AQUACULTURE EXTENSION MANUAL NO. 34 JULY 2008, 2nd ed.

BIOLOGY AND HATCHERY OF MUD CRABS *Scylla* spp.

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FOREWORD

Mud crabs (*Scylla* spp.) are a valuable source of income because they are in-demand both locally and internationally. However, the growth of the mud crab farming industry has been limited by the seasonal availability of wild-caught seeds. Over-harvesting of crablets from the wild and the destruction of their habitat has also threatened their natural populations.

In order to facilitate the sustainable growth of the industry, the Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD) developed technologies for the hatchery seed production of mud crabs.

SEAFDEC/AQD has been involved in mud crab research as early as 1977. However, it was in 1997 when mud crab seed production research and development became a regular activity because of a collaborative project with the Australian Centre for International Agricultural Research (ACIAR) to develop seed production and improve farming techniques. In 2002, the European Union funded a 4-year collaborative project for the culture and management of *Scylla* species. This project also involved the University of Wales Bangor (U.K.), University of Gent (Belgium), and Can Tho University (Vietnam). The aim was to improve the reliability and economic viability of mud crab hatchery and nursery production for mangrove-pond aquasilviculture production systems and stock enhancement.

SEAFDEC/AQD persistently promotes sustainable mud crab culture through science-based technologies, and one good strategy is through the publication of aquaculture extension manuals.

This second edition manual builds upon the original manuscript published five years ago. The updated information found here is a product of SEAFDEC/AQD's thrust to continually improve its technologies. We hope this publication will be of benefit to existing and prospective hatchery investors, operators, as well as technicians, instructors, and students.

Joebert D. Toledo, D. Agr.
Chief

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INTRODUCTION

Overexploitation of mud crabs and habitat losses have resulted in both reduced landings and smaller mean capture size. In the past, match box size or bigger crabs (3-5 cm carapace width or CW) are stocked in grow-out ponds but due to the declining catch of this size, fly size crabs (0.6-1.2 cm CW; crab instar$_{4-6}$) have now become acceptable for stocking. The fly size crabs are cheaper and can easily adjust to salinity changes. Triangular net or scissors net with fine mesh size (locally known as "sid-sid") are used for gathering these smaller sized crablets. This method is destructive to the environment as the bottom substrate is scraped, killing not only crabs but also other organisms. This also further aggravates the declining population of the wild crabs.

Further expansion of crab farming has been sluggish due to the seasonal availability of seeds, which are sourced from the wild. Proper fisheries management and development of commercially viable techniques for producing seeds are crucial in making crab aquaculture sustainable. Recognizing the need of the industry, SEAFDEC/AQD developed a hatchery technology for mud crab. Tests have proven that the performance of hatchery-reared crablets is comparable with those of the wild crablets.

Hatchery is the first phase in mud crab culture and has become an essential to meet the increasing seed requirement of the industry. Since the first publication of the manual in 2003, studies have been conducted to further improve the viability of this technology. This second edition incorporates the modifications that have been made to refine the previous hatchery techniques.

This manual includes the biology of mud crab, and describes principles and procedures for spawning the mature crabs (*Scylla serrata*, *S. tranquebarica*, and *S. olivacea*) and rearing the zoea to fly size crabs. It focuses on the hatchery rearing of *S. serrata* as this species is more economically viable than the two other species. The techniques may be modified depending on the conditions or problems encountered in a specific site.

BIOLOGY OF *Scylla* spp.

Crab anatomy

Mud crabs have a flattened, broad body covered by a fan-shaped carapace (Fig. 1). Along the front margin of the carapace are six spines between the eyes and nine spines on either side (anterolateral margin). There is one pair of chelipeds and three pairs of walking legs. The fourth pair of legs are flattened and used for swimming. In males, the walking legs are used for clasping the female during copulation; females use these for scratching the eggs off just prior to hatching.

The chelipeds consist of enlarged segments (merus, carpus, propodus, dactylus and pollex) and are used for crushing shells, and holding and bringing food to the mouth.

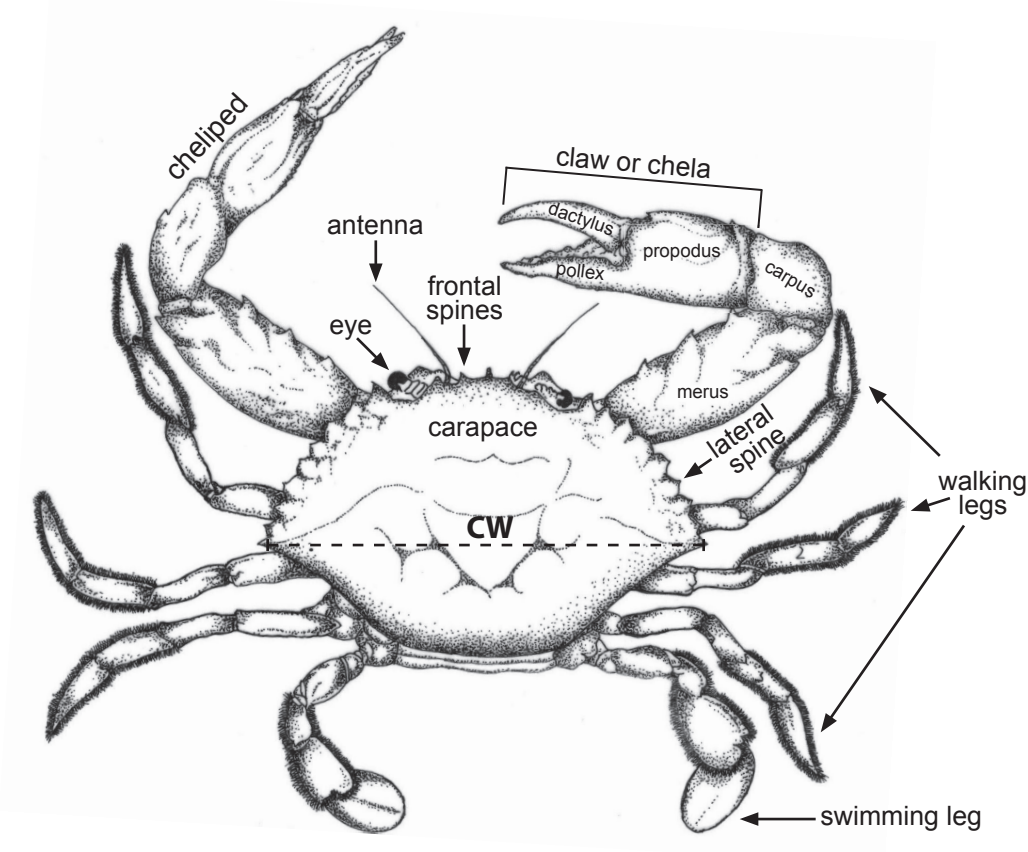


Fig. 1. Top view of an adult mud crab indicating major external parts. Carapace width (CW) is a measure of size in crabs.

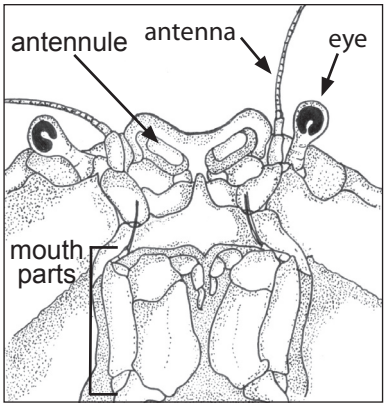


Fig. 2. View of the mouth and other parts of the head (modified from Ng, 1998)

The mouthparts (Fig. 2) are responsible for collecting and processing food. The eyes, antennules, antennae, dactylus and maxillipeds are used for sensory perception.

Mud crabs have separate sexes. Immature females have a triangular-shaped abdomen or abdominal flap (Fig. 3A) and mature females have a broader, semi- circular abdomen (Fig. 3B). Males have a T-shaped abdomen (Fig. 3C). Mature males have bigger chelipeds than females of the same carapace size.

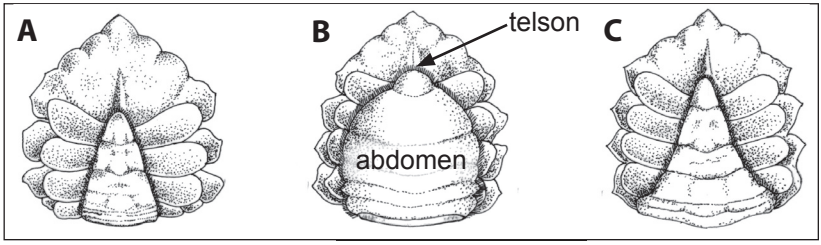


Fig. 3. The underside of mud crabs: (A) immature female, (B) mature female, and (C) male

Male crabs have two pairs of gonopods (modified pleopods) that are adapted for copulation and a pair of ejaculatory ducts that originate from an opening at the base of the last leg (Fig. 4A). Females have a pair of vulvae located on the sixth thoracic segments (Fig. 4B). The pleopods in females are used for egg brooding. The chitinous locking mechanism keeps the abdominal flap engaged with the thoracic sternite.

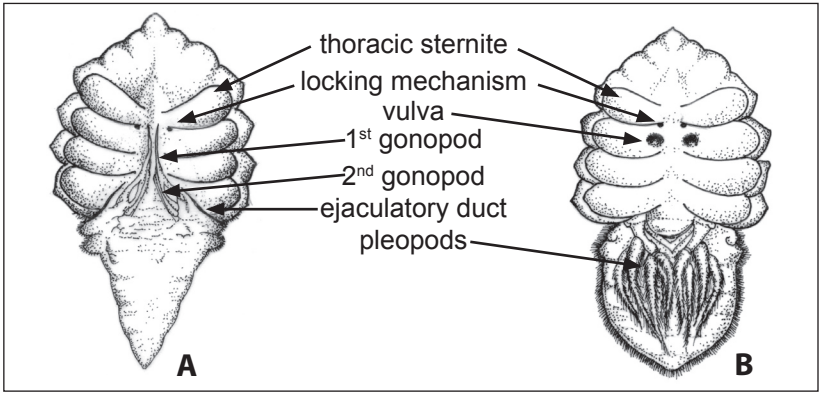


Fig. 4. Abdominal cavity of mud crab showing the gonopods of male (A) and vulvae of female (B)

Taxonomy and Identification

Mud crabs belong to Family Portunidae, the swimming crabs. Taxonomy is as follows:

- Phylum: Arthropoda
  - Class: Crustacea
    - Subclass: Malacostraca
      - Order: Decapoda
        - Infraorder: Brachyura
          - Family: Portunidae
            - Genus: *Scylla*
              - *Species:* *S. serrata*
                S. tranquebarica
                S. olivacea
                S. paramamosain

The genus *Scylla* includes *S. serrata*, *S. tranquebarica*, *S. olivacea* and *S. paramamosain* (Fig. 5). The four species can be distinguished by their external characters listed in Table 1. The first three species are common in the Philippines while *S. paramamosain* is common in Vietnam, Indonesia and Thailand.

