the largebusiness enterprises. *Penaeus monodon* produced locally are mostly exported. It would be advantageous if production is geared both for domestic and export markets.

5.1 Market considerations

5.1.1 International market

There are only three major international markets for shrimps. These are Japan, the United States and Western Europe (Table 11). The main supply comes from 30 countries of which Thailand, Indonesia, Malaysia, Philippines, Vietnam and Singapore are Southeast ASEAN countries (Table 12).

The major export market of the Philippines is Japan, followed by the United States (Table 13). The same market is shared by Thailand, Indonesia and other developing countries in the ASEAN region. A decline in the quality and price competitiveness of Philippine shrimp lead to the collapse of intensive farming operations. There has been already a slump in the Japanese market which brought the price of shrimp down. The intensive operations found it difficult to make their system economical.

The international market for shrimps produced in the ASEAN countries, particularly the Philippines, is mainly Japan. Promotion of shrimp export to the United States, Canada and Europe is being made. However, in the United States, the government is now giving emphasis to aquaculture development as it realized that a great percentage of their budget is eaten up by increasing imports of seafoods. In response to this problem, the United States government recently established six regional aquaculture research centers in different regions of the continent. The Center for Tropical and Sub-tropical Aquaculture is based in Hawaii. These aquaculture centers bring together members of the private industry, the scientific community and the extension agents to address the concerns of aquaculture through research and educational extension (Aquaculture, 1989).

Table 11. Imports of shrimps and prawns by 15 major importing countries (1986)

Quantity (Q):tons
Value (V): $ '000

	Importing country/area	Q	V	% of total V
1.	Japan	213 842	1 835 690	42.5
2.	USA	160 521	1 301 405	30.1
3.	Denmark	42 587	136 183	3.2
4.	Hong Kong	40 938	194 595	4.5
5.	France	30 923	175 119	4.1
6.	United Kingdom	24 682	128 243	2.9
7.	Singapore	19 623	51 416	1.2
8.	Spain	19 530	119 163	2.8
9.	Italy	17 607	117 591	2.7
10.	Canada	13 500	116 650	2.7
11.	Malaysia	12 797	6 575	0.15
12.	Norway	11 409	29 228	0.68
13.	Sweden	9 219	34 951	0.81
14.	Netherlands	8 135	30 070	0.70
15.	Belgium	7 029	42 913	1.0
	Total	632 342	4 319 792	100.00

Source: FAO Yearbook 1986

Table 12. Exports of shrimps and prawns by 30 major producing countries (1986)

Quantity (Q):tons
Value (V): $ '000

Origin	Q	% of Q	v	% of total V
China	49 341	9.33	351 582	11.25
India	49 203	9.31	299 665	9.59
Denmark	40 336	7.63	150 064	4.80
Indonesia	35 963	6.80	284 239	9.09
Greenland	33 133	6.27	110 278	3.53
Hong Kong	31 253	5.91	229 882	7.35
Ecuador	30 683	5.81	284 734	9.11
Thailand	28 717	5.43	167 023	5.34
Malaysia	25 366	4.80	48 382	1.55
Vietnam	19 091	3.62	72 550	2.32
Bangladesh	17 066	3.21	97 000	3.10
Pakistan	14 060	2.67	74 000	2.37
Australia	13 015	2.50	137 660	4.40
Iceland	12 389	2.34	88 360	2.83
United Kingdom	12 315	2.33	66 034	2.11
Brazil	12 285	2.30	90 107	2.88
Argentina	11 300 f	2.14	49 500 f	1.58
Philippines	11 211	2.12	103 828	3.32
Singapore	10 472	1.98	43 058	1.38
Panama	9 336 f	1.77	74 000 f	2.37
USA	9 091	1.72	69 119	2.21
Faeroe Island	8 173	1.55	20 348	0.65
Netherlands	7 852	1.49	27 113	0.87
Senegal	6 874	1.31	67 560	2.16
France	5 472	1.04	48 944	1.57
Norway	5 159	0.98	23 672	0.76
Canada	5 001	0.95	25 791	0.83
Guyana	4 980	0.94	5 000	0.16
Macau	4 931	0.93	5 390	0.17
Germany, F:R.	**4 331**	**0.82**	**10 965**	**0.35**
Total	528 399	100.00	3 125 828	100.00

Source: FAO Yearbook 1986

Table 13. Philippine export of shrimps and prawns (fresh/chilled/frozen) by country of destination, 1983-1987

Country	1983		1984		1985		1986		1987	
	Quantity (mt)	Value (P)	Quantity (mt)	Value (p)	Quantity (mt)	Value (p)	Quantity (mt)	Value	Quantity (mt)	Value
Australia	10	713	89	9 965	109	12064	81	12391	159	28146
Canada	—	—	1	126	40	3771	28	3926	70	8870
England	*	1	*	2	5	539	45	9691	9	1222
Germany,F.R.	3	56	*	**	—	—"	37	8158	19	4957
Guam	51	4749	65	5009	150	17873	101	14594	122	22104
Hong Kong	13	489	12	3828	56	3989	35	1991	58	5632
Japan	3955	295958	4482	401575	5917	811311	8686	1640435	121162	562654
Saipan	1	48	*	10	—	—	—	—	—	—
Saudi Arabia	*	29	*	**	—	—	—	—	—	—
Singapore	15	758	17	1628	4	506	16	2257	12	1487
Sweden	*	12	—	—	—	—	—	—	—	—
USA	524	34412	1563	110692	1759	298346	1854	351695	2074	459314
ArabianPeninsulaState	—	—	—	—	12	1682	13	2140	—	—
MalayaFederalof	—	—	—	—	14	867	—		—	—
Taiwan	—	—	—	—	2	523	21	2359		20
Trust Territory of Pacific Islands	—	—	—	—	1	143	1	59	4	160
Hawaii	—	—	—	—	26	5 129	235	49 264	234	53776
Nauru	—	—	—	—	*	30				—
Netherlands	—	—	—	—	9	1585	23	2779		—
France	—	—	—	—	—	—	10	1372	26	4188
Italy	—	—	—	—	—	—	7	1440	19	3347
Thailand	—	—	—	—	—	—	8	1228		
Okinawa	—	—	—	—	—	—	*	2	0	1893
Cyprus	—	—	—	—	—	—	—	—	5	373
New Zealand	—	—	—	—	—	—	—	—	—	1
Total	4572	337225	6229	532835	8104	1158358	11210	2105781	149363	1581-43

*Less than one metric ton
**Less than P1 000
Source: BFAR Fisheries Statistics

Shrimps constitute 72 percent of imported seafood consumption in the United States in 1988. The government, therefore, felt the compelling need to produce shrimps domestically. The only way the United States could produce shrimps would be to use intensive systems to compete in the global market. This goal could easily be met as the country has a well-organized research programme and their scientific institutions are well-funded. The Oceanic Institute alone which is based in Hawaii has a U$15 million Center for Applied Aquaculture Research (O.I., 1989).

Recent intensive shrimp farming trials conducted have shown that there was no reduction in growth rates as the stocking density increased from 45-100 shrimp/m^2. Yields increased directly with stocking density. Yields of 5 mt/ha/crop has already been achieved in private shrimp farm operations while research results showed the equivalent of 12 mt/ha. It was projected that it would be possible to harvest 10-20 mt/ ha/crop as a routine practice in United States shrimp farms in the next decade (Sandifer, et al., 1988). With this scenario in the United States shrimp farming outlook, sooner than expected. itwould not be very optimistic to rely on this market in the medium term future. Diversification of shrimp species for the local market would be beneficial in the long run since the local demand for shrimp is still high.

It has been pointed out in the Shrimp '88 Conference held in Bangkok, that the shrimp farming industry is approaching its peak of growth considering the fast rate of expansion. Just like any commodity in trade, the industry will follow a typical growth curve starting with development then undergoes a growth period or take-off stage; reaches maturity and then decline (Csavas; 1988). This is illustrated in Figure 13. This prediction happened sooner than expected

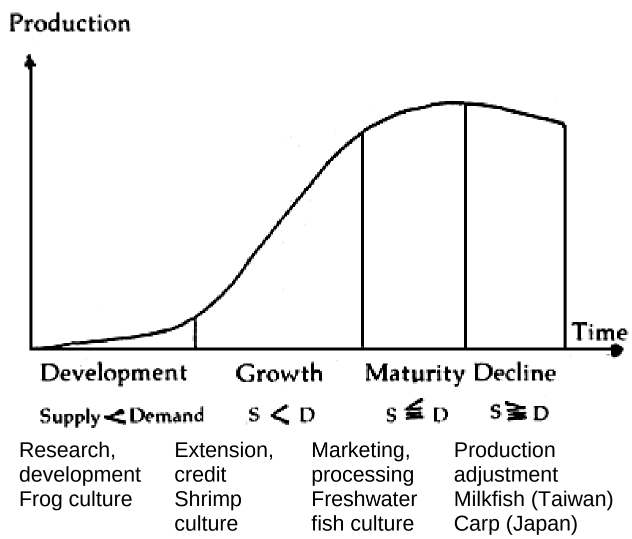


Figure 13. Growth curve of production (after Ohtsu, 1985)
Source: Csavas, 1988

It is very apparent that most developing countries are gearing towards expansion of shrimp farming. Developed countries, which are the international market outlets of Asian shrimps are also intensifying their shrimp farming development programmes, particularly the United States to reducetheir imports of seafoods. With the world supply of shrimps burgeoning to high levels, it is expected that adverse economic factors will affect the shrimp farming industry in the near future. International market demand is increasing at only 5-10 percent per year or an average of *7.5* percent. On the other hand, farmed shrimp production is increasing at the rate of 48 percent from the Western hemisphere shrimp producing countries and 32 percent from the Eastern hemisphere. These sources combined have a total production of 260 000 mt (1985). At the turn of the decade 1990 the gap of supply and demand would have been met (Rabanal, 1988). As such, there will be excess supply from thereon and prices will begin to drop. Highly intensive operations will not be able to compete due to high costs of production. Provision for diversification of product and finding new markets for new products would be advantageous. Government aquaculture research institutions must initiate studies towards this direction to provide the intensive farming operations to have alternatives for the full use of their production capacities.

Even before this paper was out, the intensive shrimp farming operators were struck by low prices of P. *monodon* in Japan, the principal export marketing shrimps from ASEAN. Export of shrimps slumped drastically in the ASEAN countries particularly in the Philippines. Other markets besides Japan are being considered but this would probably take a while to pick up in the same magnitude enjoyed from the Japanese market. It is inevitable that the intensive shrimp farms of about 1 143 ha (IAC, 1989) in the Philippines would have to restructure their loans or diversify their aquaculture operations to avoid more losses from their investments.

It is quite obvious that the semi-intensive and extensive shrimp farming systems will prevail over the intensive and super-intensive operations when the international demand declines. They could perhaps remain in business if their selling price is good enough to compensate for high production costs. Studies have shown that profits in intensive culture would be diminished with a small reduction in selling price while the semi-intensive operations could remain profitable by slightly increasing the level of productivity (Figure 14).

Intensive farms are highly capital intensive; they are also disease-prone. A comparison of economic returns of different shrimp management systems showed that intensive shrimp farming operations do not fare well when the price of shrimp in the export market fluctuates.

Comparative economic analysis: prawn (*P. monodon)* culture (Posadas, B., 1987)

		Traditional	Extensive	Semi-intensive	Intensive
A.	Assumptions				
	Farm size	7 ha	7 ha	*7* ha	7 ha
	Stocking rate	I/m^2	3/m^2	10/m^2	30/m^2
	Survival	70%	70%	70%	*70%*
	Average body weight	40 g	38 g	35 gm	30 gm
	Crops/yr	2	2	2.5	2.5
	Production/crop	280 kg	798 kg	2.45 tons	6.3 tons
	Materials/ha/crop				
	Fertilizer, organic	1 ton	1 ton	1 ton	1 ton
	Inorganic	200 kg	200 kg	—	—
	Lime	—	1 ton	2 tons	4 tons
	Tea seed cake	—	—	200 kg	400 kg
	Power (kwh)			1 000	3 000
	Labor (man-days)	60	120	240	480
	FCR	0.67	1.2	1.6	1.6
	Development cost/ha	P120 000	P150 000	P200 000	P500 000
	Initial investment/ha	P132 000	P200 000	P428 000	P1 145 000
B.	Economic indicators*				
	Payback period (yr)	4.6	2.7	1.7	1.95
	Average rate of return (%)	13	30	56	47
	Net present value				
	P150/kg, static	(86)	264	2 340	4 281
	P140/kg ± 7%	(246)	181	1 681	2 585
	P140/kg ± 20%	(376)	272	292	(985)
	Initial rate of return (%)				
	Pl50/kg, static	9	30*	*57**	46*
	P140/kg ± 7%	5	23*	47*	36*
	P140/kg ± 20%	3	9	25*	13

*Undiscounted. Payback period — number of years to recover initial investment plus interest from expected earnings.

Average rate of return — ratio between annual profits expected and value of project after depreciation of investment.

Discounted. Net present value — difference between present value of project earnings and costs; ( ) is negative value.

Initial rate of return — discounted rate which equates present value of project benefits and costs; — profitable.

Source: Aquaculture Watch, 1989.

