Chapter Three

HATCHERY OPERATIONS AND MANAGEMENT

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Considerable advancement has been made in the field of larval rearing of penaeids since the pioneering work of Hudinaga (1942). Hatchery technology has improved from laboratory scale experiments to industry level practice in a span of two decades for the West (Cook and Murphy 1966, Mock et al 1980), and in over just a decade in Taiwan (Liao 1985, 1986, Chiang and Liao 1985), as well as in the Philippines (Villaluz et al 1969, Parado-Estepa and Primavera 1988). Despite the commercial success of hatcheries for *Penaeus monodon* in Taiwan and in the Philippines, the tremendous variability in larval survival makes hatchery production unpredictable.

The following state-of-the-art for hatchery technology describes the results of basic researches as well as major industry practices relating to the following areas: site selection, hatchery design, larval rearing techniques particularly in the development of live and artificial feed, water management, and nursery practices for postlarvae. Several problems are given attention and recommendation are provided where there are solutions to the constraints presented.

SITE SELECTION

There are two important factors which determine the success of a prawn hatchery: (1) proper site selection and (2) proper technical management. In many cases, hatcheries are sited or constructed with inadequate planning and survey, either to minimize expenditure or to hasten construction. With proper site selection, prawn hatcheries have greater chances of commercial success. The criteria that follow are useful considerations before putting up a prawn hatchery.

Ecological suitability covers an assessment of water quality with reference to temperature, salinity, pH, dissolved oxygen content, organic and sediment load, nutrients, biological

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populations present, and fluctuations of the foregoing parameters.

Sufficient information defining desirable water quality parameters is available (Wickins 1976, 1986; Catedral et al 1977a, b; SCSP 1982; SEAFDEC Working Committee 1984; Murai 1985; Reyes 1985; Seidman and Lawrence 1985; Liao and Murai 1986; Kungvankij et al 1986a, b). Water quality parameters and their optimal ranges for hatchery and nursery rearing are shown in Tables 1 and 2, respectively. There are more parameters to be rigidly considered in larval rearing compared to post-larval or nursery rearing of prawn.

Climate in the area is another consideration as it affects water quality, most important factors of which are temperature and salinity (Reyes 1985; SEAFDEC Working Committee 1984; Kungvankij et al 1986a, c).

The site must be far from congested areas and possible sources of pollution like industrial discharges and ricefield effluents. Several studies have shown the correlation of hatchery survival rates with levels of heavy metals, chemicals, and other industrial pollutants in coastal waters (Cook and Murphy 1966; Cook 1969; Mock and Neal 1974; Beard and Wickins 1980; Sommani 1980; Chen 1981, 1985; Chen et al 1985; Chou et al 1985).

Fresh water and its source are also important factors in prawn hatchery operations. The most common source of fresh water is surface water which is easily contaminated. An alternative source is well water but which may also contain high mineral contents such as iron and manganese which are not suitable for prawn hatchery (Chen et al 1985, Kungvankij et al 1986c).

The hatchery must be near the source of spawners. When spawners come from broodstock sources, it is advisable that hatcheries be located near grow-out ponds or fishing grounds which may supply broodstock material in quantity. Posadas (1986) observed that eggs spawned from offshore wild spawners have higher hatching rates compared to those coming from brackishwater sources. There are no studies, however, comparing the relative performance of ablated and wild or unablated spawners with regard to spawning, quality of eggs, nauplii, and general larval performance in *P. monodon.*

Table 1. Water quality parameter ranges suitable for shrimp/prawn hatchery (SCSP 1982)