Table 1. The distinguishing characters of the *Scylla* species (modified from Keenan *et al.*, 1998)

Species (English name; local name)	Frontal spines		Chelipeds		Color and markings
	Shape	Height	Carpus spines	Propodus spines	
Scylla serrata (Giant or king mud crab; 'alimango', 'kinis', 'banhawan', 'bulik'	pointed	high	both obvious	obvious	carapace green to almost black, polygonal pattern obvious on chelipeds and legs of both sexes and on abdomen of mature female
S. tranquebarica (Purple mud crab; 'lawodnon')	blunt	moderate	both obvious	obvious	carapace green to almost black, polygonal pattern obvious on last two pairs of legs but weak on chelipeds and other legs of both sexes
S. olivacea (Orange mud crab; 'pulahan', 'amamakhaw')	rounded	low	inner absent, outer reduced	reduced	carapace brownish to brownish green, chelipeds and legs rusty brown, polygonal pattern absent
S. paramamosain (Green mud crab)	triangular	moderately high	inner absent, outer reduced	obvious	carapace green to light green, weak polygonal pattern on chelipeds and legs in both sexes

Fig. 5. The four species of *Scylla*

Life history and habitat

Scylla crabs dig and inhabit burrows in mangroves and soft-bottom shallow intertidal water (hence, the name mud crab and mangrove crab). Crabs are commonly collected by bamboo and net traps, or with bare hands.

The life cycle of the mud crab is illustrated in Fig. 6. Courtship and mating occur in brackishwaters. Mature *S. serrata* females migrate offshore to spawn. The other species prefer less saline conditions (20-25 ppt).

Spawned eggs attach to the pleopod hairs of the abdominal flap. Egg hatches into zoea and passes through five stages (zoea 1 to 5), after which it becomes megalopa. The megalopa molts once and assumes a crab-like appearance. Small crabs are found in estuaries, tidal flats, and mangroves where they burrow in mud or sand, or hide under fallen leaves and other shaded areas during the day. Crab instars and juveniles undergo several moltings until full maturity.

Food and feeding

The zoea and megalopa feed on zooplankton. Small crabs feed mainly on crustaceans, mollusks, worms, fish and plant matter. The sub-adult and adult crabs eat burrowing and attached bivalves and small crabs.

Molting and regeneration

Crabs molt in order to grow. The exoskeleton is soft immediately after molting. The crab expands its body and limbs by taking in water before the new shell hardens and usually increases in size by 30-50%. They molt frequently when small but less often when bigger. The newly molted crab is vulnerable to cannibalism; hence, it seeks shelter or burrows to escape predation.

A crab may voluntarily snap off its legs at the base when these are badly damaged or seized by other animals. Crabs are able to regenerate lost limbs. Prior to molting, a new limb bud grows out of the joint. After molting, the limb becomes bigger and harder.

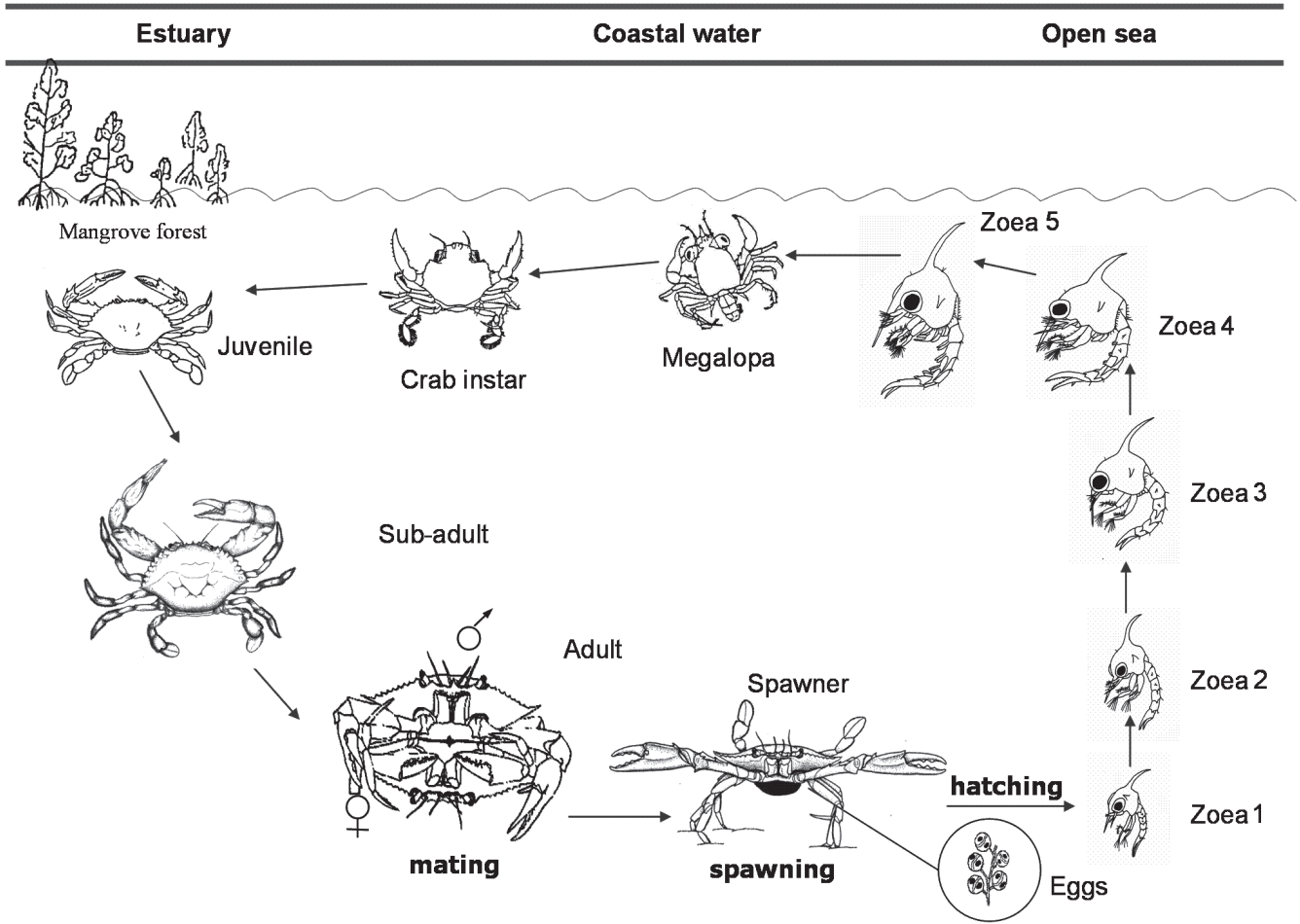


Fig. 6. Life cycle of mud crab (not drawn to scale)

Sexual maturity

Male

The testes are paired organs next to the hepatopancreas located under the carapace. Each testis connects to a vas deferens (a thin white, coiled tube) (Fig. 7A) and to an ejaculatory duct that opens on the ventral side of the last walking leg (8th thoracic segment, Fig. 4A).

As males mature, the claws enlarge after pubertal molt, the spermatophores appear in the vas deferens, and the testes become bigger. Mature males have massive testes that fill up the cavity under the carapace.

Female

A female crab has paired ovaries and oviducts situated under the carapace. Part of the oviduct also serves as the spermatheca or seminal receptacle (Fig.7B) that opens to the outside through the vulvae (Fig. 4B).

A female crab is considered mature when it has undergone pubertal molt with accompanying widening and darkening of the abdomen. Immature ovaries are thin and transparent to yellow. Mature ovaries are dark orange and fill up the cavity under the carapace.

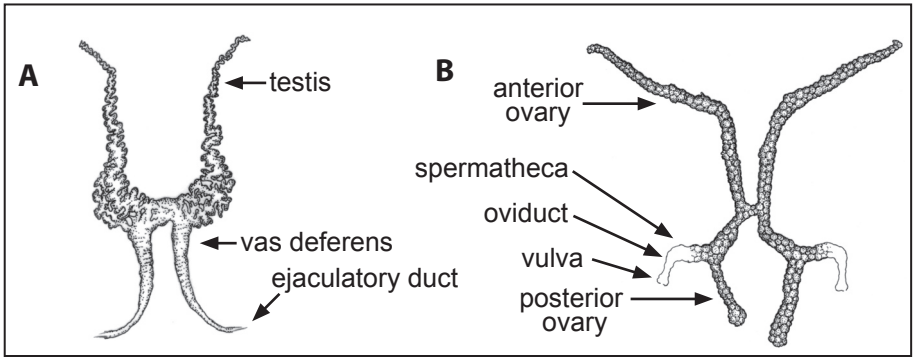


Fig. 7. Testes (A) and ovaries of mud crab (B)

Mating

In portunid crabs, mating occurs soon after molting of a mature female. The male mounts the back of the female and turns the female around so that their undersurfaces meet (Fig. 8) with abdomens extended. The spermatophores are released through the ejaculatory duct and inserted into the vulvae of the female and stored in the spermathecae with the aid of the gonopods.

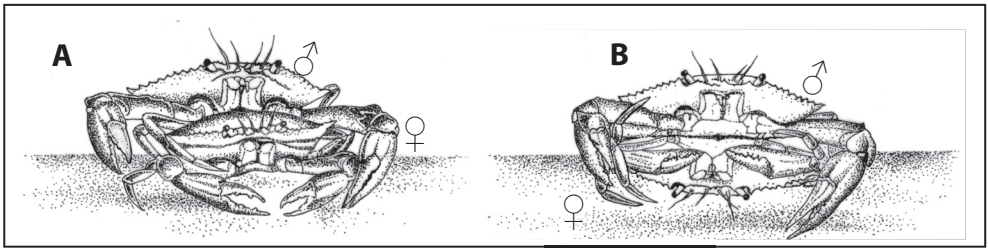


Fig. 8. Male mud crab holds the female underneath (A), and turns the female around (B)

The spermatophores can be retained through a molt. The sperm in the spermatophores remain viable for more than 6 months. The sperm received during mating can fertilize 2-3 batches of eggs. However, the third batch of eggs may have a lower fertilization rate.

Spawning

Mud crabs spawn anytime during the year. A female about to spawn raises its body away from the bottom and opens its abdominal flap to facilitate release of the eggs. The eggs are fertilized as they pass through the spermathecae. The eggs pass through the vulvae and attach to the pleopods of the abdominal flap. The newly spawned eggs appear opaque brilliant orange (Fig. 9A). Females carrying eggs are sometimes called 'berried'. With the development of the chromatophores and the eyes, the egg mass darkens to grayish orange and finally to gray (Fig. 9B).

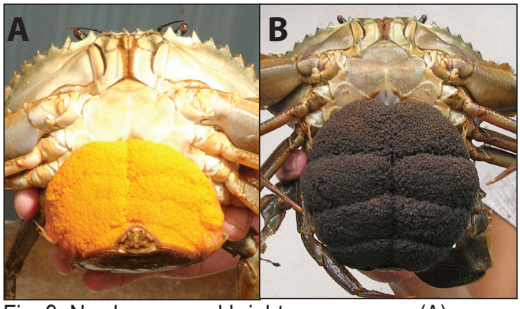


Fig. 9. Newly spawned bright-orange eggs (A) and developed gray eggs (B)

The number of eggs produced by a female may range from 1 to 6 million in a single spawning. One female can produce at least three batches of eggs with 34-59 days between spawnings.