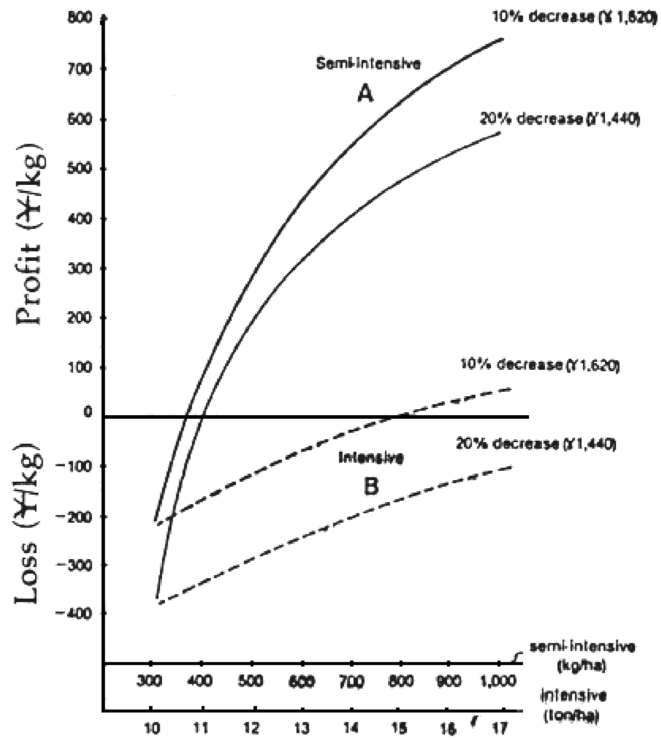


Figure 14. Profit and loss per kilogram given a decrease (by 10 and 20 percent of present levels) in selling price Source: Hirasawa, 1985

5.1.2 Domestic market

While the Asian countries produce the bulk of shrimps in the world market, the domestic consumption could be astonishingly low if one considers per caput production shown below:

Country	Per capita production (kg)
Brunei	2.306
Burma	0.019
Cambodia	0.041
Indonesia	0.694
Malaysia	4.442
Philippines	1.348
Singapore	0.752
Thailand	3.123
Vietnam	0.928

Source: Rabanal, 1988

Per capita shrimp consumption of importing countries such as Japan is 1.735 kg while the United States is 0.9 kg. From these information consumption at domestic levels could still increase significantly particularly with corresponding increase in population. There is, therefore, a large domestic market which the producers should consider. The intensive farming sector should, however, be able to decrease their selling price to become competitive in the local markets. They have to reduce their cost of production to be competitive with the semi-intensive farming operations.

5.2 Increasing the levels of productivity

Although intensive farming production techniques are being adopted in most developing countries, 83 percent of the total shrimp production is still obtained from extensive and semi-intensive farming systems. The average level of shrimp culture production in Asian countries is 284 kg/ha (Table 14).

Table 14. Average crustacean yield in Asia (1985)

Country	Average yield (kg/ha)
Bangladesh	108
Burma	173
China, P.R. of	714
India	395
Indonesia	162
Malaysia	553
Philippines	149
Singapore	1 476
Thailand	450
Vietnam	260
Average of "extensive" and "semi-intensive" Countries	240
Japan	6 145
Taiwan, R.O.C.	7 750
Average of "intensive" Countries	7 620
Asian average	284

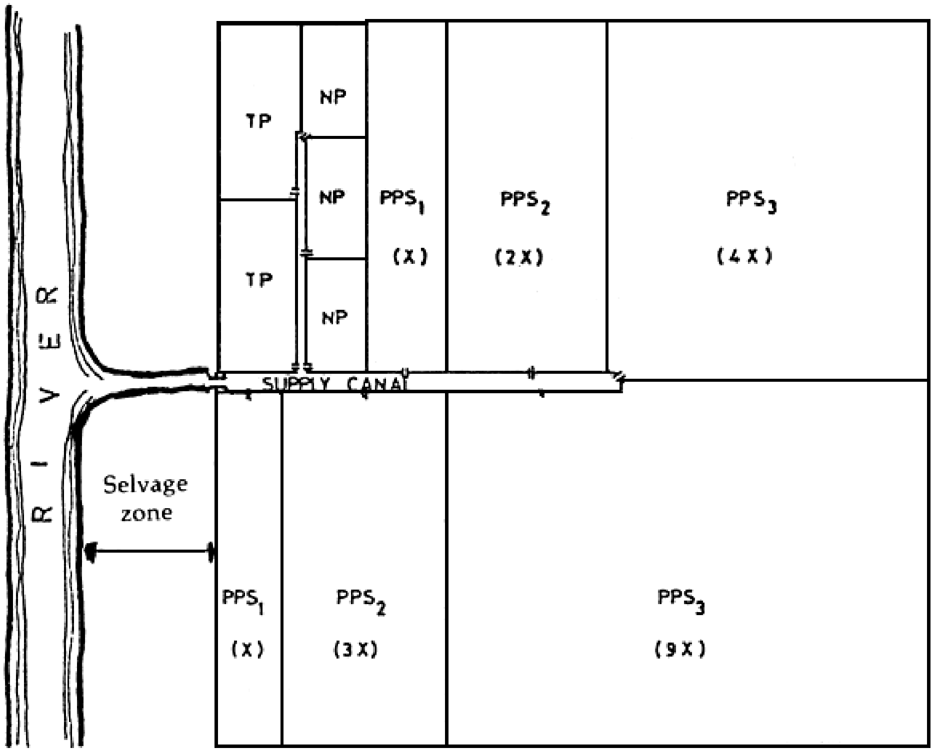
Source: Csavas, 1988

In the event of falling international market demand the possibility of increasing the levels of shrimp production would come from extensive and semi-intensive farming areas rather than the intensive farming operations due to lesser costs involved.

Extensive farming systems may not be able to increase production to high levels due to dependence on natural productivity. However, improvement in management techniques such as predator control, selective harvesting and stocking and frequent water change could increase production.

Since shrimp juveniles are available year round, selective or multiple harvesting and stocking is possible. Replacement of large shrimps harvested from the ponds with smaller sized shrimps from nurseries results to maximum use of production facility and at the same time increasing the level of production.

The pond system called the modular system as practiced in the Philippines for milkfish is also applicable to shrimp farming. The pond system consists of the nursery ponds, intermediate or transition ponds and grow-out ponds (Figure 15a); the multiple stock harvest system (Figure 15b).



Legend:
NP — Nursery pond
TP — Transition pond
PPS — Production process pond

Figure 15a. Example of a modular pond system (Source: dela Cruz, C.R., 1983)

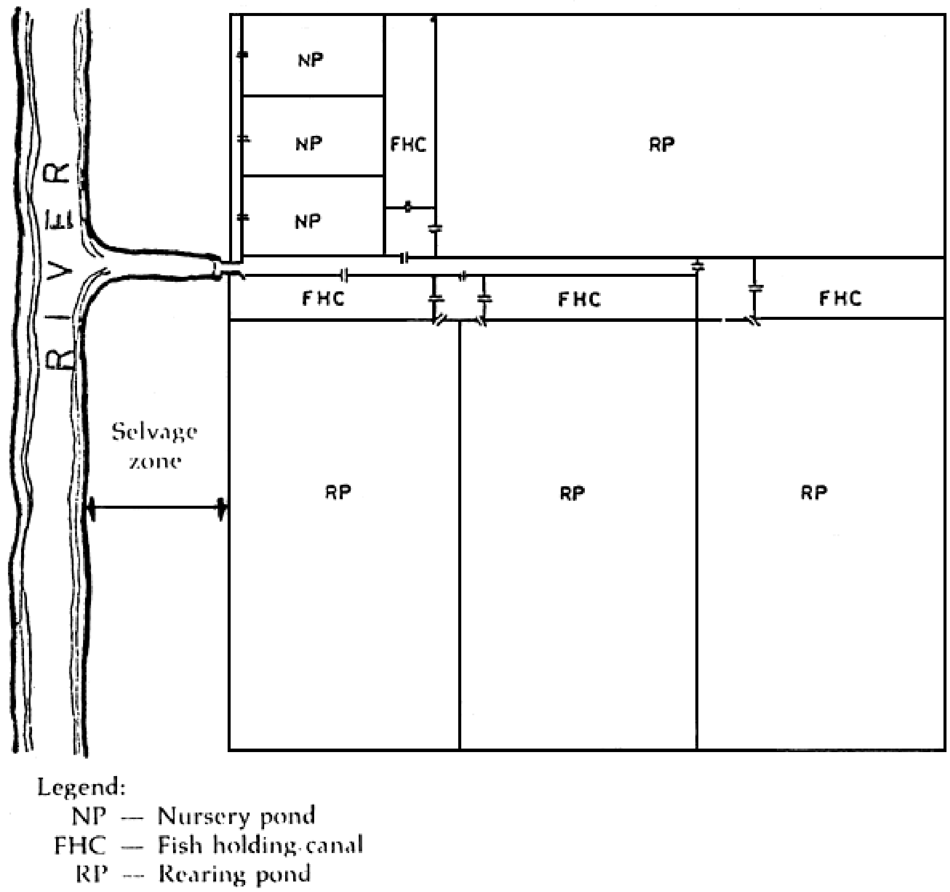


Figure 15b. Example of a multiple stock harvest pond system (Source: dela Cruz, C.R., 1983)

In Taiwan, farmers stock seedlings after finishing a previous harvest thereby fully utilizing the pond capacity while the shrimps are small (Figure 16). Under this system, 2.5 to 3 crops of shrimp is attainable annually.

Another semi-intensive system is the circulating pond use (Figure 17). Ponds may be divided into several sections of different sizes and stock small shrimps in the small units first. When they have grown to some extent, they are shifted to the next larger sections. After each movement of a batch of shrimps, the pond is cleaned and restocked with another batch repeating the same process. Within a period of three months every pond unit is filled with different sizes of shrimps. Under tropical weather conditions, it is possible to harvest 5-6 times a year.

5.3 Diversification of farmed shrimp species

5.3.1 White shrimp

In the ASEAN region, the white shrimp is abundant and wild seeds are available in large quantities. As a matter of fact wild shrimp seeds that enter brackishwater ponds are composed mainly of the white shrimp, P. *merguiensis* or locally called *hipon puti* in the Philippines.

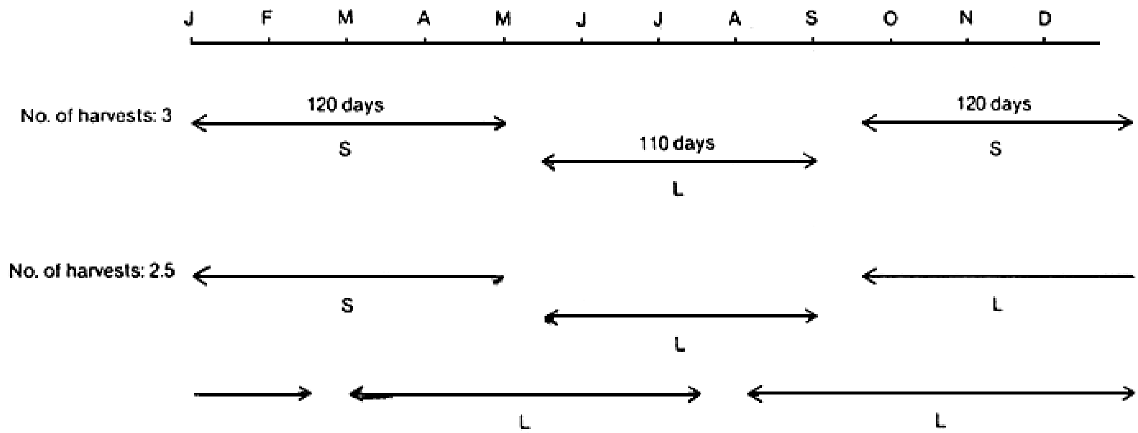


Figure 16. Schedule of pond use by month in the Tungkang area, Taiwan Size of shrimp: S — small (32-35 g); L — large (35-40 g)
Source: Hirasawa, 1985

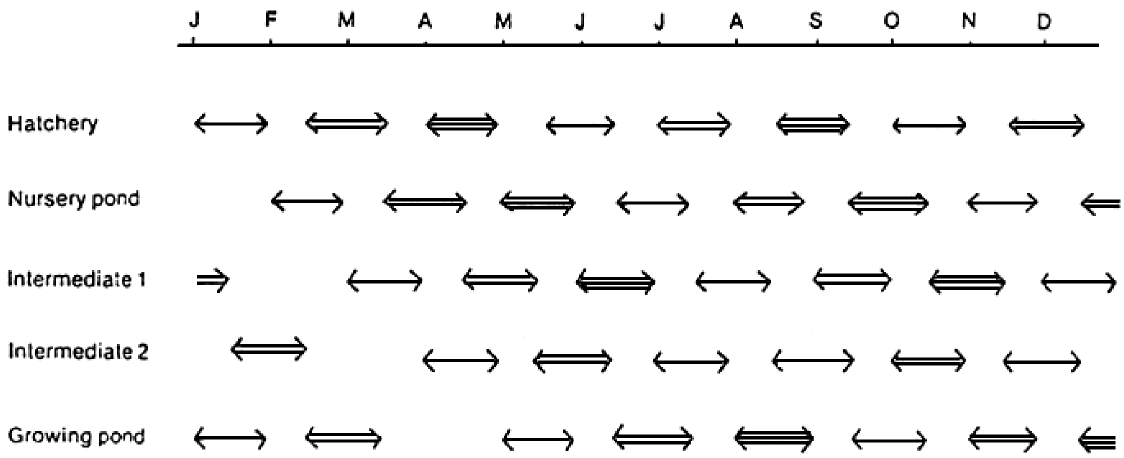


Figure 17. A model of circulating pond use. Individual stocking or crop (as identified by number of horizontal lines) may be followed through the various production phases
Source: Hirasawa, 1985

In Japan, imported *P. monodon* is mainly used in out-of-home consumption market where it is a substitute for the large white shrimp due to its lower price. The medium size white shrimp is preferred for homo consumption due to its white meat color and cheaper than the large white shrimp. The price of white shrimp in Japan has always been higher than the tiger shrimp (Figure 18).

For culture purposes, beginning at PL10-PL15, the growth rate of the white shrimp was found faster than the tiger shrimp within a 7-day rearing period. Beyond this, it does not pay to continue rearing as the growth rate declines (Figure 19). This means that one rearing cycle of the white shrimp takes only 70 days, thus making 3.4 crops of white shrimp in 240 days (Liao, 1987).