Parameter	Range	
	Freshwater	Seawater
Temperature	28° - 31°C	24° - 31°C
pH	7 - 8.5	7.5 - 8.5
D.O.	> 5 mg/L	> 5 mg/L
Salinity		28 - 33 ppt
Hardness	> 20 mg/L as $CaCO_3$	
Turbidity	< 50 FTU	< 50 FTU
Fe	< 1.0 mg/L	
Mn	< 0.2 mg/L	
Hg	< 0.001 ppb	< 0.01 ppb
Heavy metals		< 0.01 ppm
Pesticides	undetectable by GLC 0.001 ppb	undetectable by GLC
B.O.D.	< 1.0 mg/L (5 days)	< 1.0 mg/L (5 days)
Unionized NH_3	< 0.1 mg/L	< 0.1 mg/L
NO_2 - N	< 0.02 mg/L	< 0.02 mg/L

Table 2. Water quality parameter ranges suitable for farming *Penaeus monodon* in Taiwan (Chen 1985)

Parameter	Range
Temperature	28 - 33°C
pH	8.0 - 8.5
D.O. (critical)	3.7 ppm
Salinity	15 - 25 ppt
Heavy metals	
HG	0.0025 ppm
Cu	0.1 ppm
Cd	0.15 ppm
Zn	0.25 ppm
H_2S	0.033 ppm
NH_3	0.1 ppm

The economic success of hatcheries depends on its access to roads, markets, electricity, farm grower's supplies, and research centers for technical assistance. Proximity to market minimizes handling stress and expenditure in transport of fry to grow-out areas (Klemetson and Rogers 1983, Israel et al 1986, Griffin et al 1984).

HATCHERY DESIGN, EQUIPMENT, AND FACILITIES

Procurement of hatchery equipment and construction of facilities depend a lot on design which determines production target and size of rearing facility. Hatchery design, in turn, is influenced by level of financial inputs, scale of operation, technical expertise, and level of management efficiency that will run the operation (Reyes and Torres 1985).

Prawn hatchery designs evolved out of two larval rearing systems, the Japanese and the Galveston types, otherwise referred to as community (big tank) and separate (small tank) tank culture methods, respectively. The differences between these lie in the type of species which can be favorably cultured, size of rearing facilities, use of direct or indirect (separate algal tank) fertilization, stocking densities, and production costs (Liao 1984). Liao (1984) believes that the separate tank method is best for *P. monodon* larval operations.

Size of the hatchery must be based on its functional requirements and economic efficiency (Kungvankij et al 1986c). A small-scale project is defined based on capital investment, operational area, production level, and ownership (SCSP 1982). Kungvankij et al (1986c) expanded the description to include medium-scale and large-scale hatcheries. According to production methods, Taiwan has the S, M, R types (Chiang and Liao 1985) based largely on stocking densities applied and level of sophistication of rearing procedure.

Several designs or prototypes of prawn hatcheries have come about, from the most simple (Platon 1978, SCSP 1982, SEAFDEC Working Committee 1984) to the most sophisticated set-ups of Mock and Neal 1974, Mock et al (1977), Simon (1981), Treece (1985), Chwang et al (1986), Kungvankij et al (1986a, c), and Liao (1986). On the whole, hatchery design and size are decided on these considerations: facility and efficiency of

management and the innovative skills of the technician and/or hatchery operator.

Tank System

Holding and rearing tanks. The size and number of rearing tanks can be estimated (Reyes and Torres 1985, Kunvankij et al 1986c).

Typical sizes of tanks for different purposes are (in metric tons):

Nursery tanks	-	5-40 mt
Larval rearing tanks	-	1-10 mt
Spawning tanks	-	0.25-1.0 mt
Algal tanks	-	1-5 mt
Artemia tanks	-	0.25-0.5 mt
Maturation tanks	-	15-30 mt with or without bottom substrates
Sea-water reservoir	-	Capacity should be 30-50% of maximum total water consumption per day.

Tank shapes differ widely. These may be circular, rectangular or square with conical or sloping bottom toward the drain pipe. Sharp corners should be avoided, to do away with dead spots and to clean the tank effectively. Tank height should be capable of holding at least 1 m depth of water for the rearing tanks and about 0.5-0.6 m for the algal tanks.

The reservoir should be elevated so that water supply distribution would require less energy input. Algal tanks should be placed higher than the larval/nursery tanks so that transfer of natural food could be done by gravity.