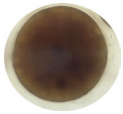
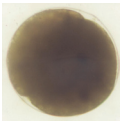
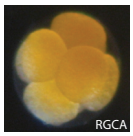
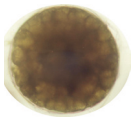
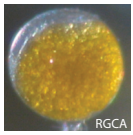
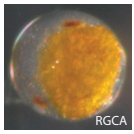
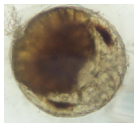
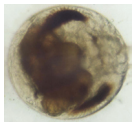
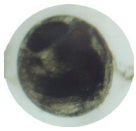
The number of zoeae produced per spawning for each species is as follows:

- *S. serrata* (480 - 915 g females): 0.50 - 6.60 million zoeae
- *S. tranquebarica* (300 - 480 g females): 0.30 - 3.5 million zoeae
- *S. olivacea* (250 - 465 g females): 0.30 - 2.7 million zoeae

Embryonic development and hatching

The eggs are almost spherical. Newly spawned eggs measure 0.31 to 0.32 mm in *S. olivacea* and *S. tranquebarica*, and 0.32 to 0.35 mm in *S. serrata*. Embryonic development is shown in Table 2. It takes 7-14 days for mud crab eggs to hatch. The duration of embryonic development varies with temperature, egg quality and other factors.

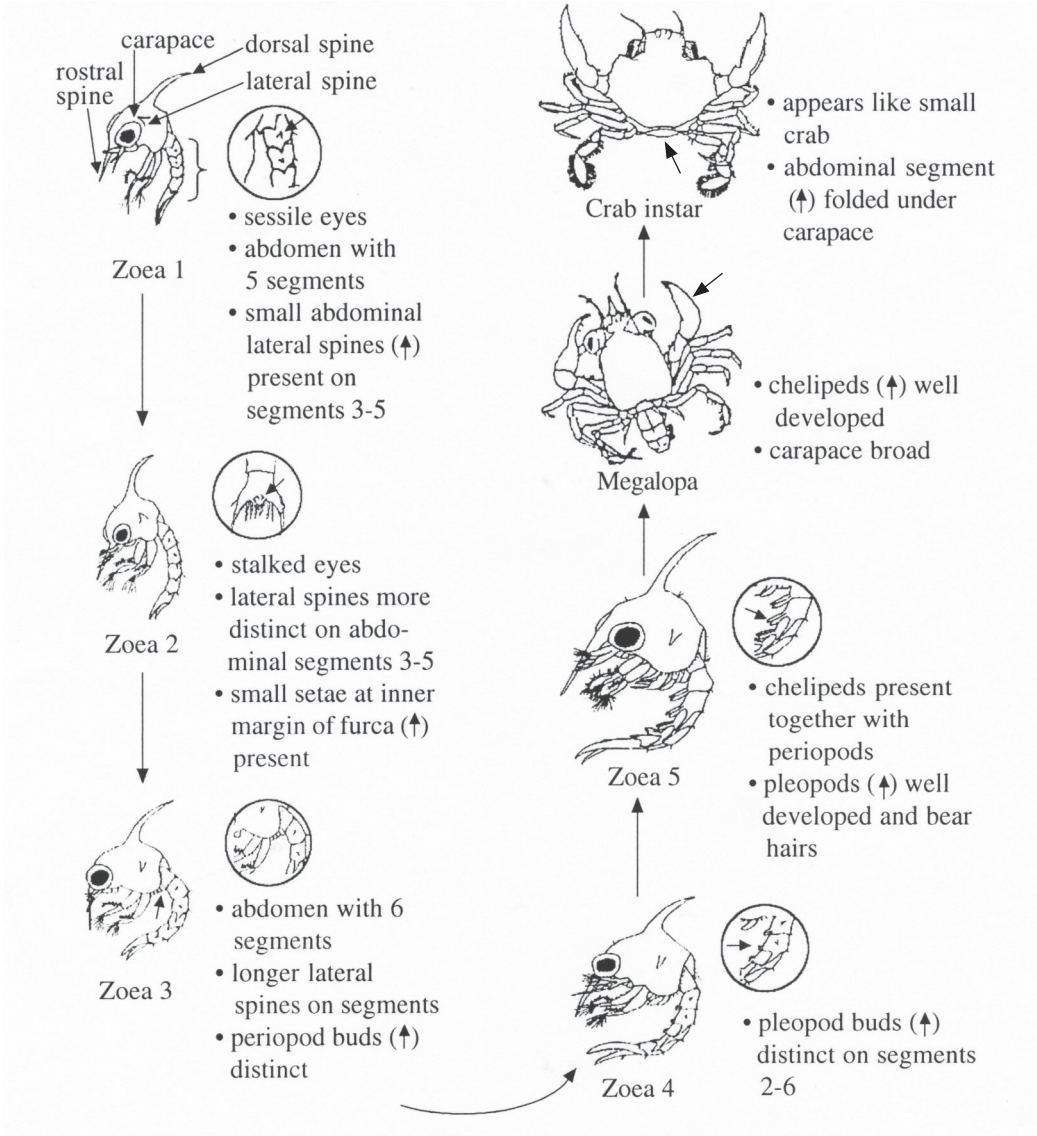
Table 2. Embryonic development of mud crab at 27-30 °C

Photo	Stage	Description	Time after spawning
	Precleavage	Newly spawned egg filled with yolk	0 h
	Cleavage	Cleavage grooves formed	3-6 h
	8-cell stage	Cell divides further into 4, 8, 16, 32 cells and so on	8-12 h
	Multi-cell stage	Multiple cells formed	13-20 h
	Naupliar stage	High cell density area visible on one side of the embryo. Embryonic body formed	2.5-3 days
	Eye formation stage	Pair of pigmented eyes visible	4-6 d
	Thoracico-abdominal stage	Thorax and abdomen apparent, larval form appears	5-7 d
	Heartbeat stage	The heart, located posterior to the yolk, starts to beat. Heartbeat increases gradually from 30 to almost 200 beats/minute. Abdomen and telson differentiated	7-9 d
	Prehatching stage	Heartbeat increases to more than 200 beats/minute. Chromatophores increase throughout the body	9-11 d

Larval development

The zoea has long rostral and dorsal spines and short lateral spines on the carapace. Larval development of mud crab is shown in Fig. 10. It takes 14-16 days from zoea 1 to megalopa stage and another 7-10 days to the first crab stage.

Fig. 10. Larval stages of the mud crab and the characters that differentiate them (Illustrations modified from Jones et al., 2005)



HATCHERY OPERATIONS

Setting up the hatchery

Site selection. In selecting a site for the crab hatchery, important criteria must be met.

1. **Seawater supply** - the hatchery should be near sandy and rocky or coral-line shores where clean seawater can be pumped easily. It should be far from possible sources of pollution. Good water quality should be available throughout the year (Table 3).
2. **Availability of electric power** - electricity is essential to life support systems and other hatchery equipment. A stand-by generator is necessary in case of electric power interruptions.
3. **Accessibility** - the hatchery should be near good roads to facilitate transportation of equipment, supplies and animals. Marketing of products will also be easier.
4. **Freshwater supply** - freshwater is necessary for washing and rinsing tanks and other implements.
5. **Environment** - the hatchery must not be in environmentally sensitive areas such as protected areas.

Design and lay-out. The size of the mud crab hatchery depends on the target production and the financial capability of the investor. A sample lay-out of a hatchery with a total rearing tank capacity of 80 tons is shown in Fig. 11. This hatchery is capable of producing about 96,000 fly size crablets (0.6-1.2 cm CW) per run. The ratio of rearing tanks to natural food tanks is 1:2-2.5.

Table 3. Suitable ranges of water quality for mud crab larvae

Parameter	Range
Temperature	27-31°C
Salinity	22-32 ppt
Dissolved oxygen	>4 ppm
pH	7.5-8.5
Unionized ammonia	≤1 ppm
Nitrite	≤0.1 ppm

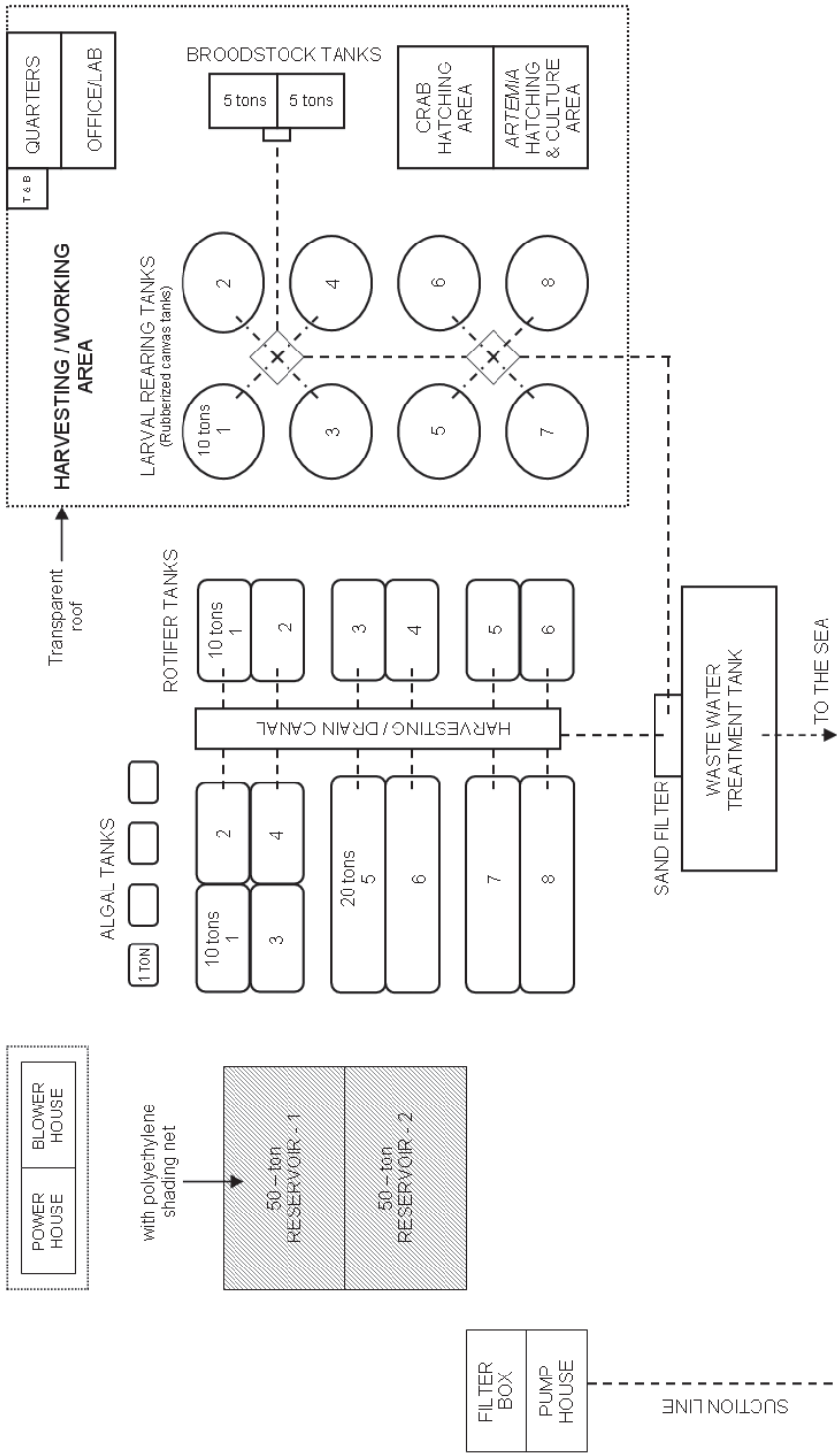


Fig. 11. Sample lay-out of a mud crab hatchery

Tanks. For better water circulation, tanks in the hatchery are preferably circular or rectangular with rounded corners. The bottom should be flat and sloping towards the drain. Tanks can be made of concrete, fiberglass, or wood with rubberized canvas lining. Wall and bottom surfaces should be smooth.