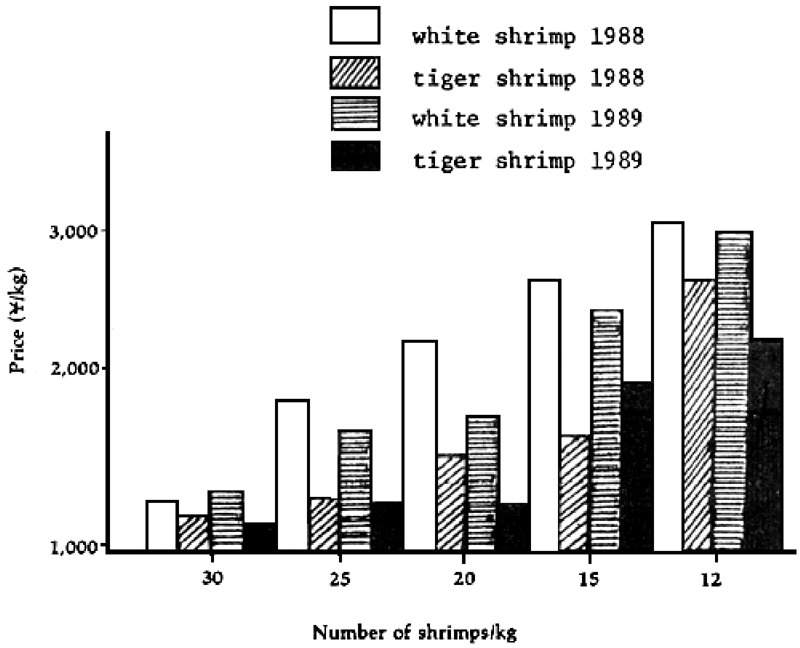


Figure 18. Wholesale prices of shrimps in Japanese market
Source: INFOFISH TRADE, December 1988 and June 1989

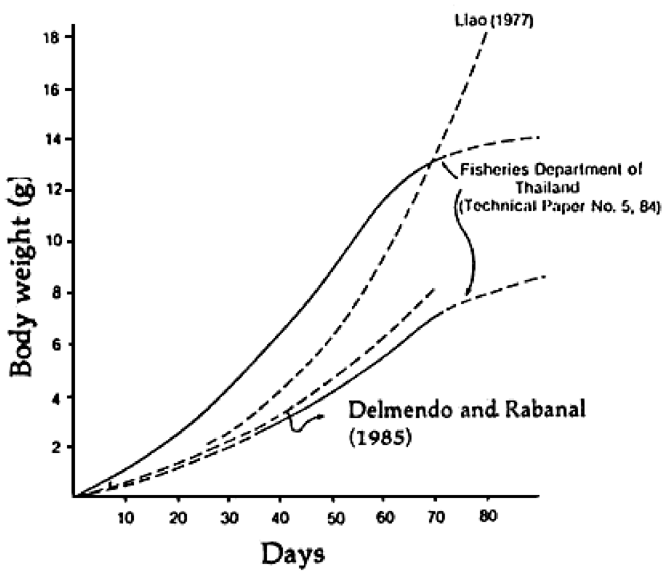


Figure 19. Growth rate of black tiger shrimp,*Penaeus monodon* (....) and white shrimp, P. *merguiensis* (__)
Source: Hirasawa, 1985

In Thailand, extensive shrimp farming is centered on white shrimp**.** An economic sampling of white shrimp farming showed a rate of return ranging from 39.5 to 59.8 percent (Table 15). Shrimp fry are abundant in tidal areas which Thai farmers pump into their ponds.

White shrimps lay eggs and spawn in ponds naturally. In the Philippines, only about 10 percent of shrimp seeds collected from the wild consists of tiger shrimp and the rest is made up mainly of the white shrimp species.

It would perhaps be beneficial to grow P. *monodon* during the wet period of the year when salinity is lower and white shrimp during summer when salinity levels are generally high. This would reduce the cost of pumping freshwater to reduce salinity in the ponds. Massive extraction of underground water for salinity control in intensive ponds could be avoided while at the same time produce a higher quality shrimp species. The fry of white shrimp is relatively easier to collect from the wild.

Table 15. Economic status of white shrimp culture in Thailand (1984)

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

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

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

Source: Hirasawa, 1985

5.3.2 Green tiger shrimp

Another species of shrimp with potential for culture is the P. *semisulcatus* called locally as *bulik* in the Philippines.

Studies conducted in Taiwan showed that rearing of this species at an initial weight of 0.16 g attained 33.69 g at a stock density of $20/m^2$ for a period of 315 days. The survival rate was 83.0 percent (Liao, 1987).

Penaeus semisulcatus is widely distributed. and its fry are caught widely in nature in sufficient quantities. It tolerates high salinity and low temperatures. The only constraint is the long rearing period to attain marketable size. It may be possible that at lower stock density, the size at marketable stage may be larger but whether this could be attained within shorter rearing period is something which needs further study.

5.3.3 *Penaeus brasiliensis*

Penaeus brasiliensis is an introduced species in Taiwan from Brazil. It attains a size of 40 g in one year. The future of this species has to be investigated also like the P. *semisulcatus.*

5.3.4 *Penaeus penicillatus*

This species is reported to be one of white shrimp species preferred in Europe and the United States. It tolerates low temperature and has a low protein level requirement of feed of 22 percent. Liao (1987) reported that it can be stocked at densities of $100\text{-}120/m^2$. The growth rate is also quite rapid during its early life stages. Figure 20 shows that P. *penicillatus* attains over 30 g in 120 days.

Of the three species, P. *penicillatus* is already being produced by Taiwanese farmers. In 1986, 2 000 mt was also produced and prospects for future export of the species is quite optimistic. Liao (1988) reported that P. *penicillatus* is resistant to low temperature; shows good possibilities for rearing in seawater; spawners are abundant; spawning by natural or induced method relatively easier than P. *monodon;* larvae has good survival and subsist in natural food in the ponds; low protein requirement and has good growth even at high densities of 100-120/m^2; it grows to uniform size.

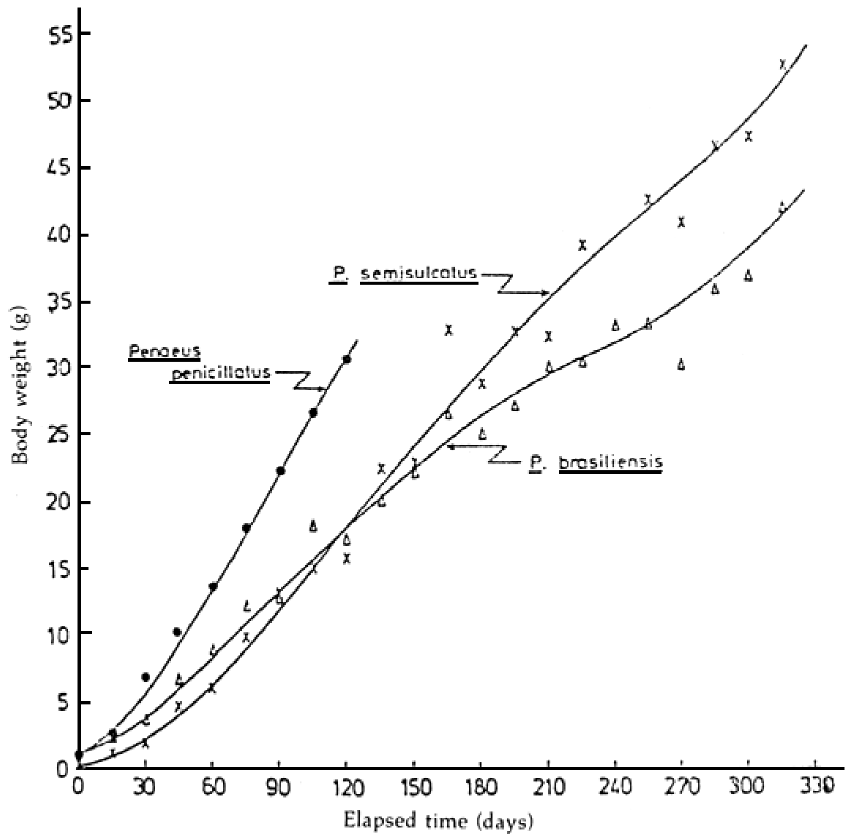


Figure 20. Growth curves comparing maximum growth attained by individuals of *Penaeus emisulcatus, P. brasiliensis* **and** *P. penicillatus*
Source: Liao, I.C. Contribution No. 74, 18th Annual Meeting of the WAS, Guayaquil, Ecuador, 1987

6. FURTHER AREAS OF RESEARCH FOR FUTURE EXPANSION OF SHRIMP CULTURE

Although shrimp farming has already advanced from the extensive system to super-intensive operations, there are still various problems which need to be studied in order to develop more practical technologies of shrimp farming.

The environmental and nutritional requirements of shrimps at different stages of growth are not well understood yet. Research on disease diagnosis and controland other related problem areas require government support to enable the industry to further increase production and standardize shrimp farming management techniques to avoid wastage of production inputs.

Improvement of genetic quality of brood-stocks also requires attention not only for shrimps but for finfishes as well.

There are certainly multifarious problems that shrimp farmers may be confronted with from day-to-day. However, adequate monitoring and recording of farming activities would enable the farmer to identify these problems and obtain solutions by consultation with field technicians, fellow farmers or known experts/institutions on the subject. On the other hand, technicians must be conversant with the technical and practical aspects of shrimp farming to be able to help the farmers at the time of need.

REFERENCES

Aquaculture Magazine. Buyers guide
1989 and industry directory.

Aquaculture Watch. Vol. 3, No. 1, Jan.
1989 1989, Asia-Pacific Information Consultants. P.O.Box 10243, MRFA, Makati, Metro Manila.

Csavas, I. Shrimp farming in Asia. IPFC
1988 WPA/WPll, FAO Regional Office for Asia and the Pacific, Phra Atit Rd., Bangkok 10200, Thailand.

de la Cruz, C. Fishpond engineering: A
1983 technical manual for small- and medium-scale coastal fish farms in Southeast Asia. SCS Manual No. 5, South China Sea Fisheries Development and Coordinating Programme, 860 Arcadia Bldg., Quezon Avenue, Quezon City, Metro Manila.

Delmendo, M.N. and H.R. Rabanal.
1973 Cultivation of "sugpo" (Jumbo tiger shrimp), *Penaeus monodon* Fabricius' in the Philippines. The Phil. Journal Fisheries, Vol. 8, No. 2. Philippine Fisheries Commission, DANR.

Gedney, R.H. Comparative study of tidal
1983 and pumped water supply for brackishwater aquacuture ponds in Malaysia. SCS/83/WP/117.

Hirasawa, Yutaka. Economics of shrimp
1985 culture in Asia. In Proc. of the First International Conference on the Culture of Penaeid Prawns/ Shrimps. AQD/SEAFDEC, Tigbauan, Iloilo.

International Aquaculture Consultants,
1989 Manila, Philippines. An assessment of the market for paddle-wheel aerators for aquaculture use in the Philippines.

Kuo, Ching-Ming. Recent developments
1986 on prawn intensification. National Conference on Prawn' Farming Technology. Fishfarmers' Technical Assistance Foundation, Inc., Metro Manila, Philippines.

Lawrence, A.L., et al. Nutritional
1986 response of marine shrimp to different levels of soybean meal in feeds. In Proc. 10th Anniversary USA-ROC and ROC-USA Economic Council Joint Conference, Taipei, Taiwan, December 1986. Eds. Dean M. Akiyama. American Soybean Assn. 541 .Orhard Rd., No. 11-03 Liat Towers, Republic of Singapore 0923,

Liao, I-Chiu. A brief review of the larval
1985 rearing techniques of penaeid prawns. Contribution No. 32 of the Tungkang Marine Laboratory, Tungkang, Pintung, Taiwan. In Proc. First International Conference on the Culture of Penaeid Prawn/Shrimps. SEAFDEC, Tigbaun, Iloilo.

Liao, I-Chiu. Prawn culture from
1987 Taiwan's experience., Contribution No. 52 of the Tungkang Marine Laboratory presented at the Round Table Panel, 18th Annual Meeting of the World Aquaculture Society, Ecuador, 18-23 January 1989.

Liao, I-Chiu. Future technology in prawn
1987 production. Contribution No. 51 from the Tungkang Marine Laboratory. Presented at the Special Session of the 18th Annual Meeting of the World Aquaculture Society held in Ecuador, 18-23 January 1989

Liao, I-Chiu and Nai-Hsiem Choo.
1987 Preliminary report on the culture of three new candidates for prawn farming in Taiwan. Presented at the Special Session of the 18th Annual Meeting of the World Aquaculture Society held in Ecuador, 18-23 January 1989.

Motoh, Hiroshi. Biology and ecology of
1985 *Penaeus monodon.* Proc. First International Conference on the Culture of Penaeid Prawns/Shrimps. SEAFDEC; 1985.

Newsline. Oceanic Institute. Undated.

Pascual, F.D. Nutrition and feeding of
1983 *Penaeus monodon.* Extension Manual No. 2, 3rd Edition. AQD/SEAFDEC, Tigbauan, Iloilo.

Rabanal, H.R. Profile of shrimp farming
1988 in Southeast Asia. Paper contributed to the Ko-Nelayan Aquaculture Seminar, Kota Kinabalu, Sabah, Malaysia, 10-13 August 1988.

Sandifer, P.A., J.S. Hopkins and A.
1988 Stokes. Intensification of shrimp culture in earthen ponds in South Carolina: Progress and prospects. Journal of the World Aquaculture Society, Vol. 19, No. 4, 1988.

Stockwell, B.A. and D.B.C. Williams.
1988 Intensive *Penaeus monodon* farming !in the island of Negros, Philippines: An examination of current culture technology and production economics. 19th Annual Meeting, World Aquaculture Society, Honolulu, Hawaii, 4-8 January 1988.

Tacon, Albert G.J. The nutrition and
1988 feeding of farmed fish and shrimp: A training manual 3. Feeding methods. GCP/RLA/075/ITA Field Document No. 7, FAO, Rome.