Tank materials. Several materials have been tested and can be considered in constructing tanks--reinforced concrete, ferrocement, concrete hollow blocks, fiberglass, canvas with marine plywood support, or laminated plastic sheets with bamboo reinforcement (SCSP 1982, SEAFDEC Working

Committee 1984, Reyes and Torres 1985, Kungvankij et al 1986c).

Air, Seawater and Freshwater Supply, and Distribution Systems

Air, seawater, and freshwater supply, and distribution systems comprise the life support system of a hatchery. For the seawater intake system, Simon (1981), SEAFDEC (Working Committee 1984), and Kungvankij et al (1986c) have outlined several methods. Pumping may be direct or from a sump pit, inshore well or from seabed, using perforated PVC pipes. Inshore wells are very popular in Taiwan as studies show that water taken with subsand prefiltration has less chemical and heavy metal pollutants compared to waters taken from coastal areas (Chen et al 1985).

Air for the hatchery can be provided by aerators, blowers, or compressors. For medium- to large-scale hatcheries, a blower is preferred to compressors because it is safer, easy to use, and provides oil-free air (Kungvankij et al 1986a, c). For tanks with less than 2.0 m water depth, a high volume, low pressure air is sufficient to provide enough water movement and dissolved oxygen needed by the larvae to survive. For backyard to small-scale hatcheries, portable aerators are used because of the following advantages: (a) tanks can be aerated separately thereby reducing energy consumption when hatchery is not operating at full capacity, and (b) there are no aeration distribution lines to be put up, cleaned, and disinfected regularly (SEAFDEC Working Committee 1984).

Centrifugal pumps are used for seawater intake due to its higher total head capacity (Kungvankij et al 1986a). Marine pumps and submersible pumps are also necessary for water transfer from sedimentation chambers to holding areas or in distributing algae to larval/nursery tanks. Pump size and capacity vary widely depending on use and efficiency (SCSP 1982, McVey and Fox 1983, Reyes and Torres 1985, Kungvankij et al 1986c). Distribution lines are usually of PVC material due to the corrosive nature of the environment.

A filtration chamber (sand and gravel, either gravity or reverse type) may be built in conjunction with the storage tank or reservoir (Reyes and Torres 1985, Kungvankij et al 1986c).

Building and other Facilities

Provision for roofing of the laboratory area, blowers, pumps, generators, and larval tanks is advisable. Roofing of larval area or building an indoor hatchery also permits easier control of temperature and salinity, and prevents contamination, thereby ensuring higher survival of larvae. Roofing materials range from translucent, transparent plastic, to materials creating a darkroom effect such as those used in Taiwan (Liao 1986).

Practical procedures in estimation of hatchery facilities, including tank sizes, blower and pump capacities are outlined in Reyes and Torres (1985) and in Kungvankij et al (1986c).

LARVAL REARING

Penaeid larval rearing techniques were developed primarily using the community culture method practiced by Hudinaga and Kittaka (1966). Consequently, methods and procedures tended to be more specialized needing more control of culture conditions, thus requiring smaller tank systems, separate algal production tanks, and more intensified stocking and monitoring procedures. Thus, the Galveston method (Cook 1969, Mock and Murphy 1970, Mock et al 1980) was developed. Most hatcheries today are gradations in development between the two methods.

In the Philippines, rearing techniques were greatly influenced by the community culture method (Villaluz et al 1969, Villaluz et al 1977). However, the development of barangay or backyard type of hatchery in 1977 (Platon 1978, 1979) showed more influence of the Galveston type of culture. The present trend in the industry is the development of small- to medium-scale, compact, and modular hatcheries for easier management and more technical control.

In Taiwan, development trends favor large tanks, increased stocking densities, popular use of formulated larval diets, and a horizontal subdivision of operations and labor among hatcheries (Chiang and Liao 1985, Liao 1986).