1 **Broodstock tanks** - tanks with a capacity of 5-10 tons and a depth of 50 cm are preferable. The tank bottom should be covered with 4-5 cm deep sand. Cut polyethylene vinyl chloride (PVC) pipes (20 cm diameter x 30 cm length) are provided as shelters for crabs.

2 **Hatching tanks** - berried crabs are held separately in 0.5 to 1-ton tanks. The tank depth should be about 50 cm.

3 **Larval tanks** - tank capacity ranges from 6 to 20 tons but 10-ton tanks are more economical and practical. Siphoning of sediments on the tank bottom becomes difficult when the diameter of the tank exceeds 5 m or the tank depth is more than 1 m. Each tank should be covered with canvas or plastic sheet in the evening. It is preferable to provide transparent roofing.

4 **Natural food tanks** - tanks for the mass production of microalgae and rotifers are necessary. Tank depth should be 0.5 to 1.0 m to allow sufficient light penetration. Transparent roofing may be provided to prevent dilution with rain.

The number and volume of natural food tanks depend on the daily requirement. The rotifer culture should not exceed the volume that the microalgae cultures can support.

5 ***Artemia* hatching tanks** - *Artemia* or brine shrimp cysts have to be hydrated and incubated in tanks for about 24 hours. Hatching tanks should be made of transparent material with a conical bottom or steep concave bottom for good circulation and for ease in nauplii collection. Unhatched cysts, empty shells, and hatched nauplii can be easily separated when the containers are provided with bottom valves or drains. Tank capacity can range from 50 to 100 liters.

6 **Reservoir** - a reservoir is necessary for chlorination and holding of filtered and treated water for daily use. The total capacity must be at least 50% of total larval tank volume. More than one unit of reservoir is advisable so that one may be cleaned and dried while the other is in use. An elevated reservoir can distribute seawater to other tanks by gravity. To avoid algal growth, opaque roofing or polyethylene shading net can be used to cover the reservoir.

Aeration system. Continuous aeration is necessary in hatchery operations to keep food particles and natural food in suspension and maintain optimum dissolved oxygen levels. An air blower is used to supply aeration.

Seawater supply. Seawater may be pumped directly from the sea or through a sump pit. Water may be prefiltered through the sand in the sand bed (Fig.12) or directly pumped to the hatchery. Seawater is then passed through an elevated sand and gravel filter (Fig. 13) prior to storage in the reservoir. The sand filter is made of graded gravel and sand that filter particulate matter.

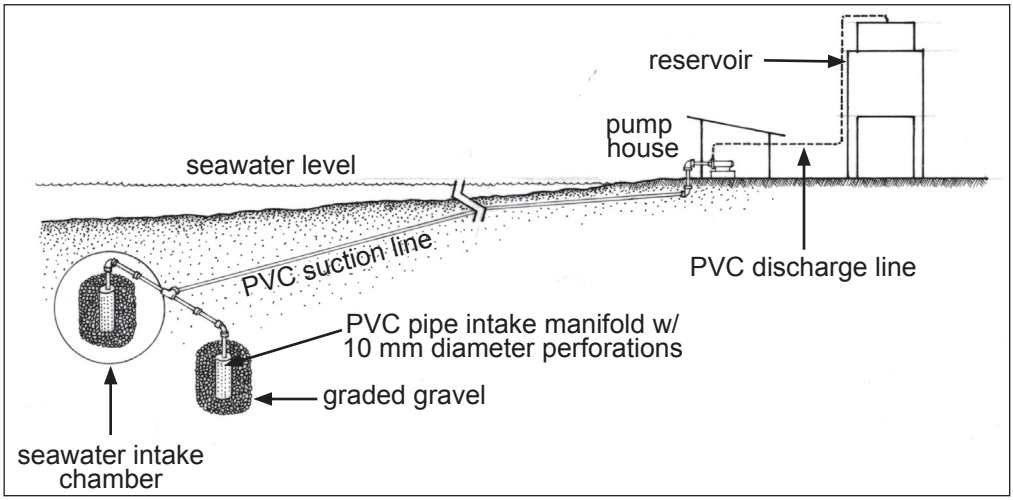


Fig. 12. Seawater intake system

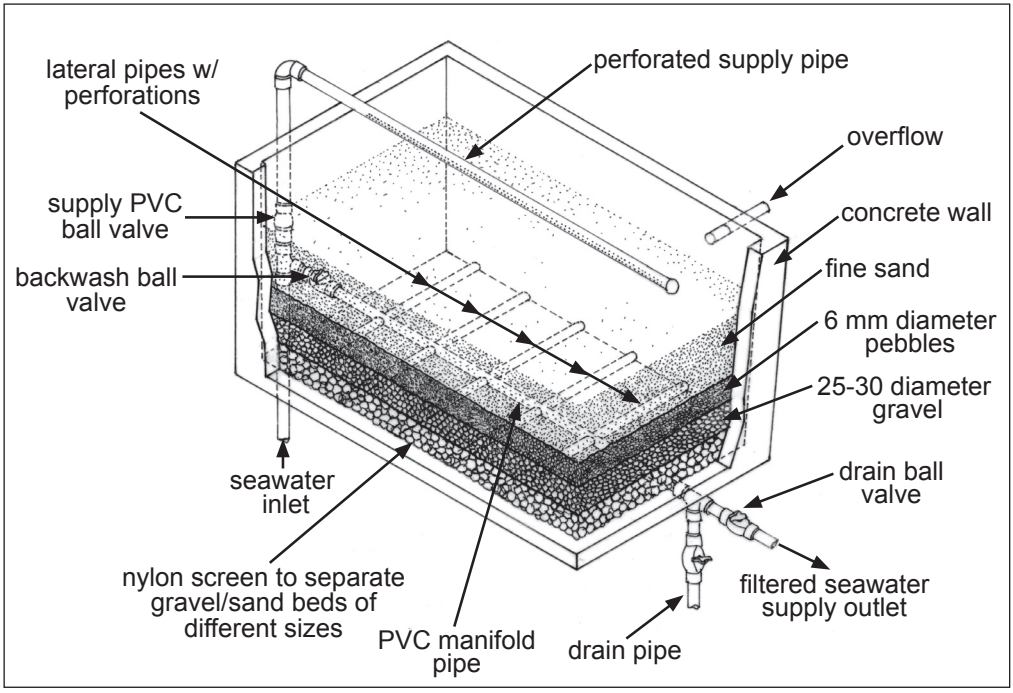


Fig. 13. Sand and gravel filtration unit

Centrifugal or submersible pumps are used to pump water from the sea to the reservoir or tanks. An aquaculture engineer should be consulted on the type of pumps and aeration and seawater systems before construction.

Equipment, tools, and supplies

- **Refractometer** - for measuring salinity
- **Thermometer** - for measuring water temperature
- **Microscope** - for counting algal cells and rotifers, detecting contaminations in the culture and monitoring health condition of larvae
- **Chlorine test kit** - for determining the amount of thiosulfate needed to neutralize or deactivate excess chlorine volume
- **Hemacytometer** - for determining the number of algal cells in a given volume
- **Modified Sedgewick Rafter counting chamber** - for counting rotifers
- **Weighing scale** - for weighing chemicals and feeds
- **Drainers and hoses** - for draining or changing water. Mesh size of nets for drainers must be smaller than the size of the larvae
- **Filter bags (5 µm)** - for filtering water
- **Basins, pails and dippers** - for transferring and feeding crabs
- **Beakers, test tubes, droppers, and graduated cylinders** - for monitoring and feeding
- **Rotifer harvesting bags, harvesting boxes, and scoop nets**
- **Plastic bags, filled oxygen tank, cardboard or styrofoam boxes, rubber bands** - for transporting of megalopae and crablets

Preparation of tanks and seawater

Tank preparation. Hatchery tanks must be cleaned well before use. These tanks must also be cleaned and dried after each run.

1. Fill the newly constructed or painted tanks with freshwater or seawater and allow to stand overnight.
2. Drain the water the next day. Refill with water and let stand for about 5 days.
3. Drain the water and scrub the tank with water and detergent. Rinse with freshwater.
4. Prepare 200 ppm hypochlorite in a bucket and splash on tank walls and bottom. Scrub tank and rinse well with freshwater.
5. Allow the tanks to dry for at least a day under sunlight.
6. Install aeration hoses with airstones 1 m apart in the tank.
7. For tanks that have been previously used, proceed directly to step 4.

Water treatment

Water for algal culture, holding the broodstock, and larval rearing is treated with 10-15 ppm calcium hypochlorite overnight in the reservoir. Hypochlorite is an oxidizing agent that kills or inhibits the growth of harmful microorganisms. Since chlorine is also toxic to crab, the water should be strongly aerated to release the chlorine residues or treated with sodium thiosulfate to deactivate the residues before use.

Chlorination of seawater

1 Pump seawater into the reservoir.
2 Determine the weight of calcium hypochlorite needed for disinfection as follows:

$$W = \frac{C \times V}{P}$$

Where: W = weight of calcium hypochlorite (g)
C = desired concentration (ppm) of hypochlorite (usually 10-15 ppm)
V = volume of seawater to be treated (ton)
P = percentage of hypochlorite in the product

3 Dissolve calcium hypochlorite in a pail of water. Stir or aerate.
4 Add the solution to the water in the reservoir. Aerate vigorously for uniform mixing.
5 After 12-24 hours, aerate the water strongly, or add sodium thiosulfate.

Application of sodium thiosulfate

1 Get about 10 mL of chlorinated water from the reservoir.
2 Put 3-4 drops of orthotoluidine solution to the water sample. Shake and a yellow color will develop.
3 Determine the amount (ppm) of residual chlorine by means of a test kit comparator.
4 Multiply the corresponding amount (ppm) by the total volume (in tons) of water to be dechlorinated. This will give the weight (g) of sodium thiosulfate to be used.
5 Weigh sodium thiosulfate and dissolve in a small amount of freshwater. Aerate this for 30 minutes to 1 hour.
6 Add the dissolved sodium thiosulfate to the chlorinated water.
7 Measure again the amount of residual chlorine in the water after 30 minutes. Residual chlorine must be zero before using the water; otherwise, repeat steps 1-7.

Production of natural food

Mud crab zoeae eat rotifers, *Brachionus* (Fig. 14). Rotifers in turn eat a wide variety of microalgae like *Tetraselmis* (Fig. 15A) and *Nannochlorum* (Fig. 15B) (formerly identified as *Chlorella vulgaris*), a single-celled green alga. *Nannochlorum* is more commonly used in the hatchery due to its ease of culture.