Uno, Yutaka. An ecological approach to
1985 mariculture of shrimp: Shrimp ranching fisheries. In Proc. First International Conference on the Culture of Penaeid Prawns/Shrimps. SEAFDEC, Tigbauan, Iloilo.

Wickins, J.F. Prawn farming today:
1986 Opportunities, techniques and developments. Outlook on Agriculture, Vol. 15, No. 2. Pergamon Journals, Ltd.

Young, R.U. Prevalent technical
1987 problems in semi-intensive and intensive culture of *Penaeus monodon* in the Philippines. National Seminar on Problems of the Prawn Farming Industry and Suggested Solutions. Fishfarmers' Technical Assistance Foundation, Inc., Metro Manila, Philippines, 23-24 October 1987.

APPENDICES

Appendix 1

ENGINEERING CONSIDERATIONS FOR DISEASE AND STRESS PREVENTION IN SHRIMP HATCHERIES AND PONDS[1]

by

R.Q. Gacutan[2] and A.T. Vizcarra[3]

1. INTRODUCTION

Developments in the technology for shrimp larval hatchery has been greatly aided by contributions from the engineering field. These are by way of the applications of engineering principles and practices which led to more efficient and more economical designs of facilities.

The first tanks utilized for *Penaeus monodon* larval rearing were of the 50-100 ton type, rectangular or square, wide and deep, roofed or open. This was adapted from the design known to be best for P. *japonicus,* the "kuruma shrimp", which had been worked out to perfection in Japan since the early 1930's.

The operation calls for spawning and larval rearing (from nauplius to zoea, mysis and postlarvae) to be done in the same tank up to harvest at PL5 stage. Even the diatom/phytoplankton feed is added to the tank in this form, culture medium and all, and made to bloom right there in the tank. The rotifers and zooplankton are, however, cultured separately. One sees, therefore, that basically a "straight run" a minimum of larval transfer from one tank to another is made. In consequence, large volume of seawater are used up for water exchange especially when a "flow-through" system is called for. Such is instituted during situations when the rearing tank is "suspect", meaning, there are indications of a disease.

This type of operation did not suit P. *monodon* larvae very well. Apparently, it appeared to be much more sensitive to metabolite build-up and subject to a wider spectrum of diseases in the tank than does P. *japonicus.*

The Taiwanese system scaled down the tank sizes by 1/5 to 1/2, so now one sees the proliferation of 10 to 20 ton sizes, still rectangular or square and of medium depth. In addition, the tanks were roofed, with a structure that made the environs warm, humid and dark. These are definite improvements of this type over the Japanese tanks. For one, there is already a separation of the process into component stages so that there are now the so-called gonadal maturation tanks, spawning tanks, and many larval rearing tanks of almost uniform sizes to be used during subsequent transfers, apparently *ad infinitum* in response to the state of health of the fry.

The phytoplankton/diatom culture, the most important food for the zoeal stages is grown separately, inside another tank or a separate air-conditioned laboratory until a dense population is attained. Once the desired density is attained, the culture is harvested, washed and offered at a "semi-controlled" density or at predetermined numbers.

Almost parallel and simultaneous to the developments in Taiwan were those occurring in the western hemispere, specifically, in Galveston, Texas by Cornelius Mock and co-workers. The tanks, now down to 1-2 tons in size, are compact. The tanks are obviously economical, for the reduction of water volumes needed; practical, for the ease in effecting transfers of larvae at any stage of the rearing cycle; clean and sanitary, for in the endless operations one can keep disease situations in check including even with the use of salts, approximating the composition of seawater as in the "instant ocean" or "artificial seawater".

Diatoms/phytoplankton are intensively cultured in demijohns, plastic sheets and even bags and, prior to addition to the culture facility, are filtered to remove the original salts of the culture medium which for a time are being eyed as probable causes of mortality. *Artemia,* the best food known for mysis and later stages is also offered in its cleanest form possible, what with the concerted attempts and works of Sorgeloos and co-workers in Belgium initially, and around the world consequently.

The hatchery designs one sees today in the Philippines is a combination of the abovementioned culture facilities. It goes without saying that the best of each system are adapted for economy and ease in instituting sanitation measures. The circular tanks are good — siphoning of excess unconsumed microencapsulated feeds, now in vogue, is made easy. Furthermore, there is the possibility of aeration coming about evenly in all parts of the tank.

Much of the developments today are engineering in nature. And many more ideas are continually packaged and added as the hatchery operator se

The engineering of ponds followed a separate and late course and was aided by very little back-up research.

In the Philippines, much of the pond area devoted to shrimp culture were old milk-fish ponds redesigned to meet the perceived specifications for penaeids,. Shrimps are, of course, known previously among bangos culturists as usual "by-products" in bangos ponds — they invariably turn up in low volumes at harvest, just enough to be noticed.

In the absence of a ready technology, the first culturists were "extensive" or "low density", in reponse to the resources available to the pond. When feeds were introduced and may come to know of the wonders they do by way of faster growth and greater survival, higher densities (semi-intensive) were tried. The importance of water, in disease control, i.e., exchange volume needed, etc., soon dawned upon the culturist and suddenly, the shift is toward intensification. With this, the culturist tried to cramp several animals within a square meter of the pond bottom 10 first, then 20, 30 and then shooting for 60 and 80.

But the environment can take only so much number of animals, nothing more. Excessively, high stocking densities unduly cause stress to the animals, load the water with hazardous metabolites and, therefore, cause DISEASE.

Late in 1986, many diseases cropped up in Negros, dimming visions of many culturists of huge profits. Before long, they realized the folly of trying to crowd the animals. Back to earth they descended and figures now point out that 15 per square meter or 150 000 per hectare is about the carrying capacity of ponds.

Nothing short of amazing, however, is the determination of many a grower to succeed in the endeavor. To avoid diseases, they tried every option available to them. Thus, we now see innovations that include concrete flumes, much more efficient aerators, central drains of various specifications, and now the "vacuum cleaner".

There are aspects neglected though. Close to a hundred percent of existing Negros ponds failed to reckon with the innumerable benefits that could be drawn from such components as a combination reservoir — treatment "kitchen" pond. Then, there was very little that was done to site the inlet canals and their corresponding drain canals separately so much so that they now operate on the basis of "what comes out must, at some future time, come in".

Likewise, they failed to reckon with Baliao's and SEAFDEC co-workers' experience on the modular pond. This system is promising for its vision on disease control. Before diseases could manifest and throw the pond into chaos, the animals are transferred into a next compartment where new conditions, better than the previous one, prevail. Thus, if the course of a disease calls for a 60-day development, it never surfaces as the population is moved to another pond within 30 to 45 days.

This paper attempts to present the areas in which these engineering concepts are applied, and speculates on some others that might be worth looking into. Obviously, this does not present all the possible improvements but it will be just a starter, to tell the engineer that he is very much needed. One has to bear in mind, though, that the engineer must proceed with the advice of the biologist, for obvious reasons.

[1]Based on paper presented at the regular annual meeting of the Society of Aquaculture Engineers of the Philippines (SAEP) held at ADP-DA/BFAR Office, Iloilo City, Philippines, 25 June 1988. This reprinting is with permission of SAEP.

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2. HATCHERY

2.1 Laying of water distribution pipes in sloping fashion

At present, water lines are laid on the ground flat or level. With this set up, water is trapped within the pipes for long hours or even a day or two after use. Seawater thus confined in these pipes is a good medium for microbial growth, especially the bacteria. When water is allowed into the tanks and through the pipes subsequently, the pathogen-rich waters get into the tanks and may then become the vector of diseases.

Sloping instead of level or horizontal lines, provided with drain plugs at strategic or lowest points, will allow total draining of water after pumping. In this manner, introduction of pathogen-rich water is prevented. The pipes are also dried in the process.

It is good piping practice to provide a pitch of 0.05 to 0.10 cm for every meter of water line. Steeper slopes may be adopted for faster drainage. The vertical rise should not, however, exceed 2 cm over any one meter horizontal distance to prevent settling of solids along the pipeline.

2.2 Separation of eggs from debris and traces of chemicals after spawning and treatment (Figure 1)

The termination of spawning at dawn is often indicated by the deposition of a thick orange scum on the tank side just above the water line. This material roughly equivalent to the placental material is a good medium for bacterial growth, which more often than not, proves detrimental to the egg and its hatching or even to the nauplius, when left unattended to. Many culturists remove the deposited orange material by wiping the tank sides with a clean piece of cloth.

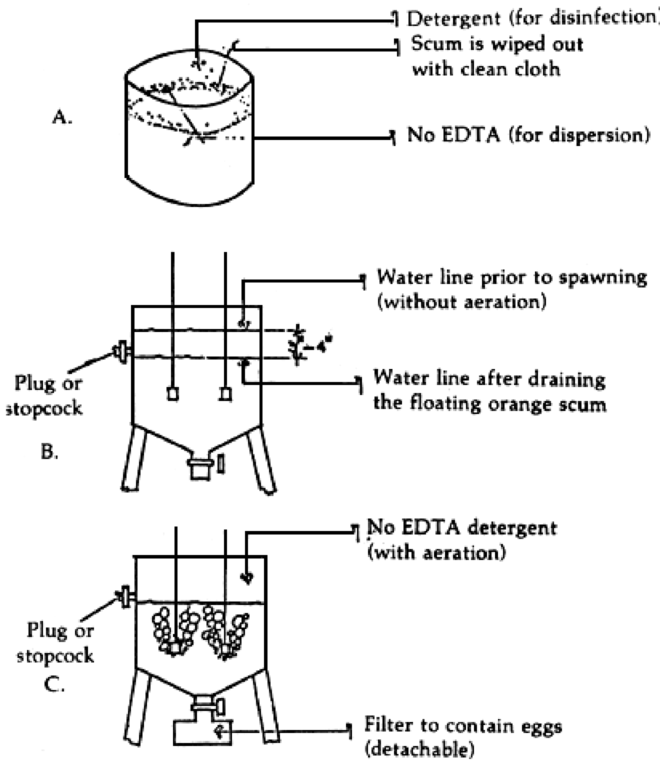


Figure 1. Improvements on spawning

Oftentimes also, a solution of sodium EDTA[1] is added to disperse the eggs, or prevent them from clumping into a mass. This solution is added to give a final concentration of 10 ppm.

It is also necessary to wash the egg in a weak solution of ordinary detergent to disinfect the surface of the eggs. Oftentimes, a 20 ppm final concentration of the detergent is used.

It is possible to construct a spawning tank that may be operated to prevent the reintroduction of the placental material into the spawning water, and at the same time allow the introduction of NaEDTA and the detergent solution almost at the same time.

The operation calls for the lowering of the water level by a stopcock in the spawning water to about 3 or 4 inches below the water level line without aeration so as not to allow the placental material to mix back into the water. The dispersant NaEDTA is next added, the water is aerated to achieve dispersion. After a specified period of time, the detergent is added. Aeration is again resumed later. The eggs are finally separated very rapidly from the water containing the two chemicals by passing the same through a filter-catchment which may be engineered to fit the spawning tank bottom. The filter should allow the solution to pass readily but should retain the eggs. A 150 micron net is suggested (Figure 1). The eggs are then quickly transferred to a clean tank of filtered seawater for hatching.

2.3 Selection and collection of starters for a diatom/phytoplankton/algal culture

The system used in the culture of diatoms/ phytoplankton for larval shrimp stipulates the addition of a high density starter culture to a tank or any other container with the necessary salts before aeration and exposure to the correct light intensity and quality.

The high density starter culture used is oftentimes obtained from an active culture about to reach the highest point in the logarithmic phase (asymptote). Active, senescent, dead cells and even bacterized cells are included. Thus, the quality of the culture is not as high as required. Selection of active cells only may be done by exposing the culture to bright flourescent light (or to sunlight for a few minutes) until a wide intensely-coloured band of the diatom/ phytoplankton is concentrated in the upper layers, or a few centimeters below the surface. It is then possible to design tanks for selective collection purposes.

By prior experimentation, one will know the exact spot or depth the active cells will occupy after a specified duration of exposure to light after aeration is stopped. The tank may then be engineered by putting a water spout within the area where the active cells suitable for starter materials would congregate.

[1]Sodium ethylenediaminetetraacetic acid a colorless crystalline acid used in the form of its salt as chelating or sequestering agent in industry

2.4 Separation of debris, ungerminated cysts and chorionic membranes from Artemia nauplii after germination

The *Artemia* nauplius is still the best food for larvae beyond the zoeal stages. Many culturists, however, are not so particular about whether what is being offered are the nauplii, healthy cysts, or ungerminated and, therefore, unhealthy cysts.

One must realize that cysts have chorionic membranes to which many different kinds of micro-organisms are trapped or encased. When offered in the form of cysts, disease can result. The ungerminated cysts should be treated with more concern than ordinarily.

Presently, the most common *Artemia* hatching facility is made of a conical tank with a tapered bottom from where aeration is directed upward. After hatching (11-14 hours), the aeration is stopped, and light is shone on a portion of the tank which allows light to permeate. The nauplii, being positively phototactic, congregate within the area and these may then be siphoned off simply by directing a rubber hose within the area.

A scheme for an *Artemia* hatching tank that makes use of the attraction of nauplii to light, the floating of chorionic debris and the sinking of ungerminated cysts has been devised.

2.5 Fitting of a spewing tube (plastic, PVC, or rubber) that washes down postlarvae adhering on tank sides (Figure 2)

It is commonly observed that postlarvae beyond PL10 adhere on the sides whether the tank inner surface is of plastic, canvas, concrete or wood. This is rampant in shaded and dark tanks suddenly opened and exposed to light during a sudden noise or approaching distraction. A few are brought to the sides by turbulence due to aeration. Many of these larvae may not be able to get back to the water and thus, die.

