AQUACULTURE EXTENSION MANUAL NO. 34 MARCH 2003

BIOLOGY AND HATCHERY OF MUD CRABS *Scylla* spp.

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For comments and inquiries: Training and Information Division
SEAFDEC Aquaculture Department
Tigbauan, Iloilo 5021, Philippines
Tel. No. (63-33) 5119172
Fax (63-33) 5118709
E-mail training@aqd.seafdec.org.ph
tvp@aqd.seafdec.org.ph
devcom@aqd.seafdec.org.ph
AQD website http://www.seafdec.org.ph

FOREWORD

Farming of the mud crabs *Scylla spp.* has been practiced in the Philippines for decades, but it has received more attention recently due to the decline of the prawn industry. Mud crabs have been identified as an alternative export and cash crop because it is tasty, in high demand in many countries, profitable to farm, and easy to transport.

Production of market-size mud crabs has been achieved by collecting juveniles and stocking them in ponds or pens in mangroves. The expanding market for mud crab has led to intensified collection of wild seed for grow-out, thus threatening the wild population. There is a need to produce seed from hatcheries to ensure the sustainability of mud crab farming.

Studies on mud crab at the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC/AQD) started in 1977, but were soon discontinued to give way to higher priority species at that time. Studies were resumed in 1997 in collaboration with the Australian Centre for International Agricultural Research (ACIAR) mainly to develop seed production techniques. Since then, mud crab seed production has been a continuing activity at SEAFDEC/AQD. In 1999, SEAFDEC/AQD offered on-the-job training to hatchery technicians. Due to the increasing interest, the first training course on mud crab seed production was offered in October 2001 under the sponsorship of ACIAR. To date, three training courses have been offered by SEAFDEC/AQD to both local and international participants. The mud crab hatchery technology was also disseminated in the Philippines through the Fisheries Technology Caravan organized by the Bureau of Fisheries and Aquatic Resources and SEAFDEC/AQD. Hatchery-reared crab juveniles are now being grown in ponds in the Visayas and Mindanao.

The hatchery protocol developed at SEAFDEC/AQD is described in this manual. We hope this would benefit present and prospective investors, hatchery operators, technicians, instructors, and students.

Rolando R. Platon
Chief

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INTRODUCTION

The mud crabs, *Scylla* spp., (Family Portunidae) are valuable components of coastal fisheries in many Asian countries. In the Philippines, mud crab culture started with low-density stocking of wild juveniles in polyculture with fish or shrimp and developed into monoculture in brackishwater ponds and cages. Recently, an integrated mangrove-mud crab farm system has been shown to be technically feasible.

Further expansion of crab farming is limited due to the lack of juveniles, which are sourced from the natural habitat. The catch of juveniles has declined over the last decade. The development of commercially viable hatchery techniques is important for sustainable crab aquaculture as well as fisheries management. Recognizing the need of the industry, SEAFDEC/AQD developed a technology for the mass production of mud crab seed.

There are advantages of using hatchery-reared over wild sourced juveniles for mud crab farming. These are:

- uniformity in size
- certainty of identification, especially in smaller juveniles
- availability throughout the year
- absence of predators and other undesirable species

This manual describes the principles and procedures for spawning the mature crabs (*Scylla serrata*, *S. tranquebarica*, and *S. olivacea*) and rearing the zoeae to juveniles. Hatchery conditions should satisfy the ecological requirements of each specific stage, thus the manual starts with a section on biology of mud crabs.

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

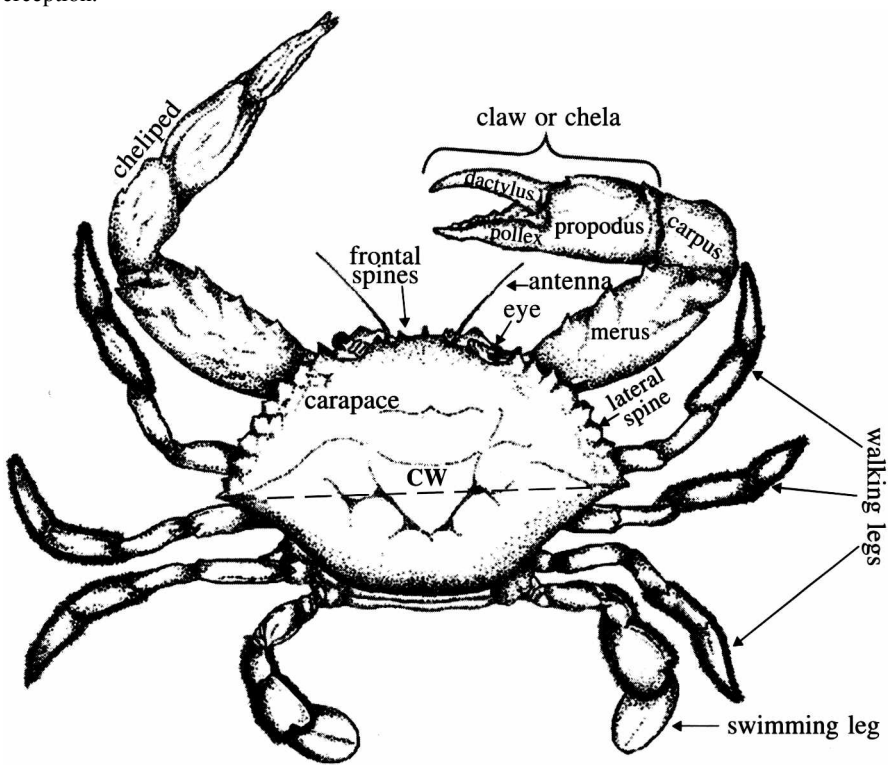


Fig. 1. Top view of adult mud crab indicating major external parts.
CW - internal carapace width is a measure of size in crabs