The Indonesian hatcheries, practice either the community culture or the separate tank culture method (Tiensongrusmee 1980, Nurdjana et al 1985). However, with the advent of

technical expertise and funding from the West and the use of formulated diets, the trend of development is toward construction of smaller tanks and intensified stocking densities (Tiro, Jr., pers. comm.).

The method developed in Tahiti is a modification of the Galveston method with the rearing parameters under strict control and independent of environmental factors (Aquacop 1983). With *P. monodon*, stocking densities are inferior to other penaeid species cultured due to its characteristic fragility during the larval stages and its susceptibility to pathological problems (Aquacop 1986).

Larval Stages

Familiarity with the different larval stages is a basic requirement in hatchery operations. This is particularly important in determining the right kind of feed to give (either natural or formulated) and in carrying out other hatchery procedures. The egg and larval developmental stages are well described by Motoh (1979, 1981). There are three larval stages, namely: (1) nauplius, (2) protozoea, and (3) mysis. The whole larval period lasts from 9 to 10 days at warm temperatures (28-32°C) and from 10 to 12 days during the rainy, cold months (25-29°C).

Tank Preparation

Maintenance of sanitation and good water quality are the two most important tasks in the hatchery. For hatcheries located in good sites with biologically clean water, tanks are simply cleaned with detergent solution and chlorox, or sprayed with hot water and diluted chlorox applied to sides (McVey and Fox 1983), then dried for at least a day before stocking. After each run, tanks as well as the pipelines and materials used in the hatchery are disinfected with 12% Na hypochlorite at 200 ppm for 24 hours (Kungvankij et al 1986a, c).

With disease-causing organisms already inherent in the surrounding waters, disinfection rates remain at 200 ppm with Na hypochlorite for the sand filters, reservoirs, rearing tanks as well as for the drainers, filters, etc. Sometimes, muriatic acid is used to bleach white tank sides and bottom.

Stocking of Nauplii

Spawners may be placed directly in larval rearing tanks or in separate spawning tanks. Use of separate spawning tanks is presently the preferred practice to allow spawner and/or egg treatment in a separate culture milieu. Another advantage is that the larval tanks can be stocked with a predetermined number of nauplii per liter (Parado-Estepa and Primavera 1988).

Stocking densities for nauplii ($N_{III}N_{IV}$) being practiced are 50-100 ind/liter (SCSP 1982, SEAFDEC Working Committee 1984) or 100-150 ind/liter (Aquacop 1983, Kungvankij et al 1986a). For large tanks, Simon (1981) reported a range of 20-40 nauplii/liter.

Spawners may be disinfected with formalin (50 ppm) and Furanace (3 ppm) (Platon 1978) or with Treflan (0.5-1.0 ppm), $KMnO_4$ (3 ppm), and formalin (25 ppm for 10-15 min) (Kungvankij et al 1986c).

Eggs may or may not be treated. Preventive treatment consists of dipping eggs in 1.0 ppm methylene blue or 0.5 ppm malachite green for 10 min, or 3.0 ppm $KMnO_4$ for 30 min (Kungvankij et al 1986c). Mock (1982) reported egg treatment with malachite green (0.06 ppm) as sufficient. Earlier reports (Platon 1979) gave a dose of 5.0 ppm for malachite green for egg treatment. Lio-Po et al (1978) reported the toxicity of malachite green on the larvae of *P. monodon* in direct proportion to the dose and length of exposure time, although no adverse effects were noted on development and molting.

When spawners or eggs receive no treatment, nauplii may be given a prophylactic dose of 0.1 ppm Treflan R (Lio-Po and Sanvictores 1986) or 5.0 ppm given to egg and nauplii (Aquacop 1983).

Liao (1977, 1984, 1986; Liao and Chao 1983) did not report any disinfection or prophylactic and/or a curative treatment given to penaeid larvae.

Feeds and Feeding

Several larval rearing schemes are being practiced in different hatcheries. Basically, the difference lies in variations

of feeding and management schemes which are influenced by site, season (Hudinaga and Kittaka 1975), sizes of tanks used, and the innovative skills or experience of the technicians (Liao 1986, Kungvankij et al 1986c).