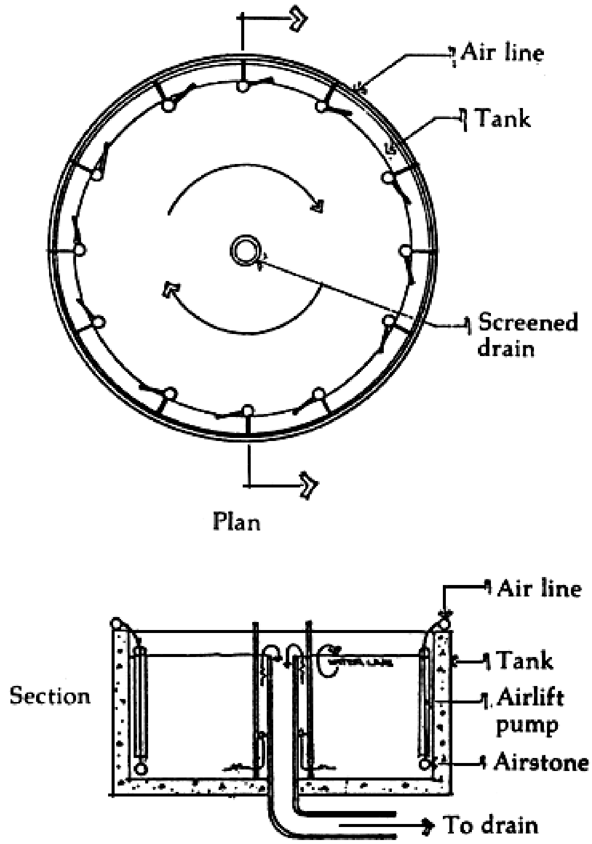


Figure 2. Airlift pumps to wash down post-larvae adhering to tank sides

The tanks may be fitted with circumferential or peripheral ring just above the water line, made of plastic, PVC or even rubber, with perforations from which water flows out and splashes against the tank walls. The water will gently wash down the animals back to the water. The design should see to it that the water spewed out comes from the tank and is brought into the circuit by a recirculating pump. Furthermore, no water should be lost during the process.

Alternatively, the tanks may be equipped with airlift pumps at the sides which aside from washing the wayward postlarvae back to the water, will aerate and recirculate the water in the tank (Figure 2).

2.6 Sinking of airstones at different depths in a hatchery tank; closely-spaced aerators (Figure 3)

Many hatcheries especially those operated by Taiwanese employ an unusually large numbers of airstones spaced between 20 to 30 cm. The aeration rate in each air-stone is controlled, however, so that the turbulence created is not violent. These air-stones do not rest on the tank bottom but are elevated 7.5 to 10 cm above. Some technicians elevate these airstones alternately or in a pattern so that some are *7.5,* 15, 22.5 and 30 cm above the bottom (Figure 3).

These arrangements assure that no specific spot of the tank becomes stagnant or anoxic. Furthermore, food due to the large number of aerators and their elevation at different heights is suspended for a long time before sinking.

2.7 Treatment of larvae using coloured compounds such as trifluralin, malachite green, oxytetracycline, furanace, etc.

Pathogens such as fungi and bacteria can gain foothold anytime during the rearing cycle despite precautions against their introduction. Fungi are treated with trifluralin or malachite green; and bacteria, with oxytetracycline, furanace, furazolidone and other antibiotics. These four compounds have a common characteristic: a chromophore or simply, colour.

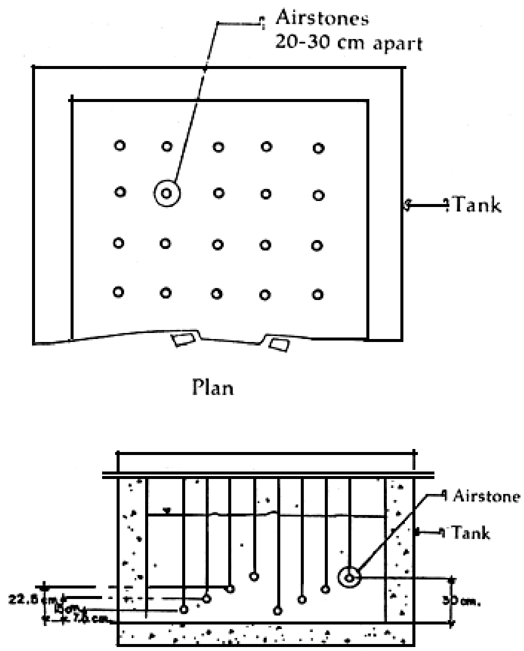


Figure 3. Airstones, closely-spaced and set at different depths

It is emphasized that these are to be used following some rigid requirements. On exposure to light, for example, coloured compounds may undergo changes but the more common reactions are: rapid decay, or a heightening of the killing effect, not only on the target microorganisms but also on the animals which they are supposed to protect.

Thus, these coloured compounds should be used as water additive only at night, or in the almost complete absence of light. It is, therefore, suggested that hatchery tanks are provided with an adjustable shed, the roof of which will cut off light before it strikes the water surface or the larvae.

2.8 Regulation of diatom/phytoplankton blooms by controlling light that filters into the hatchery at certain times of day

The diatom/phytoplankton density needed in larval rearing progressively increases from Zoea-1 up to Mysis-3. *Chaetoceros calcitrans* density, for example, should be 50-60 x 10^3 cells/ml by ZI and up to 100-120 x 10^3 cells/ml for MI. Since diatoms/phytoplankton are usually offered during the height of their log phases, they can continue their growth and multiplication in the rearing tank such that the density may be more than what is required. Excessive density is not good as more food leads to higher levels of toxic metabolites, and when the diatoms/phytoplankton are senescent they settle on the tank bottom to be acted upon by bacteria which increase in number at the expense of the dying diatoms/phytoplankton.

The larval rearing tanks used for zoea and mysis should, therefore, include provision for movable/detachable roof that will enable one to regulate the amount of light and the duration of exposure of diatoms/ phytoplankton to daylight.

Three of the more troublesome contaminations in hatcheries are diatoms/phytoplankton species *Licmophora abbreviata, Nitzschia closterium* and a blue-green alga, *Schizothrix calcicola.* Licmophora attaches to the exoskeleton and makes the larvae heavy and unable to swim normally while *Nitzschia,* considered the "pest" of hatcheries multiplies fast. The cells then clump and attach to the setae, gills and extremities. Oftentimes, covering the tank with a black cloth or plastic will prevent the diatoms/phytoplankton from multiplying rapidly. *Schizothrix calcicola,* on the other hand, succeeds in a situation where there are plenty of bottom organic deposits. A complete water change, coupled with a black cover and addition of fresh diatom/phytoplankton food usually controls *Schizothrix.*

2.9 Inhibition of the growth of certain bacteria by exposing tanks of light at certain times of day

At times, bacterial growth at the bottom, characterized by a faint red or pink colour develops. This is especially true in shaded tanks. Presumably, this is due to unconsumed diatoms/phytoplankton or micro-encapsulated feed.

This is easily controlled by exposing the tank to full sunlight in the morning. It is, therefore, a good plan to have the roof detachable or movable by sliding.

2.10 Transfer of larvae from one tank to another without lifting them out of the water (Figure 4)

Transfer of animals from one tank to another especially in the earlier larval stages are invariably stressful. The stress may, however, be reduced or minimized if the larvae are transferred without lifting them out of the water. This means that transfers will be effected purely on the basis of water seeking its own level. The "ladder" system of setting up tanks offers a means of transferring larvae from one tank to another earlier stage of culture are elevated with respect to a succeeding stage culture tank.

2.11 Percolation pond

It is common knowledge that when one hatchery is struck by a disease, it is purely a matter of time before nearby hatcheries are stricken by the same disease. The obvious explanation is that these neighbouring hatcheries obtain their water supply from the same source. Moreover, they usually discharge their waste waters directly into the same body of water that serves as their source of water. The chances of cross-contamination are naturally high. And then, as experience shows, there is nothing to prevent hatcheries from clustering along and around an area that has been tested to be suitable for hatchery purposes.

Hence, certain measures to prevent or minimize cross-contamination are in order. One inexpensive means is the use of a percolation pond. Its primary purpose is to "treat" waste water, mainly through the unit process of filtration, before this is disposed back to nature. The waste water, in effect undergoes some degree of cleansing before it finds its way back to the sea. Disease-causing or carrying agents originating from one hatchery are, therefore, prevented from spreading to neighbouring hatcheries.

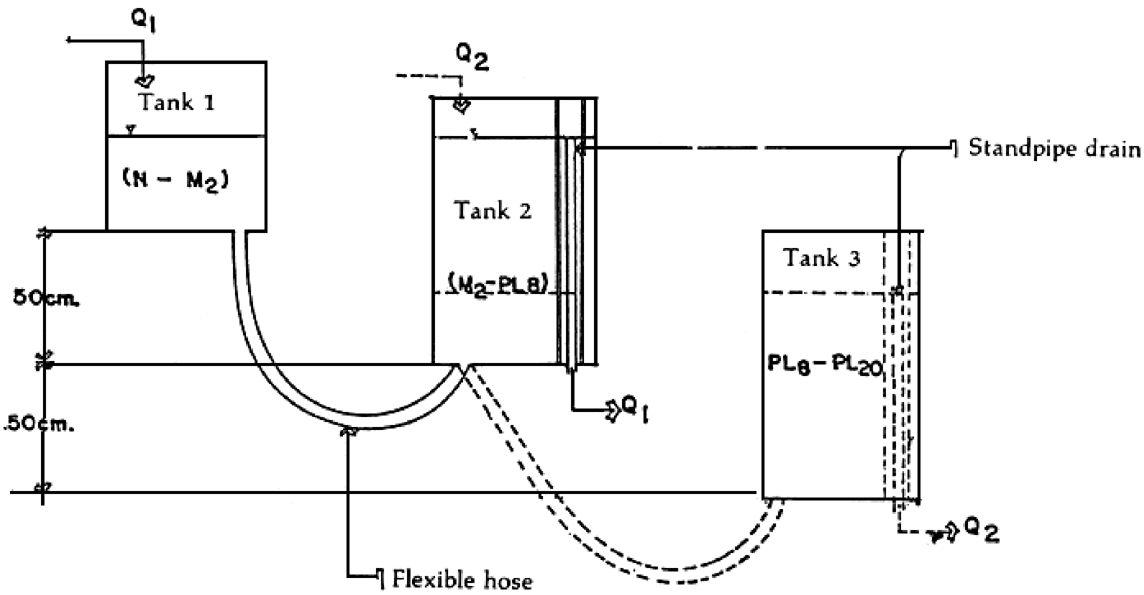


Figure 4. "Ladder" system of setting up tanks

The percolation pond or seepage pit is appropriate where the underlying earth, is absorbent and the water table is low. Where these conditions are not satisfied, a tile drain field may be substituted.

2.12 Intake systems with prefiltration

A large PVC pipe direct intake pipe may be perforated with 1/2" holes and covered with 2-3 layers of a fibrous material like Ecofelt T-21 or T-22 or any similar material that serves to filter out some of the suspended solids in the water. This system will, however, only do in pacific waters.

Fine-textured granular materials such as those found in the seabed near most hatcheries, are effective in filtering out pollutants. Water that passes through these materials, while not bacteriologically pure, is at least relatively free of suspended sediments. Hatchery operators would, therefore, be well-advised to make good use of such natural cleansing ability. Two types of intake systems which avail of the filtering ability of the seabed are the vertical well and the buried perforated pipes. Both systems are good in the sense that the seawater they provide has already been filtered.

At present, the more common water intake is the vertical well which consists of a covered, circular concrete ring or similar structure to which a pipe is connected and through which water is pumped by suction to a filter box, and later to a reservoir. Seawater is allowed to seep only through the well bottom.

It appears though, that between the two, the perforated pipe system would make the better alternative, for two reasons. Firstly, it is less susceptible to damage caused by high and strong waves because it has no exposed superstructure. Secondly, it can be relied upon to deliver more water. With a given cross-sectional area, the amount of water that a seawell can supply is limited by the difference between the levels of water inside and outside the well. On the other hand, a pump that is directly connected to the perforated pipes can create a negative pressure inside the pipes which effectively multiplies many times over the actual physical difference between the water level inside the pipe and that of the sea. This enables the perforated pipe type of intake to supply much more water than the well.

2.13 Filtration and backwashing

Filtration is the removal of suspended solids contained in the water as it passes through the filter bed by a complex process involving one or more removal mechanisms such as straining, sedimentation, interception, adhesion and flocculation. Back-washing is the removal of the suspended solids that have accumulated within the filter bed by washing these away with sufficient water flow usually in reverse direction to that of filtration. Invariably, hatcheries filter their water supply. It is, however, doubtful whether the filters are being backwashed as often as necessary.

Filters in prawn hatcheries must be back-washed when either of two conditions is reached, i.e.,

a) When the suspended solids in the effluent begin to exceed the level that can be tolerated by the larvae.

b) When the head loss across the filter bed exceeds the static head, that is the underdrains are under negative head, at which point the filter output capacity drops drastically.

In properly designed filters, both conditions should occur simultaneously (Figure 5).

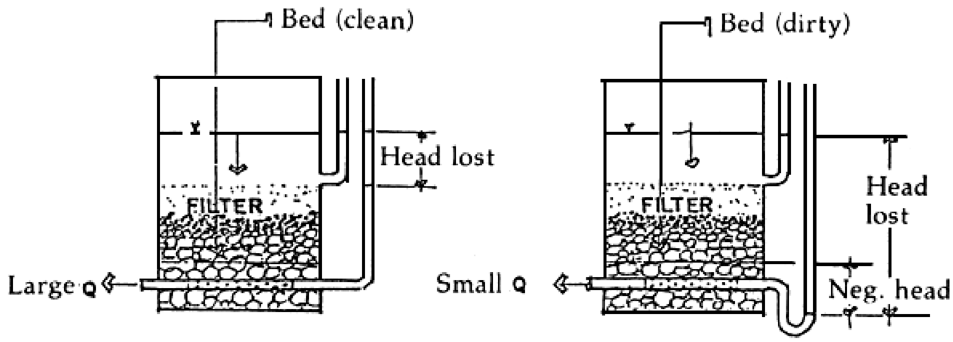
3. PONDS

3.1 Daily water change of at least 10 percent to replace anoxic/toxic waters with fresh seawater to reduce pathogen load

For human kind, water therapy, or the consumption of extra volumes of drinking water in excess of the usual daily requirement all in a very short duration often leads to well-being at least, or to the extent of curing some diseases and disorders. There is a biological basis in fact to this practice and which is not ordinarily, adequately and precisely explained in scientific and medical circles.