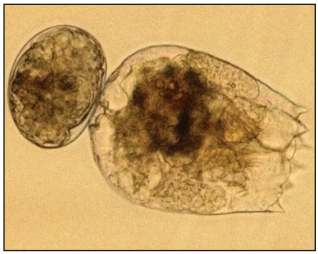


Fig. 14. Adult rotifer *Brachionus rotundiformis* (190-215 µm)

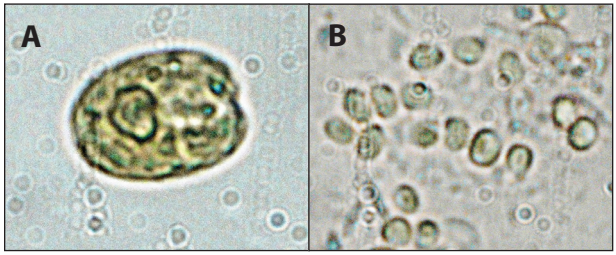


Fig. 15. The unicellular algae *Tetraselmis* (10-16 µm) (A) and *Nannochlorum* sp. (4-8 µm) (B)

The production of natural food has to be synchronized with the hatchery operation so that food will be available as soon as the eggs hatch to zoeae. To determine the number and volume of tanks to be used, a scale-up schedule for the initial culture of *Nannochlorum* and *Brachionus* must be made. Since it takes about 3-4 days for both to reach peak density, three sets of tanks must be available for the scale-up culture. About 20% of the starter culture is needed as inoculum. A sample schedule for a hatchery with 80-ton rearing tank capacity is shown in Fig. 16.

Culture of *Nannochlorum* or *Chlorella*

1. Obtain the initial inoculum of *Nannochlorum* from the Natural Food Laboratory of SEAFDEC/AQD. In Fig. 16, this is about 32 liters for 160-liter initial culture.
2. Fill a clean tank with seawater (preferably 25 ppt) to 80% of the desired volume and add the inoculum.
3. In a separate tank, dissolve the fertilizers in clean water as follows:

21-0-0 (ammonium sulfate)	100 g/ton of culture
16-20-0 (ammonium phosphate)	20 g/ton
46-0-0 (urea)	40 g/ton

4. Add dissolved fertilizers to the culture tank. Aerate. *Nannochlorum* will be ready after 3 days.

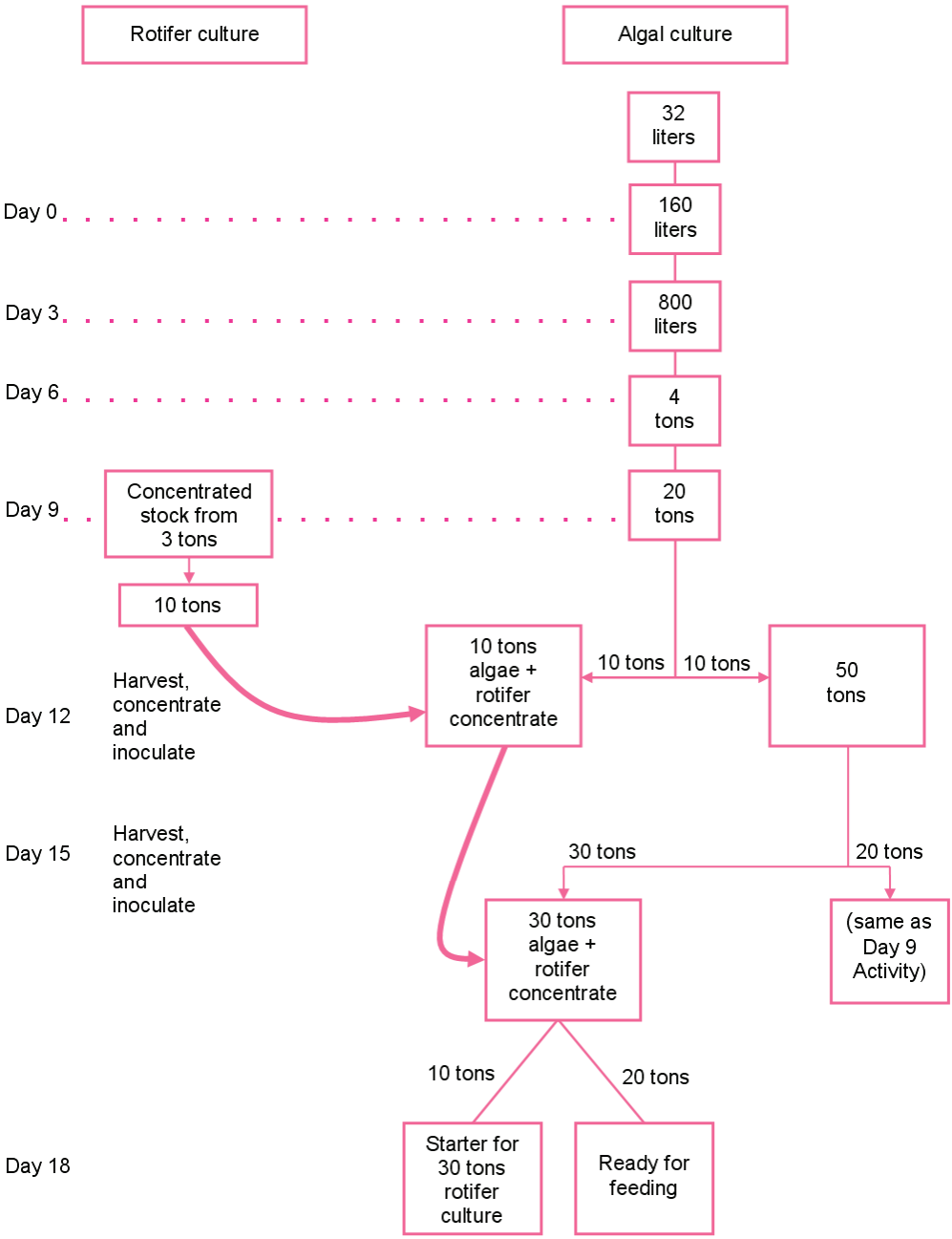


Fig. 16. Production schedule for scale-up of microalgae and rotifers for larval food. This schedule represents one set of culture. Another set must be started on day 2 and the third set on day 3 so that food will be available daily

Culture of the rotifer *Brachionus*

1 Obtain rotifers from SEAFDEC/AQD. The volume of inoculum must be at least 30% of the total volume. In Fig. 16, the initial volume is 3 tons. This inoculum must be concentrated to 10 to 30 liters for ease of transport. A daily requirement of 20 tons rotifers can be obtained after 18 days from start of natural food culture as shown in Fig. 16.
2 Add the concentrated rotifers to the *Nannochlorum* culture. The initial density after addition must not be lower than 15 rotifers/mL.
3 If *Nannochlorum* is not sufficient, add baker's yeast (about 1 g yeast/million rotifers/day). Frequent feedings or continuous drips are desirable. Rotifers fed with algae are more nutritious for crab larvae than rotifers fed with yeast. Rotifers may be enriched with highly unsaturated fatty acid (HUFA) 6-12 hours before harvest. Various enrichment diets for rotifers are commercially available. The feeding protocol is indicated in the product label.
4 Harvest and concentrate the rotifers by a 50-65 µm mesh plankton net bag. Use the harvest (30%) to inoculate the next set of *Nannochlorum* tanks and the rest (70%) as food for the crab larvae.

Hatching and culture of *Artemia*. *Artemia* is a protein-rich food and is available in cyst form packed in cans. After 18-24 hours of incubation in seawater, the cysts release free-swimming nauplii that can be fed directly to zoeae and megalopae.

Hatching of *Artemia*

1 Determine the hatching efficiency (varies with brand) of the *Artemia* cysts and total volume of the larval tanks where *Artemia* will be used.
2 Determine the weight of *Artemia* cysts to be incubated as follows:

$$W = F \times H \times V$$

Where:
W = weight of *Artemia* cysts (g) to be incubated
F = feeding rate (0.5 – 1.0 *Artemia*/mL)
H = hatching efficiency of given batch (g cysts/million nauplii)
V = total volume of larval tanks (tons)

3 To disinfect cysts, dissolve thoroughly 0.3 g calcium hypochlorite/liter of seawater (if concentration of hypochlorite is 60%) in a clean *Artemia* hatching tank. Aerate.
4 Place the cysts in the hatching tank at 3-5 g cysts/liter of water. After 30 minutes, harvest and wash the cysts thoroughly.
5 Place the disinfected cysts in a hatching tank with clean seawater. Aerate the water to suspend all the cysts. Incubate for 18-24 hours as specified on the product label. Illuminate the tank to ensure efficient hatching.

Harvesting of *Artemia* nauplii

1 Remove aeration and cover the tank except a small rim area. Nauplii will concentrate in the lighted area.
2 Siphon the nauplii with a small hose onto a collecting net of 120-150 µm mesh size.
3 Wash the nauplii with seawater or freshwater. Transfer nauplii to a pail with seawater and feed to crab larvae.

Culture of *Artemia*

1 Wash the newly hatched nauplii on a 150 µm mesh net with clean water and stock at 1,000-3,000 *Artemia*/liter in a 1-ton tank with seawater.
2 Provide the tank with moderately strong aeration using a lift system or open line (no airstones).
3 Prepare a suspension by soaking 1 kg rice bran in 4 liters seawater. Aerate for 1 hour. Squeeze the suspension through a 60 µm plankton net to obtain the particle sizes suitable for *Artemia*. Provide strong aeration to the suspension.
4 Feed suspension to *Artemia* frequently or in continuous drips. Avoid overfeeding to maintain good water quality. Use a secchi disc to determine water transparency at 10-15 cm during the first three days and 20 cm thereafter.
5 Replace 30-50% of the water 2-3 times a week. Maintain water quality by siphoning the waste materials from the bottom and/or by flow-through removal daily.
6 Harvest the *Artemia* after 5-7 days depending on the desired size. *Artemia* reach adult size in about 2 weeks at 26.5-30°C. *Artemia* may be fed with the green algae *Tetraselmis* or enriched with HUFA emulsion 6-12 hours before harvest. Various enrichment diets for *Artemia* are commercially available.

Management of broodstock

Selection and transport. Mature females with dark orange ovaries obtained from either brackishwater ponds or mangroves are held in tanks until the eggs are spawned. Mature ovaries can be seen by carefully depressing the first abdominal segment adjacent to the carapace (Fig. 17). Berried females may also be held in tanks until their eggs hatch. It is easier to obtain females with mature ovaries than berried females. However, it takes weeks for the mature crabs to spawn in the hatchery. Crabs with fully mature ovaries spawn within 2-3 weeks but those with ovaries that are not fully mature (yellow to light orange) may take more than 3 weeks to spawn.

It is difficult to determine if females are mated because the spermathecae are not visible externally. Therefore, it is advisable that several females be gathered to obtain a higher percentage of mated females that will give viable eggs.

Berried females from ponds sometimes have eggs heavily infested with protozoans and other microorganisms that lead to egg mortality during incubation.