Most hatcheries, regardless of size, require the culture of at least two, sometimes four types of living food organisms--unicellular algae or yeasts for protozoea stages, rotifers for transitional period from protozoea to mysis, and *Artemia* for mysis to post-larval stages (Wickins 1986).

Proper identification or selection of the most adequate live food organism propelled the development of hatcheries into successful industry practice. Phytoplankton species which are popularly cultured and used as feed include *Chaetoceros* sp., *Tetraselmis* sp., and *Skeletonema* sp. (Kungvankij 1972, 1976; Simon 1978; Quinitio and Villegas 1982; Aujero et al 1983; Liao et al 1983; McVey and Fox 1983; Liao 1984, 1986; Wilkenfeld et al 1984; Kungvankij et al 1986a, c).

Simplification of algal production techniques led to studies using frozen algae (Mock and Murphy 1970, Aujero and Millamena 1981). Combinations of algal feeding with prepared diets such as egg yolk (Gabasa 1982, Quinitio and Reyes 1983, Quinitio et al 1983, SEAFDEC Working Committee 1984), soybean curd or meal (Liao 1986, Kungvankij 1986c), and baker's yeast (Villegas et al 1980) were tried. Feeding with marine yeast was reported by Aujero et al (1985) and Kungvankij et al (1986c).

Protein sources, alternative to the costly *Artemia* nauplii, were also developed using processed/minced fish tissue (Khannapa et al 1980, Kungvankij et al 1986b). In an effort to make *Artemia* a complete food for penaeid larvae, enrichment techniques with essential amino acids have been developed (Leger et al 1986, Kontara 1986).

The development of artificial larval diets may be the greatest improvement yet in larval rearing schemes with regard to simplification of feeding regimes. Three main types of artificial larval feed are: (1) freeze-dried or processed natural products (e.g., BP, AS, *Spirulina*), (2) microparticulate diets, and (3) microencapsulated diets. The last type is gaining popularity in hatchery use because of the ease in preparation and the wide range of dietary ingredients already incorporated

in the diet (Jones 1985, Scura et al 1985, Jones et al 1987). However, all these prepared and formulated diets still cannot altogether replace the use of live natural feed in hatcheries, although recent research findings indicate that carrageenan-bound diets may support larval development and could be used as a total algal replacement diet (Yashiro et al 1985; Jones et al 1987; Bautista and Millamena, unpubl.).

With phytoplankton as main feed during the larval stages, adequate timing and proper programming are necessary to meet day-to-day food requirements. One has to take precaution in cases when algae fail to bloom or collapse during the culture period.

Water Management

One of the major factors contributing to inconsistent post-larval production is water quality. Most prawn hatcheries have not operated successfully due to poor management of water quality (Chen HC et al 1984, Chen JC et al 1984). Maintenance of water quality cannot be overemphasized as it directly relates to survival. The most important water parameters to be monitored during the larval stages are temperature (30± 2°C), salinity (32 ± 2 ‰), and pH (7.8-8.3) (Liao 1986, Body and Liao 1987). Ammonia levels should not exceed 1.5 ppm for NH_4 and 0.1 ppm for NH_3 (Kungvankij et al 1986c).

Water, before coming into the hatchery, usually passes through subsand or mechanical filters, and then disinfection follows using either or most of these methods: chlorination (10-200 ppm), surface active chemicals, oxidizing agents, heat, and ultraviolet radiation (Treece 1985, Wickins 1986). Sometimes, addition of the disodium salt of EDTA (ethylene diamine tetra-acetic acid) is practiced to chelate heavy metals as well as enhance hatching rates of eggs and naupliar metamorphosis (Simon 1978, 1981; Mock 1982; McVey and Fox 1983; Sunaryanto 1986; Licop 1988).