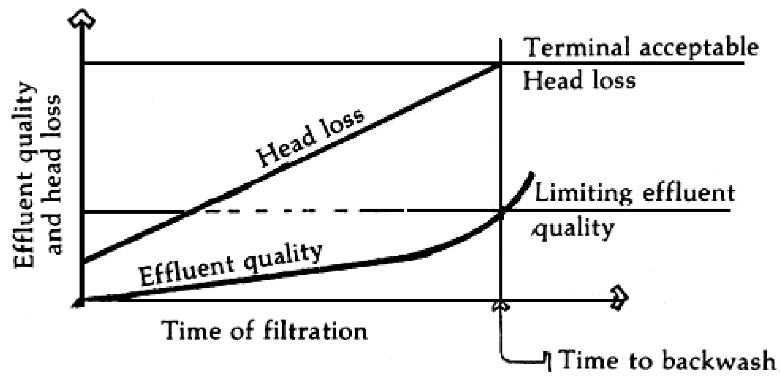
In shrimp culture, a parallel technique, water change, is now emerging as a very powerful tool for disease control. Not only are potentially pathogenic microorganisms washed away from the soil and water when pond water is changed, but toxins and other hazardous metabolites and substances are diluted and are, therefore, made ineffective against the animals.

For a theoretical example: let us assume that a particular toxin (toxin A) is lethal to shrimp when a concentration of 0.1 ppm is built up in the environment. Let us assume further that on a particular day (say, Day 4) toxin A has already reached a concentration of 0.09 ppm and that the 0.1 ppm level is to be attained on the next day (Day 5) if no water change is instituted. If 10 percent of the water is replaced on Day 4, however, the upward trend (to reach 0.1 ppm) is temporarily stopped and the concentration of toxin A is reduced to 0.081 ppm (instead of reaching 0.1 ppm). The level of toxin A falls short of the lethal concentration, and diseases and, therefore, mortalities due to the toxin are averted.



1. Start of filtration 2. Time to backwash

A. Backwashing as governed by head loss across the filter bed.



B. Conditions prevailing in properly designed sand filters.

Figure 5. Indicators of when to backwash sand filters

In pond construction, therefore, before even a shovel of soil is taken out, an ample source of CLEAN water, free of pathogens and contaminations should be assured. In the planning process, the installations and other support system should be to supply the minimum daily 10 percent water volume necessary to make this important replacement in pond water.

3.2 Water changes (20-33 percent or more) to induce molt periodically should be resorted to

From the foregoing discussion, water changes do not only lead to reduction of toxins and neutralization of unfavorable factors but may also be employed to induce molting and, therefore, physical growth.

In shrimp, molting is induced when the water change far exceeds the 10 percent level. It is believed that 20-33 percent of water change can induce molt. Each molt does not necessarily reflect growth; it actually leads to the loss of 6 to 10 percent of the body weight, and apparently of lots of energy. The weight and energy lost are, however, more than made up for by nutrition and other consequent activities provided sufficient time is given for the animals to replenish and recover.

The interval for induced molting in shrimp is ideally every 6 days or so for shrimps less than 20 g in average weight; every seven days for 21 g animals, and so on until 15 days for shrimps of average body weight of 33-35 g.

In the planning of a pond system, the design should not only include provisions for 10 percent water replacement per pond daily but also for induced or forced molting at 20-33 percent at specified days. Therefore, the pumps to be specified should be checked and double-checked to avoid under-utilization as well as overutilizatfoh. If there are reservoirs, treatment or impoundment ponds, the volumes necessary for the water changes outlined above should be fulfilled.

3.3 Provision for an increased surface area for shrimps by constructing "hotels" in the pond

When stocking density adopted was 150 000 animals per hectare, hardly were there reports on mass mortalities directly attributable to pathogens or unfavorable environment. When higher densities were attempted, many reports of mass mortalities and diseases surfaced.

In the stocking density of 150 000 animals per hectare, 15 individuals are confined within one square meter area. When 30 to 60 are placed, instead of 15, the area intended for an individual is drastically reduced. In other words, there is now over-crowding.

It is well to realize that the square meter area can take only so many shrimps and higher stocking densities unduly stress the animals. The resources have to be stretched a little bit more and the animals become less healthy. There is a maximum density of animals which does not bring about stress. This is the carrying capacity. What is the carrying capacity then, is it $15/m^2$, or is it $60/m^2$? We have to research some more to fix this figure.

In shrimp ponds, what is important is the capacity of the bottom and not the volume of the column or depth of water above this area. The shrimps rest on the bottom and do not swim. Therefore, the depth is apparently immaterial in this regard.

The carrying capacity of ponds may be stretched if a series of refuges is added. The best way to do this is to provide multi-storeyed "hotels" for the shrimp. In a 1.5 m deep pond, the additional tiers or storeys may be placed at 0.5 m and 1.0 m depths to complement the bottom. The shrimps can then dissipate in space and the density is decreased when they move out to the extra tiers or false bottoms (Figure 6).

3.4 Surface waters versus underground waters as factors for disease

For a quite a time, seawater tapped from the sea surface was the usual source of water. When pumped in at high tide, the water is clean and even needs no mechanical filtration. The seawater can thus, be obtained in its unadulterated raw form. When pumped in during low tide, however, the water is turbid and definitely needs filtration.

The latter situation must have convinced growers to tap other sources. This was filled in by waters from underground and collected in wells by percolation. Since this water passes through sand and other subterranean materials, by filtration, the water is made cleaner.

It did not take long, however, to prove otherwise. Based on the Taiwanese experience in 1987 when many crops failed due to diseases, ponds which received waters pumped up from the underground wells had the more devastating diseases. Is it due to the fact that waters supplied thus contained lower levels of dissolved oxygen? Or was it due presumably to higher levels of chemical compounds (such as ferrour sulfide) obtained from down the depths? The evidences are there.

With these, it is a nice idea to institute both systems in a farm the owner can shift to either set up handily depending on the prevailing conditions.

3.5 Selective "shutting off" and "switching on" of paddlewheel aerators as determined by wind directions, etc.

It is observed that paddlewheel aerators are switched on and used without regard to such factors as wind direction, temperature, and dissolved oxygen. Worse, these are switched on while it is raining, or immediately thereafter or at a time when the wind is blowing hard.

The paddlewheel, aside from increasing the dissolved oxygen is used to disrupt stratification, if there is any, of temperature, dissolved oxygen and other factors. It should be used intelligently and under unfavorable environment.

When the wind is blowing hard, it is best to switch on the aerators whose ripples and currents are directed against the direction of the wind. Aerators which run with or parallel to the direction of the wind only cloud the water.

It is also good to stop the aerators during and after a strong rain until after the water clarifies a little. The operation of the paddlewheel at this time will suspend silt, making the water turbid, especially if the water is shallow.

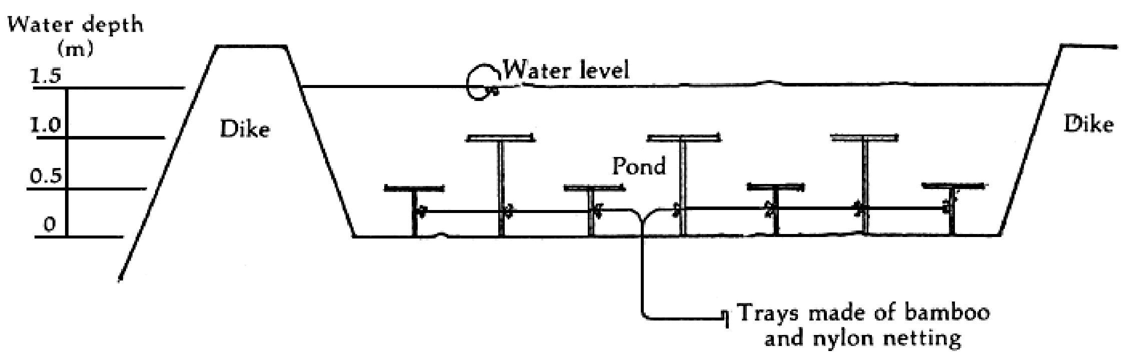


Figure 6. Multi-level refuges for shrimps in ponds

3.6 Central drains to remove anoxic/ toxic waters

The old system of pond construction is one characterized by an "out-flow from the top" system. When water is replaced and the pond gates are open, the water from the surface flows out first. What should be the object of a water-replacement scheme are the toxic/anoxic waters at the soil-water interface. This water is laden with ammonia and hydrogen sulfide, the results of feed decomposition.

Knowledge of these phenomena led to the adoption of a bottom draining system that avails of the existing designs of sluice gates. A more recent introduction is what is now known as the "central drain". In this system, the bottom is sloped toward the center. This center acts as a catchment area for unconsumed feeds. It is connected to the outside of the pond by a canal or perforated PVC pipes. One or more stand pipes regulate the water level and also determine the rate of water discharge out of the pond.

When the standpipe is put down or opened, anoxic/toxic waters are sucked down to the pipe and discharged out, and if the perforations allow, even bring the unconsumed bits and pieces of food with the outrushing water. Of course, something must cover the perforations (a nylon net or polyfelt 220 or any other suitable material) so as to deter escape of the animals.

The set up may be modified further by laying down a series of pipes radiating out from the central drain, with each pipe complete with perforations and covering net just like the above.

Lately, we have seen the introduction of a "vacuum cleaner" as the Negros fish-farmers call it. It is nothing but a submersible pump fitted with a long plastic tube through which anoxic/toxic mud/substratum empties when the unit is switched on. So that the submersible pump will not sink and get stuck in mud, the unit may be fitted on a floating structure and submerged just enough to bring the toxic/anoxic waters and mud out.

3.7 "Kitchen ponds" and "kitchen tanks" on pond dikes to preferentially culture nutritious phytoplankton to be added to the pond after a day of culture

It is considered among the Taiwanese that brown water is best for rearing shrimps. The brown color is due to the high density and predominance of diatoms. The disadvantage lies on the fact that the growth of diatoms cannot be maintained for long. The bloom "collapses", the cells senesce fast, sink to the bottom and die. Green water, characterized by pre-dominance and bloom of green phyto-plankton is less desirable, but persists for a long time.

In a pond, it is very unlikely to have a brown bloom for a long time. However, it is possible to assure large volumes of actively-growing mono-specific cultures of nutritious diatoms by: (a) culturing the diatom in fiberglass or plastic-lined wooden tanks right on the pond dikes for a day, and pump it into the pond when the culture blooms or reaches its assymptote; and (b) by culturing a mixed population of -diatoms in a "kitchen pond" or "reservoir" and subsequently pumping it into a pond when a suitable population density is reached.

These alternatives may be planned and incorporated into the overall pond designs.

3.8 Sedimentation tanks

Water involved in pond operations is far more voluminous than that in hatcheries. The use of filtration to clean the water for ponds is, thus, impractical. Fortunately, the water quality requirements in ponds are less severe considering the sturdier nature of juveniles and adults compared to larvae and postlarvae. Nonetheless, the fact remains that excessive suspended solids in pond waters can cause gill irritation. Inpond where the presence of toxic substances cannot be avoided, the abrasive action of suspended solids is enhanced. Aside from its harmful effects to the animals, too much solids in the incoming water can cause siltation in the supply canals and in the ponds. This leads to reduced capacity of the canal and less effective volume of water in the pond.

To mitigate these undesirable conditions, a sedimentation chamber can be constructed at the initial point of the supply canal. In this chamber, the suspended particles that are heavier than water are separated from the water by gravitational settling. Extracting the sediments from a confined chamber is obviously an option preferable to scraping silt all over the canals and ponds.

Appendix 2

FORMULATED DIETS TESTED AND PROVEN UNDER INTENSIVE SHRIMP REARING CONDITION

Ingredient (%)	Diet 1	Postlarvae 2	Juveniles 3	4
Giant tiger shrimp (P. *monodon)* — **dry diet, pellet**				
Fish meal	30	30	27.5	29.3
Shrimp meal	—	—	27.5	17.4
Shrimp meal	15	15	—	—
Soybean meal	15	—	—	—
Copra meal	—	—	—	10
Ipil-ipil leaf meal (dried soaked leaves)	—	20	—	—
Wheat/bread flour	10	10	15	15
Sago palm starch/corn starch	—	—	5	5
Rice hulls (filler)	—	—	—	5.9
Rice bran	14.8	9.8	20	10
Potato starch	5	5	—	—
Cod liver oil	9	9	—	—
Corn oil	—	—	4	2.6
Vitamin/mineral premix V-22[1]	0.95	0.95	0.95	—
Vitamin premix[2]	—	—	—	1
Mineral premix[3]	—	—	—	1
Dicalcium phosphate	—	—	—	2.8
Vitamin C	0.05	0.05	0.05	—
Antioxidant (BHT)	0.2	0.2	—	—
Nutrient content, % dry matter				
Crude protein	41.9	40.7	35.7	NA
Lipid	14.1	15.9	7.4	NA
Crude fiber	3.4	4.9	8.0	NA
Ash	10.6	10.6	16.9	NA

[1]Allowance provided for destruction of heat labile vitamins during diet preparation (steaming and drying). Vitamin/mineral composition/kg premix: vitamin A 1 760 000 USP units, vitamin D_3 660 000 USP units, vitamin E 770 IU, vitamin K 120 mg, thiamine 440 mg, vitamin B_{12} 4 400 ug, niacin 6 000 mg, calcium pantothenate 1 200 mg, choline chloride 44 000 mg, folic acid 22 mg, $FeSO_4$ 8 800 mg, KI 440 mg, $CaCO_3/PO_4/SO_4$ 120 000 mg, $CoSO_4$ 44 mg, $CuSO_4$ 440 mg, $MgSO_4$ 6 600 mg, KSO_4 66 mg, $ZnSO_4$ 17 600 mg, $MnSO_4$ 12 000 mg, L-lysine HC1 6 600 mg, Methionine 8 800 mg, (V-22 is a vitamin-mineral premix for poultry).