Fig. 17. Practical determination of gonad maturity

1. Choose active crabs that have clean and hard shells, and complete limbs. The recommended minimum body weight is 450 g (12.5 cm CW) for *S. serrata* broodstock, and 350 g for *S. tranquebarica* (12.2 cm CW) and *S. olivacea* (11.5 cm CW).
2. If crabs are berried, select those with brown or gray egg mass (eggs are already fertilized). Egg mass should be clean and intact.
3. Tie chelipeds to prevent fighting among crabs, but do not tie those that are berried.
4. Put non-berried crabs in woven pandan bags (bayong), carton or plastic box with holes for ventilation. Line the bottom with damp cloth or leaves.
5. Put berried crabs in pail or styrofoam box with clean seawater, preferably from the source where crabs are collected. Put enough seawater to immerse the crabs and prevent drying of eggs. The eggs die in less than an hour out of water. Aerate the water by portable battery-operated aerators.
6. Avoid exposing the crabs to direct sunlight and strong wind as they may be dehydrated and die.

Acclimation and disinfection. Mud crabs are hardy but can die from inappropriate handling or exposure to extreme conditions. Acclimation is necessary since sudden change in environmental conditions such as salinity and temperature can weaken the crabs.

1. Put crabs in the empty basin and pour seawater over them slowly every 5 minutes for about 30 minutes. For berried crabs, acclimate them until salinity and temperature are similar to the water in the hatching tank.
2. Transfer crabs to a basin containing 150 ppm formalin for 30 minutes to disinfect.
3. Untie crabs and stock in broodstock tanks (see page 14). For berried crabs, put them in hatching tanks (one crab/tank). Aerate moderately.

Feeding and water management. Crabs are fed natural food such as mussels, marine worms (polychaetes), fish or squid with or without artificial diets. Each food is given separately to avoid selective feeding on preferred diets.

Feeding of broodstock

1 Determine the feeding rate based on current food consumption and crab biomass.
2 Feed crabs with mussel meat and marine worms or squid in amounts equal to 10-15% of crab total weight daily. Give 30-40% of the daily ration in the morning and the remaining amount in the afternoon.
3 Put food on perforated plastic trays for easy removal of the excess. Remove uneaten food before the next feeding. Excess food encourages growth of harmful fungi and bacteria.

Thirty to fifty percent of water is changed 3-4 times a week. Water depth is maintained at 50 cm. Water temperature and salinity are maintained at 27-30°C and 30-34 ppt, respectively. The sand bottom is cleaned 1-2 times a week during water change.

Spawning. Crabs that spawn in broodstock tanks are easy to recognize because the abdominal flaps extend outward. These crabs must be taken from the broodstock tank and maintained in hatching tanks for easy monitoring of egg development and retrieval of newly hatched zoeae.

Maintenance of berried crabs

1 Disinfect berried crabs in 150 ppm formalin bath for 30 minutes.
2 Stock each crab in a 500-liter tank with aerated seawater.
3 Feed crabs mussel meat, fish, marine worms, or squid at 10-15% of total weight daily. Remove uneaten feeds after 4 hours. Discontinue feeding when eggs become brown.
4 Siphon out detached eggs and excess food before water change. Change about 80% of the total water volume in the tank daily. Retain 20% of water in the tank to prevent egg desiccation.
5 Sample a small amount of eggs 2-3 times during the incubation period to examine embryonic development and biofouling.
6 Apply 0.1 ppm Treflan* (44% trifuralin) to the water every 2-3 days to prevent fungal infection
7 Cover the tank.
8 Check for hatching (usually occurs early in the morning) and remove the crabs after all the eggs are shed.

Crabs that have released their eggs are returned to the broodstock tank for later spawning. An adult crab can spawn three times within 4-6 months without further molting and mating.

*mention of a product brand does not mean endorsement by authors or by SEAFDEC/AQD

Larval rearing

Stocking of zoeae. Newly hatched zoeae must be collected within an hour to prevent microbial attack. The initial stocking density in the larval rearing tank is 60-80 zoeae/liter. Only the zoeae from the first two spawnings of a female crab are recommended for larval rearing.

Collection and stocking of zoeae

1 Turn off aeration in the hatching tank. Allow dead zoeae, unhatched eggs, feces and other waste products to settle. Siphon them out.

2 Cover the tank but leave a small opening. Allow the zoeae to concentrate in the lighted area for about 20 minutes.

3 Siphon the zoeae with a 2-cm diameter hose into a harvesting net box placed in a basin with gently flowing seawater (Fig. 18).

4 Scoop out the zoeae with a bowl and put in a 50- to 100-liter bucket. Aerate the zoeae suspension.

5 Get four 100 mL subsamples from different sections of the bucket and count zoeae individually. Get the average count and multiply by 10 to get the number of zoeae per liter in the bucket.

6 Compute the volume of zoeae suspension (liter) to be placed in each larval rearing tank with the following formula:

Fig. 18. Siphoning of zoeae into a harvesting box with 150 µm mesh size net. The net retains the zoeae while allowing the water to pass through

$$V = \frac{D \times T}{Z}$$

Where: V = volume of zoeae suspension (liter)
D = desired stocking density (60 zoeae/liter)
T = volume of larval rearing tanks (liter)
Z = density of zoeae in suspension (zoeae/liter)

7 Determine the water temperature in the rearing and hatching tanks. Proceed to No. 8 if the difference is more than 1°C. Otherwise, stock zoeae directly in the tank.

8 Put the larvae in basins. Allow the basins to float on the rearing water for 10-20 min. Pour a liter of water from the rearing tank to the basin every 5-10 min until conditions in the tank to the basin are similar. Allow the water to overflow in the basin and slowly release the zoeae into the rearing tank.

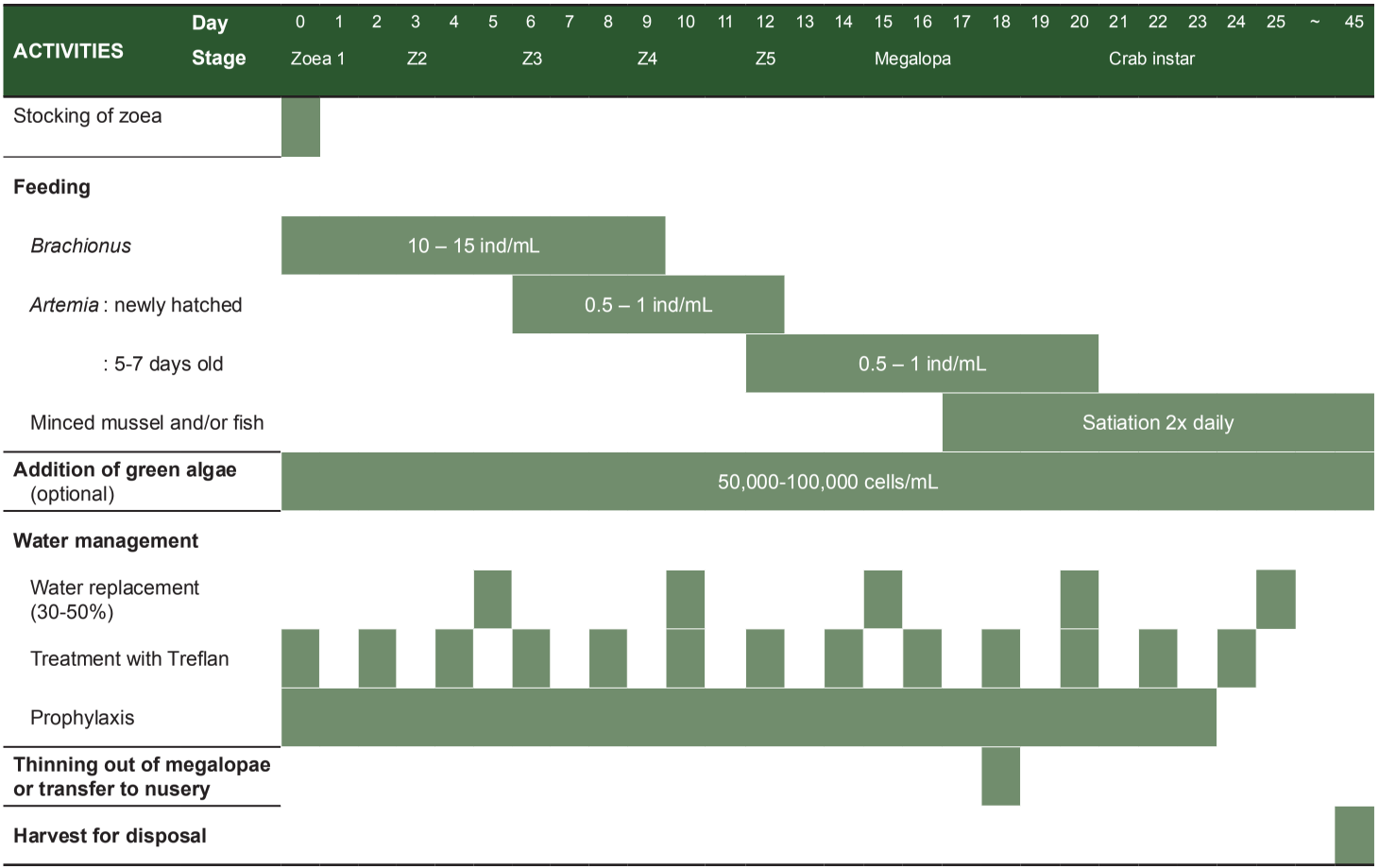


Fig. 19. Feeding and water management during hatchery operation

Feeding. Newly hatched zoeae have to be fed immediately since the egg yolk is depleted. Crab larvae may consume phytoplankton, but these are low in protein content. Rotifers are commonly fed to larvae because these are easy to propagate. The density of rotifers to be maintained in the rearing tank is 10-15/mL (Fig.19). Newly hatched *Artemia* are given to zoea 3 until megalopa at 0.5 – 1.0 ind/mL. Larger 5-7 day old *Artemia* are fed to zoea 5 and early megalopa. Later megalopae can be fed minced fish and mussel meat.

The densities of rotifers and *Artemia* are maintained by regular addition of these food organisms. High food density increases the chance of larvae to capture food organisms. *Nannochlorum* may also be added in the rearing tank at 50,000-100,000 cells/mL as food for rotifers.

Small crabs are fed minced mussel or fish at 40-50% of total weight daily or to satiation. Crabs are fed twice a day.

Estimation of algal density

1 Take samples from the algal tank and rearing tanks. Use clean test tubes or small containers.
2 Place a cover slip at the center of a hemacytometer (Fig. 20).
3 Load a small amount of the sample in the V-groove of the hemacytometer. Allow 1-2 minutes for algal cells to settle. The cells must be evenly distributed. Otherwise, discard the sample, clean the hemacytometer and reload sample.
4 Count the cells under a microscope, scanning left to right and top to bottom (see block B, Fig. 20).
5 Compute as follows:
a. Use the center blocks (1, 2, 3, 4 and 5) in counting small cells (>1 million cells/mL) like *Nannochlorum*.