Water treatment prior to stocking may consist of NaEDTA, anti-fungal, and anti-bacterial prophylactic doses. Treflan (at 0.1 to 0.2 ppm) is sufficient to deter fungal infection but does not affect egg and nauplius development and survival (Lio-Po and Sanvictores 1986). Bacterial treatments consist of application of chloramphenicol (2-6 ppm preventively and 2-10

ppm curatively) (Aquacop 1983) and antibiotics such as Maracyn I, Maracyn II, and Terramycin (McVey and Fox 1983). Simon (1981) reported that Furanace, tetracycline, and/or Erythromycin are routinely used at 0.5-1.0 ppm every two days during the post-larval stages or as required during the earlier stages.

Lagenidium is reportedly controlled by malachite green (0.01 mg/l). Chloramphenicol (1.0 ppm) and Oxytetracycline (3.00 ppm) are given for bacterial infection and 10% formalin (5.0 ppm) for *Zoothamnium* infestation (SCSP 1982). For the recent hatchery problem caused by luminous bacteria, Sunaryanto and Mariam (1986) reported prophylactic treatment using Chloramphenicol, Furazolidone, and Prefuran. Treatment dosages range from $\geq$ 1.0 ppm for Prefuran, $\geq$ 20 ppm for Chloramphenicol, and $\geq$ 10.0 ppm for Furazolidone.

Current research trends intend to do away with all variables (e.g., algal quality, *Artemia*, water quality) by more controlled culture techniques and the optimization of the larval rearing system. This is the reason for the intensification of research on the development of a recirculated water system through biological filtration (Wickins 1983, Aquacop 1986). Typical water management schemes for close mariculture systems in which water is recirculated, may consist of a number or all of the following: sediment settling, mechanical filtration, biological filtration, physical absorption, and disinfection (Treece 1985).

During the culture period, accumulation of fecal matter and the decomposition of excess food (whether live or artificial) cause the deterioration of the water quality of the culture medium. Kungvankij et al (1986c) described water exchange as (a) batch (or static exchange), (b) semi-batch, (c) flow-through, (d) recirculating, or (e) a combination of methods. Water change may start on the fourth day after stocking (at Protozea II) or when any of the parameters present a problem for larval survival. Batch water exchange may range from 30-50% and may be done every other day or daily starting mysis stage. Semi-batch and flow-through methods are usually implemented as treatment protocols in cases of disease attacks and fluctuations in water quality parameters. However, one must be aware not to apply water change when most of the population are undergoing molting especially during late mysis and post-larval stages (Parado-Estepa and Primavera 1988).

Siphoning of excess food and wastes at the tank bottom is also done during mysis and post-larval stages when bottom sedimentation becomes highly apparent (Kungvankij et al 1986c).

Monitoring

While hatchery techniques still aim to achieve higher and predictable survival rates, hatchery performance still relies on the experience and skill of hatchery operators/technicians. Regular monitoring of water quality parameters, feed densities, larval development, and presence/absence of disease in culture tanks comprise the day-to-day chores in the hatchery.

Liao (1986) attributed the success of Taiwan hatcheries to the diligence of operators/technicians who monitor feed quantity and larval quality at least six times a day, from morning to midnight.

A daily record of physico-chemical parameters, feeding, and larval observation is helpful towards understanding the results of the rearing activity (SEAFDEC Working Committee 1984).

Harvesting

Harvesting may be done during $M_{11}M_{111}$ or PL_4PL_5 stage which could be nursed in outdoor bigger tanks, or finally at PL_{20} to PL_{25} for grow-out.

Harvesting procedures arc outlined for small tanks by the SEAFDEC Working Committee (1984) and for small- to medium-size tanks by SCSP (1982) and Kunvankij et al (1986a, c). Water in the tank is reduced to one-fourth capacity and the larvae are collected through the drain/harvesting pipe into a harvesting box or *hapa* net. These are scooped and placed in 20-l basins for population estimate.

NURSING OF POSTLARVAE

Larval rearing may terminate at the $M_{II}M_{III}$ or the PL_4PL_5 stage, when fry are harvested and arc further reared in nursery systems for two to four weeks before final stocking in

grow-out ponds. Nursery systems supply the transition areas where young postlarvae are acclimated to environmental conditions similar to grow-out ponds (Parado-Estepa and Primavera 1988).