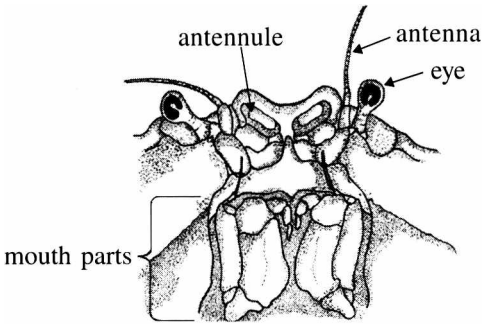


Fig. 2. View of the mouth and other parts of the head (modified from Ng, 1998)

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.

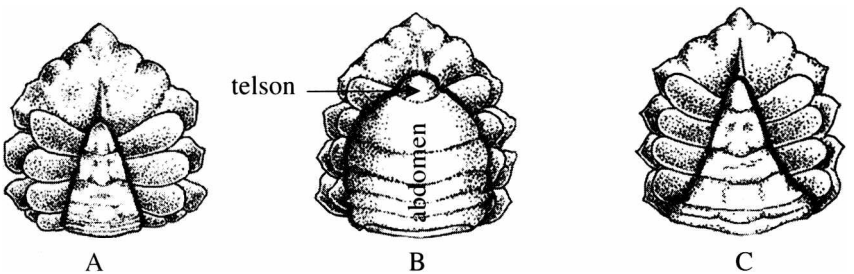


Fig. 3. The underside of mud crabs: A) immature female, B) mature female, and C) male

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 locking mechanism keeps the abdominal flap in place.

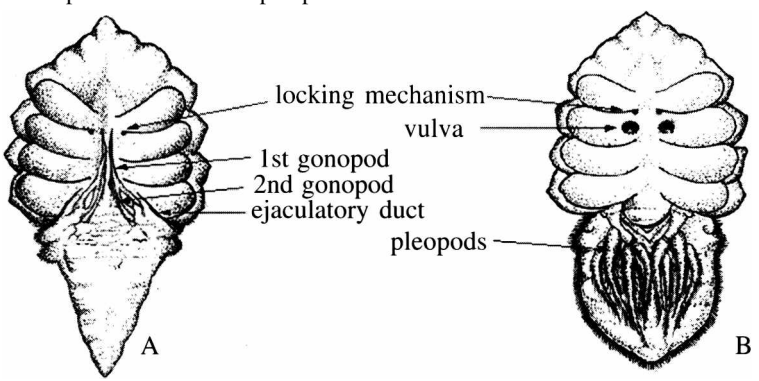


Fig. 4. Abdominal cavity of mud crab showing A) the gonopods of male and B) vulva of female

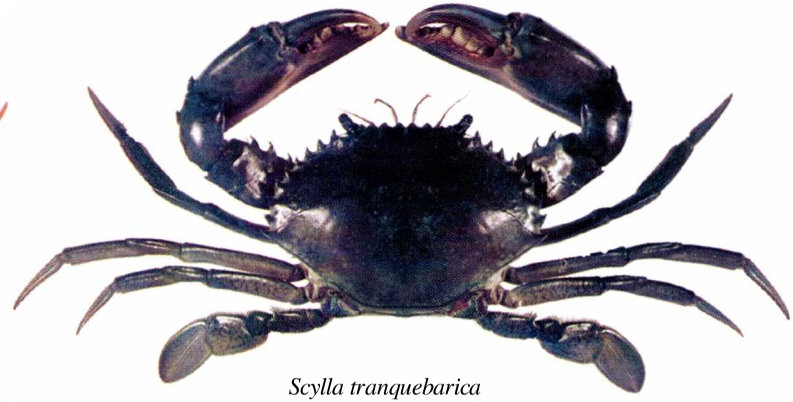
Identification

The genus *Scylla* includes *S. serrata, S. tranquebarica, S. olivacea* (Fig. 5) and *S. paramamosain.* The four species can be distinguished by the external characters listed in Table 1. The first three species are common in the Philippines, *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')	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; 'pulang alimango')	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

Scylla serrata



Scylla tranquebarica

Scylla olivacea

Fig. 5. The three species of *Scylla* commonly found in the Philippines

Life History and Habitat

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

Scylla serrata prefers more oceanic waters (28-35 ppt). The other three species of *Scylla* prefer less saline waters (18-25 ppt). The life cycle of the mud crab is illustrated in Fig. 6. Courtship and mating occur in brackish waters. Mature *S. serrata* females migrate offshore to spawn. The three other species of *Scylla* spawn in lagoons, bays, inlets and coastal seas within a few kilometers of mangrove habitats.