[2]To supply/kg dry diet: thiamine 30 mg, riboflavin 80 mg, pyridoxine 40 mg, vitamin B_{12} 0.1 mg, niacin 400 mg, pantothenic acid 200 mg, biotin 2 mg, inositol 600 mg, folic acid 10 mg, choline chloride 5 000 mg, para amino benzoic acid 150 mg, ascorbic acid 500 mg, vitamin A (20 000 IU) 40, vitamin D_3 10 mg, vitamin E 150 mg, vitamin K 30 mg, BHT 10 mg, finely ground corn meal 2 747.9 g.

[3]To supply/kg dry diet: $K2HPO_4$ 1 g, NaH_2PO_4 2.15 g, Ca $(H_2PO_4)4.H_2O$ 2.65 g, $CaCO_3$ 1.05 g, calcium lactate 1.65 g, KCL 0.28 g, $MgSO_4.7H_2O$ 1.0 g, ferric citrate 0.12 g, $AICl_3.6H_2O$ 0.0024 g, $ZnSO_4.7H_2O$ 0.0476 g, $MnSO_4.6H_2O$ 0.0107 g, CuCl 0.0015 g, KI 0.0023 g, $CaCL_3.6H_2O$ 0.014 g, finely ground corn meal 0.0215 g.

Source: Vogt, Quinitio and Pascual (1986) Diet 1 and 2; Pascual (1983) — Diet 3; Lim and Destajo (1979) — Diet 4.

Ingredient (%)	Diet 1	Postlarvae 2	Juveniles 3	Production 4
Giant tiger shrimp (P. *monodon)* — dry diet, pellets				
Meat meal	—	—	—	21.5
Fish meal	7	10	27	—
Soluble fish protein concentrate	5	5		6
Shrimp meal	12	15	—	8
Meat and bone meal	7	7	10	—
Soybean meal	—	—	15	—
Soybean cake	24	20	—	—
Sesame cake meal (expeller)	—	—	5	—
Groundnut meal (expeller)	—	—	5	17
Copra cake	5	—	10	—
Leaf meal	—	—	5	—
Rice bran (solvent extracted)	—	—	10	—
Maize	—	—	4	—
Rice	—	—	—	6
Wheat gluten	7	7	—	10
Tapioca		—		—
Blood meal	3	2	—	11
Alkane yeast	10	—	—	—
Brewers yeast	—	10	—	—
Cod liver oil	6	—	—	4
Fish oil	—	6	—	—
Cereals (wheat, corn, rice)	—	10	—	—
Spirulina	2	—	—	—
Peptonal	5	—	—	—
Snail meal *(Trocus* or *Achatina)*	2	2	—	—
Vitamins and salt[1]	5	6	—	8
Vitamin and mineral premix[2]	—	—	1	—
Antioxidant (BHT)	—	—	0.02	—
Antioxidant (ethoxyquin)	—	—	0.015	—
Methionine	—	—	—	0.5
Nutrient content, %				
Crude protein	52.2	49	37.1	40
Lipid	9.5	10	*7.8*	NA
Crude fiber	NA	NA	7.0	NA
Ash	NA	NA	12.9	NA

[1]Number one protector vitamin premix provides/kg diet: vitamin A 80 000 IU, vitamin D_3 8 000 IU, vitamin E 150 mg, vitamin K 8 mg, vitamin C 600 mg, thiamine 18 mg, riboflavin 16 mg, niacin 400 mg, calcium pantothenate 200 mg, pyridoxine HC1 16 mg, folic acid 17 mg, vitamin B_{12} O.O[4] mg, biotin 0.02 mg, choline chloride 1 500 mg, inositol 800 mg, para amino benzoic acid 60 mg (premix used by AQUACOP, 1978, for P. *merguiensis;* composition of premix used in present formulation not cited).

[2]premix supplies/kg diet: thiamine HCL 120 mg, riboflavin 40 mg, pyridoxine HCL 120 mg, nicotinic acid 150 mg, calcium pantothenate 100 mg, folic acid 5 mg, biotin 1 mg, vitamin B_{12} 0.02 mg, inositol 400 mg, choline chloride 1 200 mg, Na-ascorbate 5 000 mg,\agr\C-tocopherol 200 mg, menadione 40 mg, vitamin A 5 000 IU, vitamin D_3 1 000 IU, Zn 40 mg, Mn 20 mg, Cu 4 mg, I 0.8 mg, Co 0.12 mg.

[3]Author cites that wheat gluten would be a better binding agent; Kanazawa (1984).

Source: AQUACOP (1983) — Diet 1 and 2; Kanazawa (1984) — Diet 3 (also fed as a complete diet for P. *merguiensis,* AQUACOP (1977).

PURIFIED COMPLETE EXPERIMENTAL TEST DIETS — FISH AND SHRIMP

Ingredients (%)	H-440[1]	C102[2]	NRC (1983)
Fish standard reference diets			
Casein, vitamin free	38	40-(45)	32
Gelatin	12	4	8
Starch	—	11-(16)	—
Dextrin, white	28	9	30
D-glucose (cerelose)	—	5	—
Cellulose flour	—	3	19
Soybean oil	—	—	3
Corn oil	6	—	—
Cod liver oil	3	—	—
Fish oil	—	15-(10)[3]	3
Amino acid supplement[4]	—	2	—
Vitamin premix H-440[5]	9	—	—
Vitamin premix C102[6]	—	3	—
Vitamin premix NRC (1983)[7]	—	—	1
Mineral premix H-440[8]	4	— .	—
Mineral premix C102[9]	—	8	—
Mineral premix NRC (1983)[10]	—	—	4

[1]Diet preparation: dissolve gelatin in cold water. Heat with stirring on water bath to 80°C. Remove from heat. Add with stirring — dextrin, casein, minerals, oils and vitamins as temperature decreases. Mix well to 40°C. Pour into containers; move to refrigerator to harden. Remove from trays and store in sealed containers in refrigerator until used. Consistency of diet adjusted by amount of water in final mix and length and strength of beating.

[2]Adjust protein and lipid levels if necessary (depending on fish species). Steam pellet at 5-10 psi without water.

[3]Marine oil with 0.05 percent antioxidant (or other oils as required).

[4]Supplement includes 0.5 percent methionine, 1 percent arginine and 0.5 percent starch.

[5]Vitamin mixture provides/kg dry diet: alpha cellulose 80 g (as filler; delete 20 g cellulose and add 20 g of carboxymethylcellulose binder for preliminary feeding), choline chloride 5 g, inositol 2 g, L-ascdrbic acid 1 g, nicotinic acid 750 mg, calcium pantothenate 500 mg, riboflavin 200 mg, thiamine HC1 50 mg, pyridoxine HC1 50 mg, menadione 40 mg, folic acid 15 mg, vitamin B_{12} 11 mg (add vitamin B_{12} in water during, final mixing), biotin 5 mg, alpha-tocopherol acetate 400 mg (dissolve tocopherol in oil mix).

[6]Vitamin mixture provides/kg dry diet: vitamin A acetate 7 000 IU, vitamin D_3 3 000 IU, vitamin E 200 IU, vitamin K 50 mg, thiamine HCl 40 mg, riboflavin 60 mg, D-calcium pantho-thenate 200 mg, biotin 0.5 mg, folic acid 20 mg, vitamin B_{l2} O.2 mg, niacin 300 mg, pyridoxine HC1 40 mg, inositol 500 mg, ascorbic acid 500 mg, choline citrate 6 000 mg, alpha cellulose or starch in sufficient quantities to bring the total premix to 30 g.

[7]Vitamin mixture should meet or exceed levels presented by NCR (1983) and allow for processing and storage losses.

[8]Mineral premix contains/100 g premix: calcium biphosphate 13.58 g, calcium lactate 32.70 g, ferric citrate 2.97 g, magnesium sulphate 13.20 g, potassium phosphate (dibasic) 23.98 g, sodium biphosphate 8.72 g, sodium chloride 4.35 g, $AICL_3.6H_2O$ 0.015 'g, $ZnSO_4.H_2O$ 0.30 g, CuCl 0.01 g, $MnSO_4\,H_2O$ 0.08 g, KI 0.015 g, $CoC1_2.6H_2O$ 0.10 g.

[9]Mineral premix provides/kg dry diet: $CaHPO_4.2H_2O$ 30 g, $CaCO_3$ 3 g, NaCl 15 g, $KaSO_4$ 20 g, $MgSO_4$; 10 g, $FeSO_4.7H_2O$ 700 mg, $MnSO_4.H_2O$ 300 mg, $ZnSO_4.H_2O$ 550 mg, $CuSO_4,5H_2O$ 160 mg, $CoCl_2\,6H_2O$ 26 mg, KI 15 mg, Na_2SeO_3 2.5 mg, alpha cellulose or starch added in sufficient quantities to bring the total premix to 80 g.

[10]Mineral mixture of Williams and Briggs (1963) supplemented with cobalt chloride (1 mg/kg diet), aluminium potassium sulphate (0.7 mg/kg diet), and sodium selenite (0.05 mg/kg diet); NRC (1983).

Source: Castell and Tiews (1980) — H-440 Standard reference diet which has proven satisfactory for use with salmonids, char, catfish, carp, sea bream, seabass, perch, red fish, pampano, red snapper, black cod and black bass. Cho, Cowey and Watanabe (1985) — C102 Test Diet. NRC (1983) - 36 percent crude protein diet containing 2.9 kcal digestible energy/g; semi-purified test diet for warm water finfish.

Ingredients (%) Diet:	Kanazawa[1]	Crab protein[2]	Bodega Bay 81S[3]
Shrimp/crustacean standard reference diets			
Casein, vitamin free	50	—	31
Egg white, spray dried	—		4
Crab protein	—	40	—
Wheat gluten	—	5	5
Corn starch	4	15	24
Glucose	5.5	—	—
Sucrose	10	—	—
Glucosamine HC1	0.8	—	—
Dextrin	—	5	—
Alpha cellulose	9.3	17.8	12.1
Residual fish oil (vitamin A free)	8	—	—
Cholesterol	0.5	1	0.5
Refined soy lecithin	—	—	10
Cod liver oil		6	4
Corn oil	—	3	2
Sodium citrate	0.3	—	—
Sodium succinate	0.3	—	—
Vitamin premix — Kanazawa[4]	2.7	—	—
Vitamin premix — crab protein[5]	—	2	—
Vitamin premix — Bodega Bay[6]	—	—	4
Mineral premix — Kanazawa[7]	8.6	—	—
Mineral premix[8]	—	4	3
Choline chloride	—	1	—
Dl-alpha-tocopherol	—	0.2	0.2
Vitamin A (50 000 IU/g)	—	—	0.1
Vitamin D3 (400 000 IU/g)	—	—	0.1

[1]Prepared as a moist diet by adding 3 g agar and 130 ml water/100 g dry diet.

[2]Dry diet contains 38.1 percent crude protein, 10.5 percent lipid and 6.5 percent ash (dry weight basis).

[3]Dry diet contains 38.8 percent crude protein, 12.9 percent lipid and 3.7 percent ash (dry weight basis).

[4]Vitamin premix provides mg/100 g dry diet: p-amino benzoic acid 10 mg, biotin 0.4 mg, inositol 400 mg, nicotinic acid 40 mg, calcium pantothenate 60 mg, pyridoxine HC1 12 mg, ribo-flavin 8 mg, thiamine HC1 4 mg, menadione 4 mg, beta carotene 9.6 mg, alpha tocopherol 20 mg, vitamin B_{12} 0.08 mg, vitamin D_3 1.2 mg, sodium ascorbate 2 000 mg, folic acid 0.8 mg, choline chloride 120 mg.

[5]Vitamin premix composition (%): thiamine HC1 0.32 percent, riboflavin 0.72 percent, niacinamide 2.6 percent, D-biotin 0.008 percent, calcium pantothenate 1.43 percent, pyridoxine HC1 0.24 percent, folic acid 0.097 percent, manadione 0.08 percent, vitamin B_{12} 0.27 percent, inositol 12.7 percent, vitamin D_3 (850 000 IU/g) 0.002 percent, vitamin A acetate (500 000 IU/g) 0.51 percent, ascorbic acid 6.1 percent, BHA 0.076 percent, BHT 0.076 percent, para amino benzoic acid 2.02 percent, cellufil 72.77 percent.

[6]Vitamin premix composition (%): thiamine HCI 0.5 percent, riboflavin 0.8 percent, niacinamide 2.6 percent, D-biotin 0.1 percent, calcium pantothenate 1.5 percent, pyridoxine HC1 0.3 percent, folic acid 0.5 percent, vitamin B_{12} 0.1 percent, inositol 18.1 percent, ascorbic acid 12.1 percent, BHA 0.1 percent, para amino benzoic acid 3 percent, cellufil 60.3 percent.

[7]Mineral mix provides g/100 g dry diet: K_2HPO_4 2 g, $Ca_3 (PO_4)_2$ 2.72 g, $MgSO_4.7H_2O$ 3.04 g, $NaH_2PO4.2H_2O$ 0.79 g.

[8]Modifieo Bernhart-Tomarelli salt mixture.

Source: Kanazawa, Teshima and Tokiwa (1977) — semi-purified test diet for penaeid shrimp; Castell (1986) — crab protein and Bodega Bay reference diets for crustaceans.

From: Tacon, Albert G.J. The nutrition and feeding of farmed fish and shrimp — A training manual 3. Feeding methods. GCP/RLA/075/ITA Field Document No. 7, FAO, Rome, 1988.