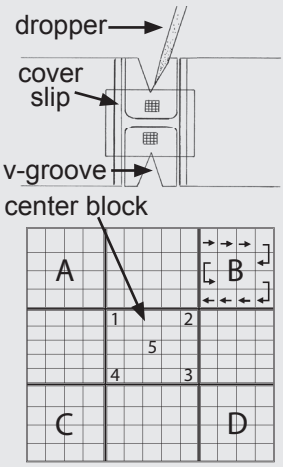


Fig. 20. Top view of a hemacytometer for counting algae

$$\text{Cell count} = \frac{\text{Average no. of cells} \times 10^6 \text{ cells/mL}}{4}$$

b. Use areas A, B, C and D for bigger cells like *Tetraselmis*.

$$\text{Cell count} = \frac{(A + B + C + D) \times 10^4 \text{ cells/mL}}{4}$$

6 Compute the volume of algae to be added to the rearing tank as follows:

$$V = \frac{(D-C) \times T}{A}$$

Where: V = volume of algal stock (liter) to be added
D = desired algal density in rearing tank (cells/mL)
C = current algal density in the larval tank (cells/mL)
T = water volume in rearing tank (liter)
A = density of the algae in stock (cells/mL)

Estimation of rotifer density

1 Get rotifer samples from the rearing tank and from the harvesting container. Put samples separately in clean 5-10 mL beakers or small containers.
2 Pipet a 1 mL sample to each well of a modified Sedgewick Rafter counting chamber (Fig. 21).
3 Add a drop of 10% formalin or Lugol's solution in each well to kill the rotifers. Mix thoroughly. Lugol's solution is made by dissolving 2 g potassium iodide and 1 g iodine crystals in 100 mL water. The solution is kept in a dark bottle.
4 Count the total number of rotifers in 1 mL sample (rotifers/mL).
5 Compute the volume of rotifers to be added to rearing tanks by the following formula:

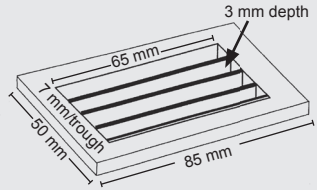


Fig. 21. Modified Sedgewick rafter counting chamber for rotifers

$$V = \frac{(D - C) \times T}{R}$$

Where: V = volume of rotifers to be added to rearing tanks (liter)
D = desired density of rotifers (per mL) in rearing tanks
C = current density of rotifers (per mL) left in rearing tank
T = volume of rearing tank (liter)
R = density of rotifers (per mL) in the harvest tank

After counting the rotifers from the rearing tank, always observe the appearance in a glass test tube or beaker. Rotifers appear as minute white dots in the water column. These observations will later help in estimating the rotifer density in the rearing tank.

Water management. Treated seawater is used in rearing the zoeae to megalopae. The rearing water is replaced at 30-50% every 5 days (Fig. 19) and when high levels of luminescent bacteria (1×10^2) are detected in the water. Regular water change dilutes the concentration of toxic metabolites in the tank. Unchlorinated seawater can be used once megalopae have molted to crab stage.

The suitable ranges of temperature and salinity for crab larvae are 27-31°C and 22-32 ppt. Salinity may be reduced gradually from ambient (32-34 ppt) to 22-26 ppt at the late megalopa or early crab stage. A natural photoperiod and light intensity are maintained in the tank. Aeration is provided throughout the rearing period.

Transfer of megalopae. Because megalopae are cannibalistic, some or all of them must be transferred to bigger tanks or net cages set in brackishwater ponds to lower the density. However, megalopae cultured in tanks, should be disposed once these reach fly size crablet (0.6-1.2 cm CW). Using several tanks to rear megalopae up to juveniles at low density is not cost effective because these tanks are better used for rearing the zoeae. Megalopae may be stocked in ponds which have wider surface area for dispersion. The ponds must be predator-free and have substantial zooplankton growth.

Healthy megalopae (5-6 day old or when they become benthic) may be harvested, packed and transported with extra care. The salinity in the larval rearing tank should be gradually adjusted to the salinity of the nursery pond.

Harvesting, packing and transport of megalopae

1 Turn off the aeration and cover the tank, leaving only a small opening. Active megalopae will concentrate at the lighted area.
2 Collect the active megalopae by scooping with a bowl or small basin, or by siphoning with a hose (3-4 cm diameter) into a basin.
3 Reduce the water level in the tank to about 8-10 cm using a drainer hose. Drain the remaining water in the tank to flow to the harvesting box in a basin. Scoop out the remaining megalopae in the harvesting box with a shallow bowl.
4 Estimate the number of megalopae by the comparison method. Count individual megalopae in one basin. Place the same number of megalopae in other basins based on the visual estimate of density in the first basin. Multiply the number of megalopae in one basin by the number of basins. Stock megalopae in tanks. Proceed to step 5 if megalopae are to be stocked in ponds.
5 Load megalopae in double plastic bags (50 x 90 cm) at a density of 50-100 ind/liter in cool seawater (22-24°C) for a transport duration of up to 6 hours.
6 Fill the inner bag with oxygen and tie the two bags separately with rubber bands.
7 Load bags in styrofoam or carton boxes, or woven 'pandan' bags.
8 Transport megalopae early in the morning, late afternoon or during cool weather when temperature is low.
9 Acclimate the megalopae to the water temperature and salinity of the ponds before release.

NURSERY OF MUD CRABS

Culture of megalopa

Tanks. The megalopae can be cultured to fly size crablets in tanks at a density of 1-2 ind/liter. Straw or ribbon-like black nets, and cut PVC pipes (Fig. 26 B) are distributed on the tank bottom to serve as shelters when megalopa becomes crablet. Some straw or ribbon-like nets may be suspended in the water column. Salinity should be in the range of 20-32 ppt.

Artemia (5-7 day old, ≥2 mm long), minced fish or mussel are fed to megalopae. Small crabs are fed trash fish, mussel, and other bivalves (e.g. 'agihis') twice daily to satiation (Fig. 19). Feed ration should be given in the morning and in the late afternoon. The amount and size of feeds are adjusted based on the consumption and size of crabs. Excess feeds are siphoned out daily. About 30% of the volume of the rearing water is replaced every 5 days.

Net cages. Megalopae can also be cultured in net cages of 1 mm mesh size and 20 m^2 bottom surface area set in ponds (Fig. 22). Ponds are prepared following standard protocol prior to use. Bamboo poles support the cages and the bottom of the net is buried 3-5 cm into the soil. There should be a good growth of natural food in the pond before the megalopae are stocked at 50-70 ind/m^2.

Fig. 22. Net cages set in earthen brackishwater pond for culture of megalopae

Minced mussel or fish are fed to megalopae. Daily ration can be divided into two feedings.

Water depth is maintained at 80-100 cm. About 30-50% of the water is replaced weekly or during spring tide. Feeding of crablets is similar to those in tanks. Nets, straw or seaweeds (*Gracilaria*) can be used as shelters (Fig. 26 B). Crablets can be harvested and disposed after 3 weeks.

Harvesting, packing, and transport of crablets

Head count of the crablets in basins with small amount of water is preferable to avoid desiccation of the crablets. Soft-shelled or newly molted crablets should not be included in the transport. Mortality during transport is usually due to

molting especially for smaller crabs (≤1.0 cm), where molting is more frequent. The crabs should be transported early in the morning, late afternoon or during cool weather.

Transport with water

1 Before packing, acclimate crablets to 22-24ºC temperature by placing ice bags in the water. This is done to prevent molting and to lower oxygen consumption during transport.

2 Use double plastic bags measuring about 52.5 x 77 cm and add 2 liters of water. Pour the water with crablets gently into the plastic bags using the following loading densities for transport duration of <8 hours:

Crab size (cm CW)	Density (crabs/plastic bag)
0.4-0.6	1000
0.7-1.0	500-750
1.1-1.4	250-500

3 Put net or straw shelters inside the bags.

4 Saturate the inner bag with oxygen and tie the two bags separately with rubber bands.

5 Put the plastic bags in styrofoam (especially if transported via airplane) (Fig. 23) or box.

6 Maintain the temperature (22-24ºC) by placing wrapped ice on top of the plastic bags.

Fig. 23. Transport of crablets in oxygenated plastic bags

Transport without water (recommended for ≥ 0.8 cm CW crablets)

1 Line carton box (45L x 34W x 10D cm) with plastic sheet and put wet sand (Fig. 24) (about 0.5- 1.0 cm thickness depending on the size of the crablets) or damp cotton cloth.

2 Load crablets into the box using the following density for up to 8 hours transport duration:

Fig. 24. Transport of crablets in wet sand

Size (cm CW)	Density (crabs/box)
0.8 - 1.0	1000
1.1 - 1.6	300-500
3.0 - 3.5	100-150

3 Seal the box with packing tape and put small holes on top of the box for ventilation.

COMMON PROBLEMS AND SOLUTIONS

Egg loss in berried females

Eggs are sometimes detached from the abdominal flap due to microbial infection, ciliate infestation, failed fertilization, nutritional deficiency, or environmental stress. At longer incubation periods, the eggs may become infected with fungi and/or infested with ciliates and filamentous bacteria that retard development and cause mortality. Berried females are bathed in 150 ppm formalin for 30 minutes prior to stocking in hatching tanks to prevent fungal and bacterial infection. The egg mass should be submerged in the solution. During incubation (between spawning and hatching), 0.1 ppm Treflan can be applied every 2-3 days until hatching.

Shell disease

Shell disease, characterized by the presence of lesions or softened and darkened areas on the exoskeleton (Fig. 25), is the most common problem in crabs held in tanks. Erosion and pitting of the exoskeleton may lead to secondary invasion of the soft tissues by pathogenic bacteria and fungi. Molting rids a crab of shell disease but older crabs have higher prevalence of this disease due to longer intervals between molting. To prevent fouling during captivity, the exoskeleton is brushed gently to keep the exoskeleton smooth and glossy.

Fig. 25. Mud crab with brown patches on the exoskeleton

Larval diseases

The most serious disease of larvae is luminous vibriosis due to the bacteria *Vibrio harveyi*. The condition is best observed by monitoring the tanks at night and watching out for luminous larvae. This occurs as a result of bacterial multiplication in infected larvae resulting in mortalities. To lessen this occurrence, seawater should be disinfected by chlorination or by other means. Since luminous bacteria are present in nearshore seawater, their numbers should be below 10^2 colony-forming units/mL to prevent infection in crab larvae.

Fungal infection is potentially serious. Monitoring of larvae by daily microscopic examination will make early detection of fungus in infected larvae possible.

Effective prophylatic methods through application of 0.1 ppm Treflan or 5-10 ppm formalin can be done.

Fouling organisms like sessile and saprophytic protozoans and filamentous bacteria may cause problems if these attach heavily on the gill surface and interfere with respiration. These organisms proliferate in rearing water with high organic load due to uneaten feeds, dead algae and larvae, and other debris. Water change should be done to remove organic matter and minimize growth of fouling organisms.

Diagnosis, prevention, and control of common diseases of mud crabs are discussed in detail by Lavilla-Pitogo and de la Peña (2004).

Incomplete molting

Incomplete molting specifically from zoea 5 to megalopa usually leads to death. Poor nutrition, low water temperature, and high dosage of chemicals are the common causes of incomplete molting. Larvae should be provided with essential fatty acid in the diet and optimum water temperature (Table 3).