Spawned eggs attach to the pleopod hairs of the abdominal flap. Eggs hatch into zoeae and pass through five stages (zoea 1 to 5), after which they become megalopae. 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-adults prey on bivalves. Adult crabs eat mainly burrowing and attached bivalves, and small crabs.

Molting

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. The crab molts 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.

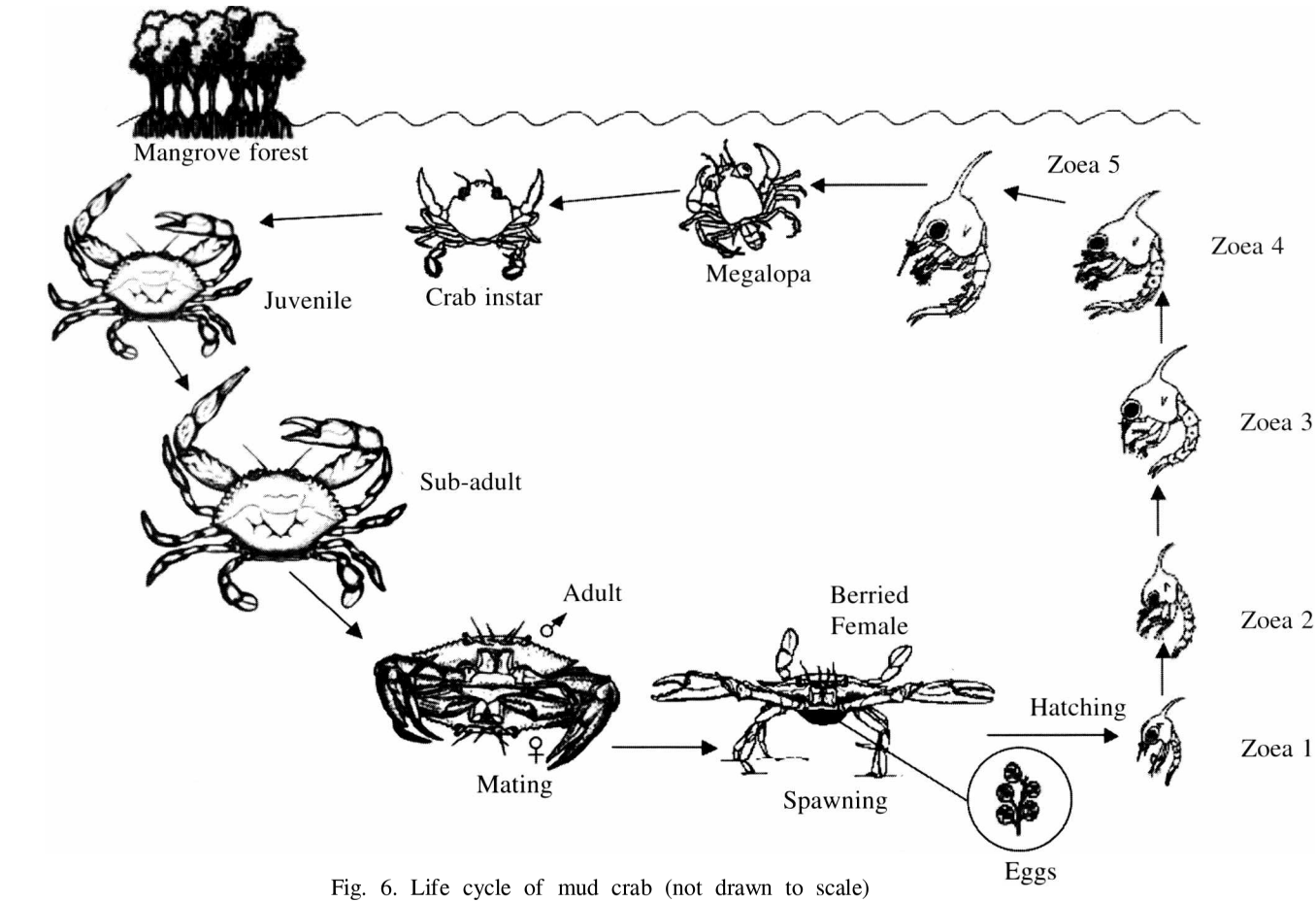


Fig. 6. Life cycle of mud crab (not drawn to scale)

Sexual Maturity

Male

The testes are paired organs next to the hepatopancreas under the carapace. Each testis connects to a vas deferens (a thin white, coiled tube) (Fig. 7A) and to an ejaculatory duct that opens at the base of the first gonopods (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 under the carapace. 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. Without dissecting the female crab, mature ovaries can be seen by carefully depressing the first abdominal segment adjacent to the carapace.