Appendix 3

HOW TO FORMULATE FEEDS FOR SHRIMPS*

Formulated feeds must contain nutrients or substances which are needed to promote growth, maintain life and provide resistance to diseases. These are composed of proteins, fats, carbohydrates, vitamins and minerals. Protein is the principal nutrient which provides growth of the animal; if fats and carbohydrates are not enough in the diet, the protein component is used for heat and energy rather than, for growth. Fats and carbohydrates are sometimes sparers of protein. Vitamins and minerals regulate bodily processes: Vitamin Bs are necessary for proper utilization of proteins, fats and carbohydrates while Vitamin A and C help build up body resistance to diseases and infection; Vitamin D and mineral such as calcium and phosphorus are necessary for shell formation. These nutrients have interrelated functions in the growth and well-being of the cultured animal. Their presence in the diet in the right proportions is, therefore, important.

1. SOURCES OF FEED INGREDIENTS

a) Protein — fish meal; shrimp meal; shrimp head meal; soybean meal; meat and bone meal.

   A combination of animal protein or plant protein is possible; substitution of animal protein with plant protein such as soybean is also possible.

b) Fat — fish oil; corn oil; coconut oil and beef tallow.

c) Carbohydrates — bread flour; fine rice bran; cassava flour; sorghum; fine ground corn; corn starch and sago palm starch.

d) Calcium and phosphorus — available in fish meal; shrimp head meal; meat and bone meal.

e) Cholesterol — shrimp head meal.

2. EQUIPMENT NEEDED

a) Weighing scale

b) Sieve

c) Mixer (5 or 10 kg capacity)

d) Meat grinder

e) Coffee grinder

f) Steamer or a big cauldron and bamboo basket for steaming

g) Saucepan for gelatinizing corn starch

h) Drier

i) Wooden ladle

j) Covered containers for pellets

3. PROCEDURE FOR FEED PRERATION

a) Grind dry ingredients finely, separately. Sieve through a No. 40 nylon mesh of 420 microns/sq. cm.

b) Weigh or measure ingredients.

c) Mix all dry ingredients <u>thoroughly</u>,

d) Add the oil and mix for another 5 minutes.

e) Gelatinize corn starch, bread flour or sago palm starch (the same way corn starch is prepared for starching clothes). One part starch in four parts water, or 50 gms in

200 cc of water for 1 kg of feed. Suspend corn starch in tap water in half the amount for the whole mixture before gelatinizing.

f) Add gelatinized starch to the dry ingredients mixture and mix well to make a stiff dough.

g) Pass this dough to a meat grinder with a 1, 2 or 3 mm die depending on the size of the shrimp to be fed. For juveniles of about 0.35 gm body weight, use 1 mm die, 2 gm shrimp — 2 mm die and 10 gm or more — 2.5 to 3 mm die.

h) Cut the extrusion into 1/2 cm lengths and steam for 5 minutes. This stabilizes the pellets. Unsteamed pellets within 30 minutes but the steamed feed could keep more than 12 hours.

i) Dry the steamed pellets in an o**ven** overnight at 60°C. In the absence of an oven, an improvised drier might be used.

j) Store the pellets in plastic bags or buckets after drying and cooling. Keep pellets in dry place to avoid spoilage. If a freezer is available this would keep the feed longer in storage.

*Source: Pascual, F.P. 1983

4. AMOUNT OF FEEDS DAILY

Eight to 10 percent of total biomass of postlarvae.

Three to 5 percent of total biomass of juveniles.

Suggested feed formulation

	Alternatives		
Ingredients	**1**	**2**	**3**
Fish meal	300	175	275
Shrimp meal	150	225	275
Soybean meal (defatted)[1]	150	200	—
Ipil-ipil leaf meal	—	100	—
Rice bran	150	80	200
Bread flour	150	100	150
Sago palm starch or corn starch	50	50	50
Oil (preferably fish liver oil; soybean oil, 1.1 ratio pf cod liver oil: soybean oil)	40	60	40
Vitamin-mineral mix[1] (V-22)	9.5	9.5	*9.5*
Vitamin C	0.5	0.5	0.5
Water	200	200	200
Total (with water)	1 200	1 200	1 200

[1]If full fat whole soybean is used, roast soybeans at 170°C for 10 minutes.
Source: Pascual, Felicitas, P., 1983.

PUBLICATIONS AND DOCUMENTS OF THE ASEAN/UNDP/FAO REGIONAL SMALL-SCALE COASTAL FISHERIES DEVELOPMENT PROJECT (RAS/84/016)

Working Papers

ASEAN/SF/86/WP/1 Rabanal, H. R. Seafarming as alternative to small-scale fishing in ASEAN region. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. 55p.

ASEAN/SF/86/WP/2 Soeyanto, T. The status of Bali Strait fisheries with special reference to Muncar, Kedonganan and Jimbaran coastal villages. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. 36p.

ASEAN/SF/86/WP/3 Boongerd, S. and S. Chitrapong. Small-scale fishing for squids and related species in Thailand. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. 44p.

ASEAN/SF/89/WP/4 Guerrero, C.V. An evaluation of the socio-economic viability of the introduction of set net on small-scale fishermen in Botolan, Zambales. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Froject, 1987. 50p.

ASEAN/SF/89/WP/5 Guerrero, C.V. An evaluation of the socio-economic viability of "payaw" on small-scale fishermen using hook and line in Masinloc, Zambales. Manila, ASEAN/UNDP/ FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. 42p.

ASEAN/SF/89/WP/6 Guerrero, C.V. An evaluation of the socio-economic viability of set net operation on small-scale fishermen in Antique and Aklan: Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. 47p.

ASEAN/SF/90/WP/7 Chitrapong, S. Demonstration of squid fishing in Indonesia. Manila, ASEAN/ UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1990. **20p.**

ASEAN/SF/90/WP/8 Guerrero, C.V. Assessment of the socio-economic impact of artificial reefs on small-scale fishermen in the Philippines. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1990. (In preparation).

Workshop Reports/Other General Reports

ASEAN/SF/86/GEN/1 Report of national consultative meeting on aquaculture engineering held in Tigbauan Research Station, SEAFDEC Aquaculture Department, Iloilo City, Philippines, 2-5 October 1985. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. 186p.

ASEAN/SF/86/GEN/2 Zabala, P. T. (Comp.) Preliminary annotated bibliography on small-scale fisheries in the ASEAN Region. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development **Project,** 1986. 41p.

ASEAN/SF/87/GEN/3 Report of the training course on shrimp culture held in Jepara, Indonesia, 2-19 December 1987. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1987. 63p.

ASEAN/SF/88/GEN/4 Report of the training course on small-scale fisheries extension held in Semarang, Indonesia, 26 January-14 February 1988. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 130p.

ASEAN/SF/88/GEN/5 Report of the training course on fisheries extension methodology held in Penang, Malaysia, 13-26 March 1988. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 266p.

ASEAN/SF/88/GEN/6 Report of the training course on seaweed farming held in Manila, Philippines, 2-21 May 1988. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 169p.

ASEAN/SF/88/GEN/7 Report of the training/study tour on fishing with "payaw" held in Manila, Philippines, 16 May-4 June 1988. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 87p.

ASEAN/SF/88/GEN/8 Report of the workshop on artificial reefs development and management held in Penang, Malaysia, 13-16 September 1988. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 188p.

ASEAN/SF/89/GEN/9 Report of the training course on seabass breeding and culture, Satul, Thailand, 1-22 August 1988. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1989. 85p.

ASEAN/SF/89/GEN/10 Report of the training course on marine finfish netcage culture, Singapore, 5-24 September 1988. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1989. 193p.

ASEAN/SF/89/GEN/11 Report of the workshop on shrimp and finfish feed development, Johore Bahru, Malaysia, 25-29 October 1988. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1989. **163p.**

ASEAN/SF/89/GEN/12 Delmendo, M.N. and P.T. Zabala (Comp.). An annotated bibliography on shrimp feeds and nutrition. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1989. 34p.

ASEAN/SF/89/GEN/13 Delmendo, M.N. and P.T. Zabala (Comp.). An annotated bibliography on finfish feeds and nutrition. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1989. (In preparation).

ASEAN/SF/90/GEN/14 Zabala, P.T. (Comp.). Annotated bibliography on women in fisheries in the ASEAN region. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1990. 24p.

ASEAN/SF/90/GEN/15 A report of the training/study tour on squid fishing, Rayong and Chonburi, Thailand, 17-24 April 1990. Manila, ASEAN/UNDP/FAO Regional **Small-Scale** Coastal Fisheries Development Project, 1990. 43p.

ASEAN/SF/90/GEN/16 Report of the workshop on fishery cooperatives management, Semarang, Central Java, Indonesia, 20-15 August 1990. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1990. (In preparation).

ASEAN/SF/90/GEN/17 Report of the workshop on assessment of the contribution of women in post harvest processing and marketing of fish and fishery products, Philippines, 15-19 October 1990. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1990. (In preparation).

ASEAN/SF/90/WP/18 Report of the training course **on home-made** feeds preparation for small-scale **aquaculture** use, **Philippines, 19-25 November 1990. Manila,** ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries **Development Project, 1990. (In preparation).**

ASEAN/SF/90/GEN/19 Report **of** the **training course on set net fishing, Philippines,** 3-19 December 1990. **Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries** Development Project, 1990. **36p.**

ASEAN Fisheries Manuals

ASEAN/SF/86/Manual No. 1 Suprayitno, H. Manual of running water fish culture. Manila, ASEAN/ UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. 34p.

ASEAN/SF/88/Manual No. 2 Juanich, G.L. Manual on seaweed farming: 1. *Eucheuma* spp. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 25p.

ASEAN/SF/88/Manual No. 3 Trono, G.C., Jr. Manual on seaweed culture: 2. Pond culture of *Caulerpa.* 3. Pond culture of *Gracilaria.* Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 20p.

ASEAN/SF/88/Manual No. 4 Aguilar, E.R. A manual on set net fishing based on Philippine conditions. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. **29p.**

ASEAN/SF/90/Manual No. 5 Santos, G.A. A manual for the processing of agar from *Gracilaria.* Manila, **ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development** Project, 1990. 34p.

ASEAN/SF/90/Manual No. 6 Legaspi, A.M. Fish processing: Tuna ham making and boneless milkfish. **Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries** Development Project, 1990. **(In preparation).**

ASEAN/SF/91/Manual No. 7 Pascual, F.P. A practical guide to the preparation of home-made feeds for aquaculture. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1991. 28p.

Periodic Progress Reports

ASEAN/SF/86/PR-1 Soesanto, V. Project progress report of the ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 5 October 1985-5 April 1986. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. 9p.

ASEAN/SF/86/PR-2 Soesanto, V. Project progress report of the ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 6 April-6 October 1986. Manila, ASEAN/ UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. l1p.

ASEAN/SF/88/PPER-3 Delmendo, M.N. Project performance evaluation report of the ASEAN/UNDP/ FAO Regional Small-Scale Coastal Fisheries Development

Project, 31 July 1988. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 23p.

Technical Reports Contributed to Symposia/Meetings, etc.

ASEAN/SF/85/Tech. 1 Rabanal, H.R. and V. Soesanto. The world fishery and culture of *Macrobrahium* and related prawn species. Contributed to the National Conference on Prawn Technology, sponsored by the Philippine Fishfarmers Technical Assistance Foundation, Inc., Manila, Philippines, 27-28 November 1985. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1985. 16p.

ASEAN/SF/86/Tech. 2 Rabanal, H.R. and V. Soesanto. Commercial species of shrimps and prawns, their sources and export markets. Contributed to the Seminar on Quality Control in the Production, Processing and Marketing of Frozen Shrimps for Export, sponsored by Food Research Department, Food Terminal Incorporated, Taguig, Metro Manila, Philippines, 29-31 July 1986. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. 64p.

ASEAN/SF/86/Tech. 3 Rabanal, H.R. Status and prospects of shrimp farming in the Philippines. Contributed to the Monthly Seminar Series on Timely and Related Fisheries Issues, sponsored by the Philippine Council for Agriculture and Resources Research and Development, (PCARRD), Los Baños, .Laguna, Philippines, 5 November 1986. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1986. 24p.

ASEAN/SF/87/Tech. 4 Delmendo, M.N. Fishery administration and policy in the Philippines: Past and present. Contributed to the National Conference on Fisheries Policy and Planning, Baguio City, Philippines, 16-20 March 1987. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1987. 35p.

ASEAN/SF/87/Tech. 5 Delmendo, M.N. Milkfish culture in pens: An assessment of its contribution to overall fishery production of Laguna de Bay. Paper read in the Seminar on the occasion of the Fish Conservation Week, BFAR, October 1987 and lecture material used in the NACA Senior Aquaculture Training Course, SEAFDEC, Tigbauan, Iloilo. Manila, ASEAN/UNDP/ FAO Regional Small-Scale Coastal Fisheries Development Project, 1987. 17p.

ASEAN/SF/87/Tech. 6 Delmendo, M.N. and B.H. Delmendo. Small-scale aquaculture operations in the ASEAN countries. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1987. 49p.

ASEAN/SF/88/Tech. 7 Rabanal, H.R. History of aquaculture. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 13p.

ASEAN/SF/88/Tech. 8 Rabanal, H.R. and M.N. Delmendo. Organization of the aquaculture industry. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 10p.

ASEAN/SF/88/Tech. 9 Rabanal, H.R. Report on the World Aquaculture Society, 19th Annual Conference and Exposition, Honolulu, Hawaii, U.S.A., 4-10 January 1988. Manila, ASEAN/UNDP/ FAO Regional Small-Scale Coastal Fisheries Development Project, 1988. 99p.

ASEAN/SF/89/Tech. 10 Delmendo, M.N. Some advances attained in shrimp farming research and management practices: Insights to future prospects for expansion of production. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1989. 60p.

ASEAN/SF/89/Tech. 11 Delmendo, M.N. Bivalve farming: An alternative economic activity for small-scale coastal fishermen. Manila, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, 1989. 45p.