Cannibalism

Strategies to reduce cannibalism include reduction of density, provision of sufficient shelters, size grading, trimming of dactylus and pollex, and removal of cheliped (Fig. 26). Chelipeds are removed only in smaller crabs (<5 cm CW) because regeneration is faster than in bigger crabs. However, trimming of dactylus and pollex, and removal of chelipeds are tedious, hence, applicable only to small population of crabs.

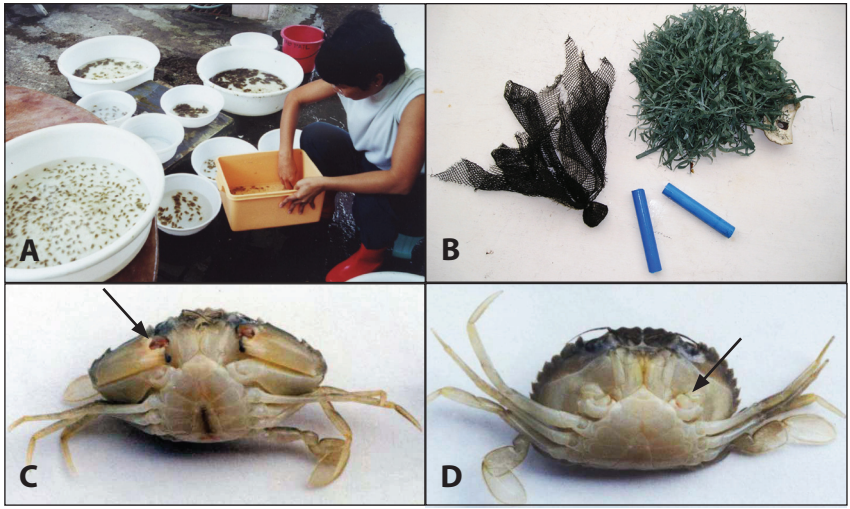


Fig. 26. Strategies to reduce cannibalism in juveniles: A) size grading, B) provision of enough shelters, C) trimming of dactylus and pollex, and removal of chelipeds

ECONOMICS OF HATCHERY

The acceptability of a new technology like the mud crab hatchery depends on its profitability. The economics of producing juveniles for a 5-year project is shown below. The assumptions (Table 4) are based on the runs that have been conducted at the SEAFDEC/AQD Crustacean Hatchery, where 1 to 10 ton larval tanks are used.

The technology in this manual starts with the sourcing of females as broodstock and ends with the production of fly size crablets. Existing shrimp or fish hatcheries may be rented and used for production of crablets. The capital assets relevant to this technology and the depreciation schedule using straight line method computation are given in Table 5.

A cost and returns analysis of a rented hatchery where minor upgrading and repair of the plumbing, aeration, and electrical system are needed before it can be used for crablet production is shown in Table 6; analysis of operations in a newly-built hatchery complex is shown in Table 7. Comparison shows that net income is higher with newly-built hatcheries (₱140,845/run) than with a rented hatchery (₱121,586/run). This could be attributed to the higher estimated rent of facilities (₱50,000/run) in contrast with depreciation cost (₱22,807/run) of a newly-built hatchery. Thus, economic indicators with reference to operating costs also showed better results in favor of newly-built facilities, i.e. lower break-even price (₱1.53/crablet) and lower break-even quantity (49,052 crablets/run).

Table 4. Assumptions used in the computation of costs and returns for the hatchery of mud crab

Broodstock	
% of broodstock that will survive and mature	45
Average zoeae produced/female	1,200,000
Average body weight of broodstock	600 g
Total number of broodstock required	7
Hatchery	
Stocking density of larvae	80/liter
% of zoea that will survive to the megalopa stage	3
% of megalopa that will survive to fly-size crablets	50
Number of runs/year	6

However, due to the lower investment cost associated with a rented hatchery (₱160,000) than with new facilities (₱819,200), economic variables with reference to recovery of investment costs obviously revealed better results from hatchery operations using rented facilities. For example, operations in rented hatchery showed shorter payback period (0.21 years) and higher return on investments (456%).

Financial analysis over the five-year project duration (Table 8) showed that it is better to rent existing hatcheries because of higher internal rate of return (IRR) at 455% and discounted benefit-cost ratio (BCR) at 16.02. In comparison, IRR is 99% and discounted BCR is 3.64 with a new hatchery. This shows that the overall lower cost of investments and lower depreciation cost in rented facilities could sufficiently overcome the rental cost. Nevertheless, either in rented or newly-built hatcheries, the analysis presented in this chapter demonstrates the profitability of mud crab hatchery technology based on the runs conducted at SEAFDEC/AQD.

Table 5. Depreciation schedule of capital assets in a new mud crab hatchery

Item	Quantity	Total cost (₱)	Economic life (yrs)	Depreciation/ year (₱)
Larval rearing tanks*	80 T	80,000	5	16,000
Natural food tanks*	184 T	159,000	5	31,840
Other tanks	10 T	20,000	10	2,000
Reservoir with filter tank	100 T	200,000	10	20,000
Drainage system		20,000	10	2,000
Water pump	1 pc	15,000	2	7,500
Air blower	1 pc	30,000	3	10,000
Generator	1 pc	30,000	3	10,000
Electrical system		50,000	10	5,000
Plumbing		10,000	5	2,000
Roofs, sheds, walls ,etc		100,000	10	10,000
Fence		25,000	2	12,500
Office and laboratory		80,000	10	8,000
Total		819,200		
Depreciation/year				136,840
Depreciation/run				22,807

*canvas tanks

Table 6. Costs-and-returns of a rented hatchery with a total larval tank capacity of 80 tons. The final product is fly-size crablets.

Item	Quantity	Unit cost (₱)	Total cost (₱)
Sales	96,000	3.00	288,000
Variable cost/run			
Broodstock (kg)	7	350	2,489
Broodstock feeds (kg)	75	18	1,344
Artemia (can)	8	1,350	10,560
Crablet feeds			1,000
Natural food starters			500
Fertilizers			240
Other chemicals			5,881
Other supplies (nets, hoses, etc)			20,000
Electricity			12,000
Marketing (2% of revenue)			5,760
Miscellaneous (5% variable cost)			2,989
TOTAL VARIABLE COST			**62,763**
Fixed cost/run			
Depreciation of equipment			8,250
Rent on land and hatchery			50,000
Labor			36,000
Interest on investment cost (12%)			3,200
Repair and maintenance (5% of fixed assets)			6,202
TOTAL FIXED COST			**103,652**
Total production cost/run			166,414
Total production cost/year (6 runs/year)			998,486
Net income/run			121,586
Net income/year at 6 runs/year			729,515
Capital assets			160,000
Payback period	0.21		
Return-on-investment	456%		
Variable cost/unit	0.65		
Break-even price (₱/crablet)	1.73		
Break-even quantity (crablets/run)	55,471		

Table 7. Costs-and-returns of a new hatchery with a total larval tank capacity of 80 tons. The final product is fly size crablets.

Item	Quantity	Unit cost (₱)	Total cost (₱)
Sales	96,000	3.00	288,000
Variable cost/run			
Broodstock (kg)	7	350	2,489
Broodstock feeds (kg)	75	18	1,344
Artemia (can)	8	1,350	10,560
Crablet feeds			1,000
Natural food starters			500
Fertilizers			240
Other chemicals			5,881
Other supplies (nets, hoses, etc)			20,000
Electricity			12,000
Marketing (2% of revenue)			5,760
Miscellaneous (5% variable cost)			2,989
TOTAL VARIABLE COST			**62,763**
Fixed cost/run			
Depreciation			22,807
Rent on land			3,000
Labor			36,000
Interest on investment cost (12%)			16,384
Repair and maintenance (5% of fixed assets)			6,202
TOTAL FIXED COST			**84,392**
Total production cost/run			147,155
Total production cost/year (6 runs/year)			882,930
Net income/run			140,845
Net income/year at 6 runs/year			845,071
Capital assets			819,200
Payback period	0.83		
Return-on-investment	103.16%		
Variable cost/unit	0.65		
Break-even price (₱/crablet)	1.53		
Break-even quantity (crablets/run)	49,052		

Table 8. Financial analysis of operations of mud crab hatcheries over a five-year duration

New Hatchery

	Year 0	1	2	3	4	5	Total
Gross revenue		1,728,000	1,728,000	1,728,000	1,728,000	1,728,000	8,640,000
Investment cost	819,200			40,000	60,000		919,200
Total cost		882,930	882,930	882,930	882,930	882,930	4,414,650
Net income	(819,200)	845,070	845,070	805,070	785,070	845,070	3,306,150
NPV, 12%, 5 years	(731,429)	673,685	601,504	511,637	445,470	428,139	1,929,005
IRR%							99%
Discounted BCR							3.64%

Rented Hatchery

	Year 0	1	2	3	4	5	Total
Gross revenue		1,728,000	1,728,000	1,728,000	1,728,000	1,728,000	8,640,000
Investment cost	160,000			40,000	60,000		260,000
Total cost		998,486	998,486	998,486	998,486	998,486	4,992,430
Net income	(160,000)	729,514	729,514	689,514	669,514	729,514	3,387,570
NPV, 12%, 5 years	(142,857)	581,564	519,254	438,199	379,900	369,594	2,145,654
IRR%							455%
Discounted BCR							16.02

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APPENDIX

Some useful unit equivalents:

1 gram (g)	= 1,000 mg = 1,000,000 (or 10^6) µg
1 kilogram (kg)	= 1,000 g = 1,000,000 mg
1 micron (µm)	= 1,000 ng or nannogram
1 millimeter (mm)	= 1,000 µm
1 centimeter (cm)	= 10 mm
1 meter (m)	= 100 cm = 1,000 mm = 1,000,000 µm
1 liter (L)	= 1,000 mL = 1,000,000 µL
1 ton (water)*	= 1 m^3 = 1,000 L
parts per thousand (ppt)	= mg/g = g/kg = mL/L = L/ton = mg/mL* = g/L * = kg/ton
parts per million (ppm)	= mg/L* = mL/ton = mg/kg = g/ton

* Based on density of water which is 1 g/mL

GLOSSARY

Berried female - crab that has released eggs; so called because eggs are attached through filaments and egg mass appears like berries

Cannibalism - eating the same species

Crablets - all juvenile crabs with carapace width of 1-3 cm

Exoskeleton - body or shell of a crab

Hatching efficiency, *Artemia* - grams of cysts that will produce one million nauplii

Hatching rate - the percentage of eggs which hatch into the nauplius (*Artemia*) or zoea (crabs) stage

Megalopa - the larval stage after zoea and prior to crab instar (plural form: megalopae)

Molt - to shed off the shell

Prophylaxis - any means to prevent diseases (e.g. application of chemicals)

Regeneration - growing back of lost limb or body part, characteristic of crabs

Salinity - concentration of dissolved salts

Setae - spines or hair-like projections

Spermatheca - anatomical structure in female crabs where spermatophore is deposited during mating (see Fig. 7B)

Spermatophore - sac-like structure enclosing spermatozoa in males, deposited in spermatheca of females during mating

Thoracic sternite - pertaining to the segmented chest cavity located on the ventral side of the crab

Zoea - the first larval stage in crabs (plural form: zoeae)

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