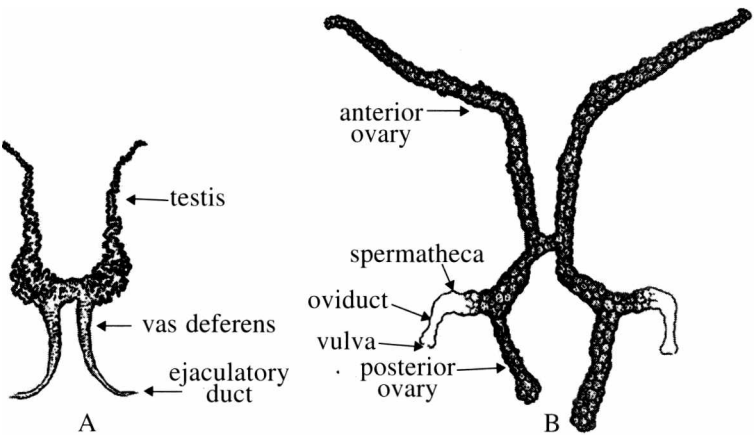


Fig. 7. A) Testes and B) ovaries of mud crab

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 under surfaces meet (Fig. 8) with abdomens extended. With the aid of the gonopods, the spermatophores are released through the ejaculatory duct and inserted into the vulvae of the female and

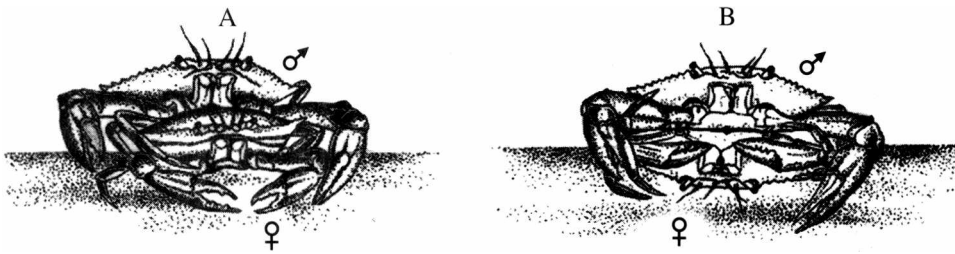


Fig. 8. A) Male mud crab holds the female underneath, and B) turns the female around

stored in the spermathecae. Copulation lasts only a few days, but the male may continue to protect the female until the shell hardens.

The spermatophores can be retained through a molt and remain viable for long periods. The sperm received during one mating can fertilize 2-3 batches of eggs. However, the third batch of eggs may have 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 spermatheca. The eggs pass through the vulvae and attach to the pleopod hairs of the abdominal flap. The newly spawned eggs appear opaque brilliant orange. 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.

The number of eggs produced by a female increases with size and may range from 1 to 6 million eggs per female in a single spawning. One female can produce at least three batches of eggs.

At SEAFDEC/AQD, the number of zoeae produced per spawning for each species is as follows:

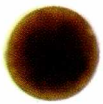
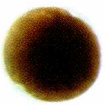
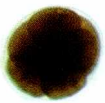
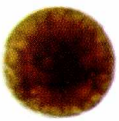
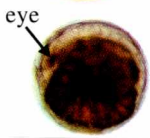
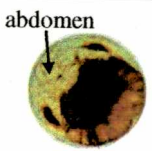
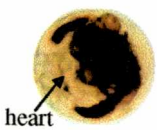
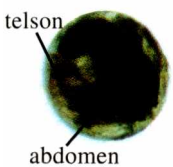
- *S. serrata* (350 - 700 g females): 0.8 to 5 million zoeae
- *S. tranquebarica* (240 - 300 g females): 0.7 to 3 million zoeae
- *S. olivacea* (360 - 465 g females): 0.4 to 2.7 million zoeae

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 0.33 to 0.35 mm in *S. serrata.* Embryonic development is shown in Table 2.

It takes 9-14 days for mud crab eggs to hatch. The duration of embryonic development varies with temperature and other factors.

Table 2. Embryonic development of giant mud crab at 27-29.5 °C

Photo	Stage	Description	Time after spawning
	Precleavage	Newly spawned egg filled with yolk.	0 hours
	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

Zoea has long rostral and dorsal spines, and short lateral spines on the carapace. Larval development of mud crab is shown in Fig. 9. It takes 16-18 days from zoea 1 to megalopa stage and another 7-10 days to the first crab stage.