Nursery systems may consist of concrete tanks (Mock and Neal 1974, Mock et al 1977, Kneale et al 1982) with or without recirculating water systems, earthen ponds (Apud et al 1983), and net cages located in bays, lagoons, or fishponds (De la Pena et al 1985).

Tank Nursery

The materials most commonly used are fiberglass, concrete, marine plywood, or bamboo. Substrates are installed in the tank in straight or zigzag fashion. Subtrate materials are usually of nylon or polypropylene netting or locally made bamboo slats.

Stocking densities may range from 5 000-10 000/ton. A variety of feeds arc introduced to the 5-day old postlarvae to wean them from phytoplankton and *Artemia* diet (Djunaidah and Saleh 1986). Either mussel meat, trash fish, and *Acetes* are given, after being blended to the desired size and consistency. Feeding is at 2 g/ton or 10% of the total biomass. Formulated diets are fast becoming popular in post-larval rearing (Manik et al 1980).

Water management consists of 50% water change and/or flow-through to encourage good growth and better survival rates (Kungvankij et al 1986c). Excess food should be siphoned out regularly.

Salinity may be lowered by 2-5 ppt per day until the salinity of the grow-out pond is approximated.

Pond Nursery

Usually a pond nursery is utilized to grow PL_{10} to PL_{15} fry to juvenile sizes of 1-2 g. An area of 500-2000 m^2 with water depth at 40-70 cm is used. Stocking density is from 100 to 150 ind/m^2. The most important aspects of pond preparation to be done before stocking are the elimination of pests and

predators (by application of rotenone) and fertilization to encourage benthic algae to bloom. Sometimes active feeding is administered. Water change may be tidal. The culture period may last from 35-60 days (Baliao, pers. comm.) with recovery rate from 65-95% (Baliao, unpubl.).

Cage Nursery

This system is site specific to cover bays and lagoons, although it could also be applied in conjunction with grow-out ponds. De la Pena et al (1985) described the system as follows: The cage is made of nylon netting supported by bamboo or stainless steel and buoys or floats. Stocking densities may range from 5 000-10 000 PL/m^3. Feeds given are trash fish and/or mussel meat, blended or ground and spread on a feeding net which is positioned vertically inside the net cage. Management consists of daily checks of net damage and the physico-chemical parameters of the bay water. Larval quality is also monitored daily.

ECONOMICS OF HATCHERY PRODUCTION SYSTEM

Israel et al (1986) have two important conclusions in their comparative report on the different scales of *P. monodon* hatchery production systems. Prawn hatcheries whether small-, medium-, or large-scale are all highly profitable business operations, as shown by the the very high levels of computed undiscounted and discounted profitability indicators before and after sensitivity analyses. Of the three systems, however, the smaller hatcheries showed a better profitability performance.

Platon (1978) and the SEAFDEC Working Committee (1984) showed the benefit-cost analyses for backyard to small-scale hatcheries. Kunvankij et al (1986c) showed the economics of a medium-scale hatchery. Agbayani (1985) reported the production economics of an integrated prawn hatchery-floating cage nursery project of the SEAFDEC Batan Station. All these studies showed the high profitability of *P. monodon* hatchery operations.

Several models for budget analyses of penaeid shrimp hatchery facilities have been published based on the Texas A&M hatchery facilities (Johns et al 1981, Griffin et al 1985) where

the relationships between the engineering design of facilities, the environmental and managerial factors affecting shrimp growth and survival, as well as the factors affecting production costs and profit, were presented.

PROBLEMS AND RECOMMENDATIONS

As mentioned earlier, a disturbing fact surfaces side by side with the commercial success of prawn hatcheries. This is the unreliability or unpredictability of post-larval survival. Lawrence and Huner (1987) recognized several variables affecting a successful hatchery operation: (a) nauplii quality, (b) algal quality and quantity, (c) *Artemia*, and (d) water quality. These variables determine the problems of the prawn hatchery.