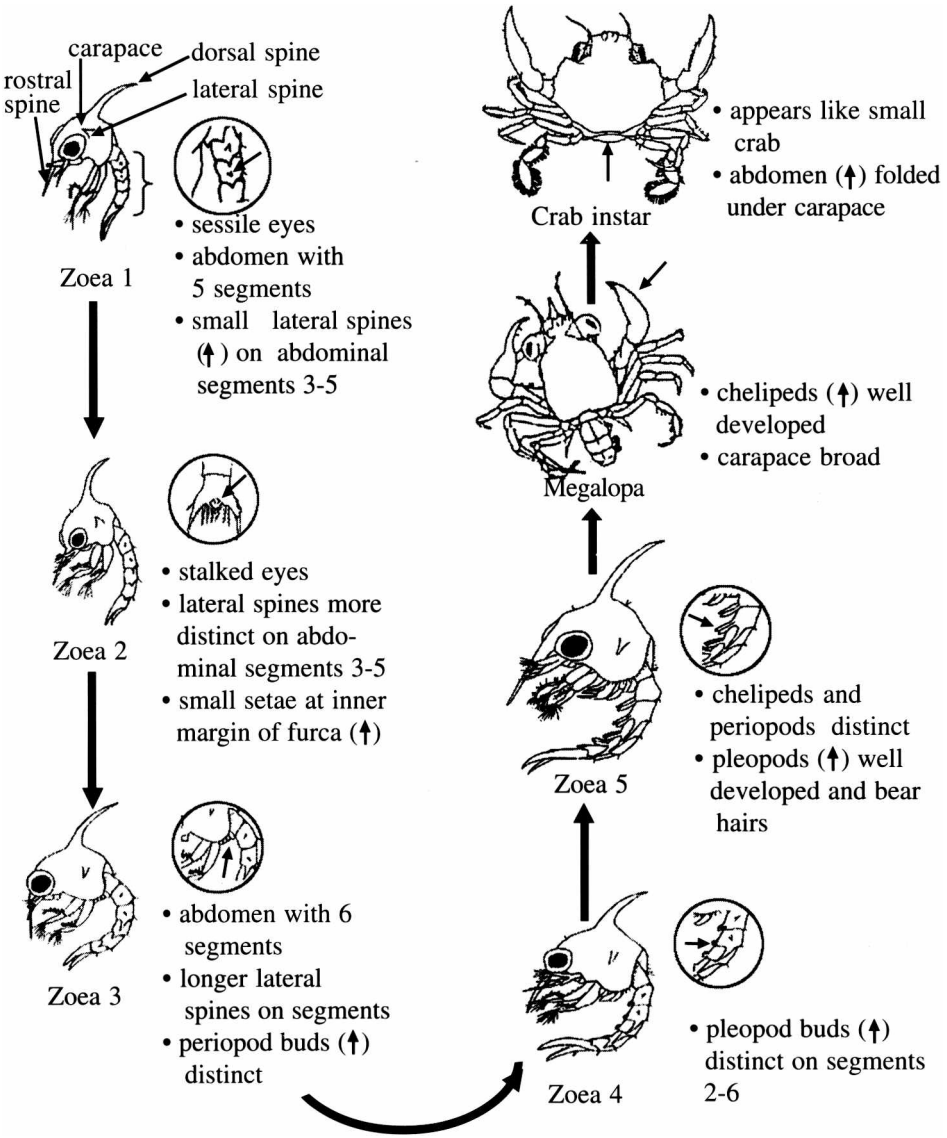


Fig. 9. Larval stages of the mud crab and the characters that differentiate them (illustrations from Dr. David Jones)

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 coralline shores where clean sea water can be pumped easily. It should be far from possible sources of pollution. Good water quality should be available throughout the year.

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
   Fresh water 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 Layout

The size of the mud crab hatchery depends on the target production and the financial capability of the investor. A sample layout of a hatchery with a total rearing tank capacity of 80 tons is shown in Fig. 10. This hatchery is capable of producing about 192,000 megalopae/run. The ratio of rearing tanks to natural food tanks is 1:3.

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 sand. Cut PVC pipes (20 cm diameter x 30 cm length) are provided as shelters for crabs.