Spawner Supply and Selection

The problem of obtaining a consistently good quality batch of nauplii necessarily relates to quality of spawners that are received by the hatchery. Lawrence and Huner (1987) reported that the difference in quality of larvae batches may be due to the following: (a) spawning females (i.e., between wild and matured in captivity), (b) period of time the female has been kept in "production" mode, (c) the diets fed to maturation stock, and (d) the physical and hormonal manipulations performed on broodstock animals to encourage them to be productive.

Liao (1984, 1986) recognized this problem and suggested that researches should center on nutritional requirements, reproductive physiology, and process of cultivation to facilitate maturation without resorting to artificial means (i.e., ablation). One of the culture methods recommended is sea ranching.

Adaptations to Site Conditions and Site Selection

As discussed earlier, with stringent criteria defining a suitable site, most hatchery entrepreneurs decide on constructing a hatchery with little or no site selection process at all, to cut down pre-investment costs. Usually, hatcheries are situated along the same coastline, within sight of each other, on the

assumption that if one hatchery produces postlarvae successfully, the site must be suitable. Most often, in cases such as this, the site may not be the source of hatchery problems but the waste mismanagement of one hatchery which could have repercussions on all hatcheries located in the area.

Availability and Quality of Live and Formulated Food

Mass culture of algae causes problems, sometimes when one least expects it. Algal collapses as well as quality of cells vary within the culture period and cause mortalities or weakening of larvae when fed. Hatchability of *Artemia* cysts also depends on quality of batches produced. A need to optimize feeding regimes of live food is a must, to predict survival rates in hatcheries. Corollary to this, a complete formulated larval diet which is economical and can replace live feeds (or at least dependency on live feeds) must be developed.

Disease

With intensification of stocking densities, it is inevitable that an environment inimical to the larvae develops and opens weakened larvae to attacks by disease-causing organisms. Disease also is inevitable in an area where waste water from hatcheries is indiscriminately put back into the coastal water without treatment. Many new disease-causing organisms have developed and have been observed because of the indiscriminate use of antibiotics as prophylactic agents in hatcheries. Most hatcheries also do not observe proper sanitation in their surroundings as well as in their tanks. There is a need for strict observance of sanitary rules and prophylactic measures in hatcheries.

Water Quality

There are seasonal changes in water quality of coastal waters (Chen et al 1985, Chen 1985). Industrial pollution contributes to the deterioration of water supply sources for hatcheries. More controlled culture techniques should be practiced to optimize the larval rearing system being used. This could be enhanced by development of a recirculating system through biological filtration, automation of different hatchery

procedures, and constant monitoring of incoming water as well as coastal water for signs of pollution.

Reliable Technicians

The boom in hatchery business created the need for trained technicians who are reliably schooled in basic theories related to larval rearing and who can be depended upon to make the right decisions most of the time. The technicians must be diligent and should consider hatchery work a twenty-four-hour job.

Many technicians working in hatcheries today are neither trained nor have they undergone sufficient training. It is suggested that these technicians should undertake thorough training to understand the basics of larval rearing technology, and should establish constant contact with training institutions or with fellow technicians to gain insights into new management techniques in the prawn hatchery industry.

Information Flow

In the Philippines, the archipelagic nature of the country deters a smooth communication flow between: (1) hatchery operator and another hatchery operator, (2) research institution and hatchery operator/technician, and (3) hatchery operator and pond grower.

A feedback mechanism between the research institution and the hatchery operator is necessary. Also, hatchery operators should develop open communication lines among themselves to prevent excessive competition and subsequent collapse of postlarvae price. It is also important that a network of information be developed between hatcheries and pond grow-out to properly time hatchery harvests with pond stocking periods.

Formation of cooperatives is recommended, and government should take the initiative to form a communication or information network among these prawn industry components to facilitate growth and development of a successful hatchery industry, following the Taiwanese model.

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