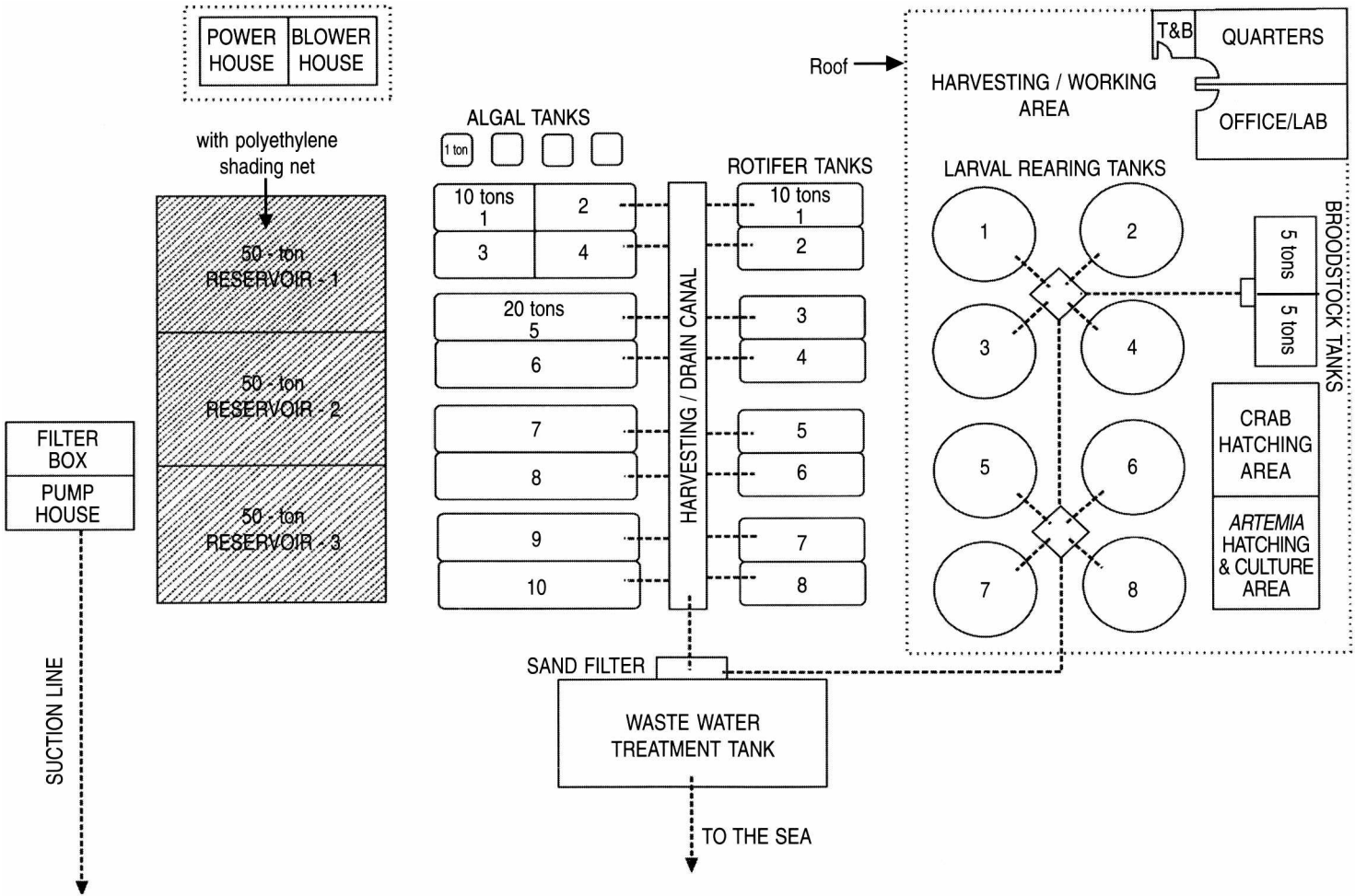


Fig. 10. A sample lay-out of a mud crab hatchery

2. Hatching tanks

Berried crabs are held separately in 500 to 1000-liter or 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 to 15-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. 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 should be provided to allow illumination but 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. Containers 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 be 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 foods in suspension and to maintain optimum dissolved oxygen levels. An air blower is used to supply aeration.

Seawater Supply

Sea water may be pumped directly from the sea or through a sump pit. Water may be prefiltered through the sand in the sea bed (Fig. 11) or directly pumped to the hatchery. Sea water is then passed through an elevated sand filter (Fig. 12) prior to storage in the reservoir. The sand filter is made of graded gravel and sand that filter particulate matter.

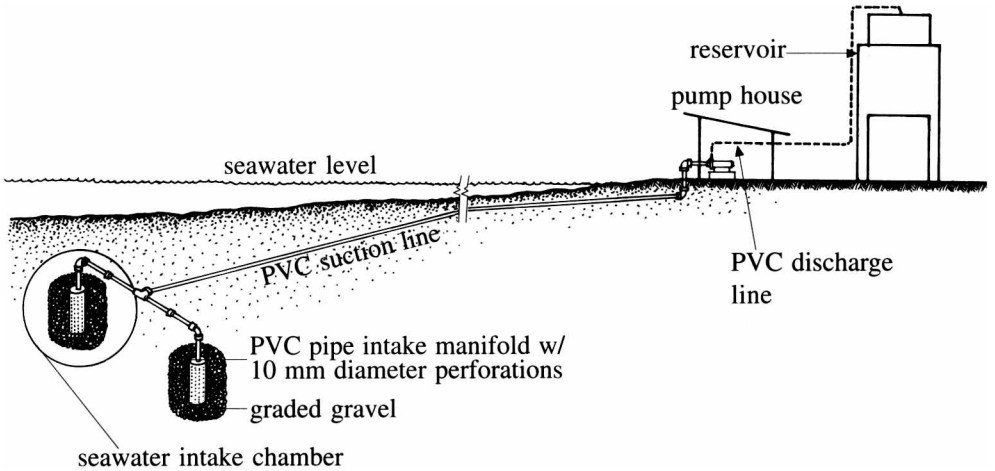


Fig. 11. Seawater intake system

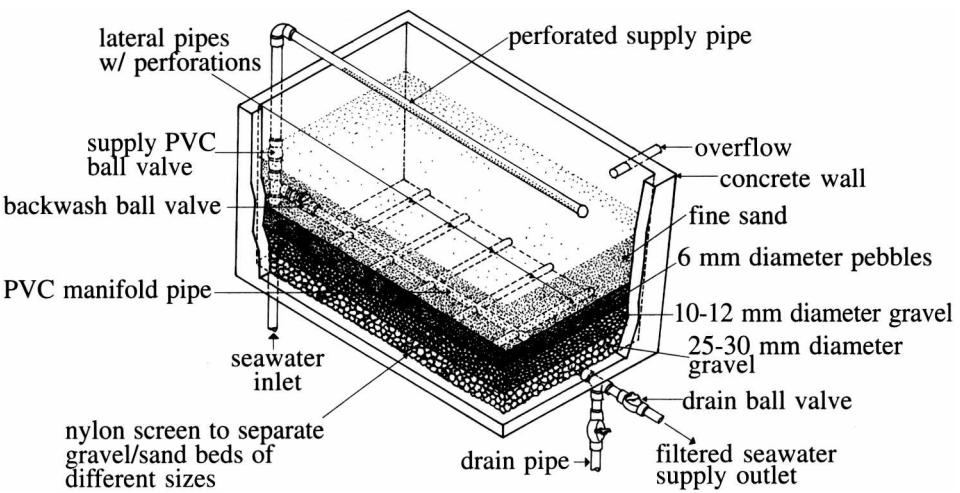


Fig. 12. Sand and gravel filtration unit

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, and for detecting contaminations in the culture and abnormalities of the larvae
- Chlorine test kit - for determining residual chlorine concentration in the water to know the amount of thiosulfate needed
- Hemacytometer - for determining the number of algal cells in a given volume
- 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 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, native baskets, and rubber bands - for harvesting and transporting of crabs

Preparation of Tanks and Sea Water

Tank Preparation

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

To prepare the tanks

1. Fill the newly constructed or painted tanks with fresh water or sea water 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 fresh water.
4. Prepare 200 ppm hypochlorite in a bucket and splash on tank walls and bottom. Scrub tank and rinse well with fresh water.
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

Water Treatment

Water for algal culture, for holding the breeders, and for larval rearing is treated with 10-15 ppm calcium hypochlorite (*HTH dry chlorine or similar product) overnight in the reservoir. Hypochlorite is an oxidizing agent that kills or inhibits the growth of harmful microorganisms. Since it is also toxic to crab, the chlorinated water should be strongly aerated to release the chlorine residues or treated with sodium thiosulfate to deactivate the residues.

To chlorinate sea water

1. Pump sea water 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 sea water 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.

To apply 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 fresh water. 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 1-7.

*Mention of a product brand does not mean endorsement by authors.

Production of Natural Food

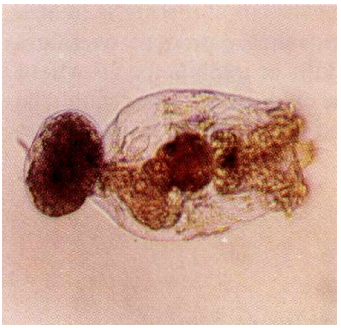


Fig. 13. Adult rotifer *Brachionus rotundiformis* (190-215 µm)

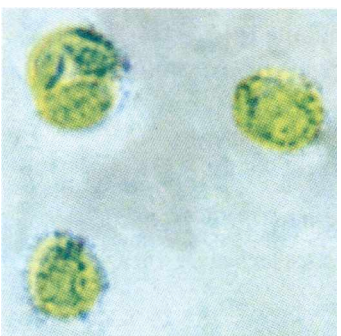


Fig. 14. The unicellular alga *Nannochlorum* sp. (4-8 µm)

Mud crab zoeae eat rotifers, *Brachionus* (Fig. 13). Rotifers in turn eat a wide variety of microalgae but *Nannochlorum* (Fig. 14) (formerly identified as *Chlorella vulgaris),* a single-celled green alga, is more commonly used in the hatchery due to its ease of culture.

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, there must be available three sets of tanks for the scale-up culture. About 10-20% of starter culture is needed as inoculum. A sample schedule for a hatchery with 80-ton rearing tank capacity is shown in Fig. 15.

Culture of *Nannochlorum* or *Chlorella*

To culture *Nannochlorum* or *Chlorella*

1. Obtain the initial inoculum of *Nanno hlorum* from the natural food laboratory of SEAFDEC/AQD or a nearby hatchery. In Fig. 15, this is about 32 liters for a 160-liter initial culture.
2. Fill a clean tank with sea water (preferably 25 ppt) to 80% of the desired volume and add the inoculum.
3. 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.

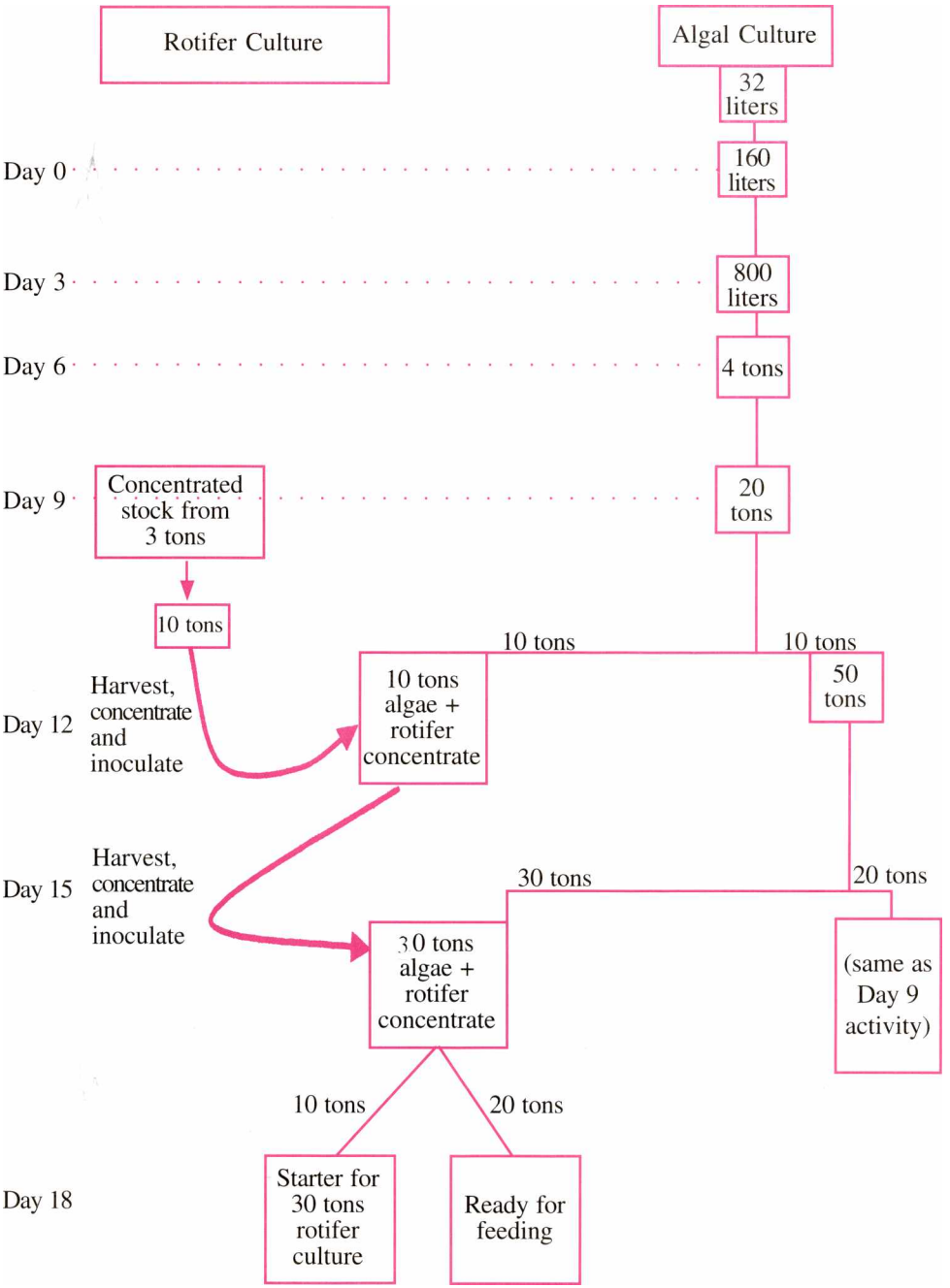


Fig. 15. Production schedule for scale-up of algae and rotifers for larval food. This schedule represents one set of culture. Another set must be started on day 2 and the third set on day 3 so that food will be available daily.

Culture of the Rotifer *Brachionus*

To culture rotifers

1. Obtain rotifers from SEAFDEC/AQD or a nearby hatchery. The volume of inoculum must be at least 30% (not concentrated) of the total volume. In Fig. 15, 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. 15.
2. Add the concentrated rotifers to the *Nannochlorum* culture. The initial density after addition must be 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 algae are more nutritious for crab larvae than rotifers fed 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 sea water, the cysts release free-swimming nauplii that can be fed directly to crab zoeae and megalopae.

To hatch *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 (0.5-3 *Artemia*/ml)
H = hatching efficiency of given batch (g cysts/million)
V = total volume of larval tanks (tons)

3. To disinfect cysts, dissolve thoroughly 0.2 g calcium hypochlorite/ liter of sea water in a clean *Artemia* hatching tank. Aerate.
4. Place the cysts in the hatching tank at 1.5 grams cysts/liter of water. After 30 minutes, harvest and wash the cysts thoroughly.
5. Place the disinfected cysts in a hatching tank with clean sea water. Aerate the water vigorously. Incubate for 18-24 hours as specified on the product label. Illuminate the tank to ensure efficient hatching.

To harvest *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 150 µm mesh size.

3. Wash the nauplii with sea water or fresh water. Transfer nauplii to a pail with sea water and feed to crab larvae.

To culture *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 sea water.

2. Provide the tank with moderately strong aeration with coarse air stones.

3. Prepare a suspension of 1 kg rice bran in 4 liters sea water. Squeeze the suspension through a 60 µm plankton net to obtain the particle sizes suitable for *Artemia.* Dilute the suspension in a container and provide strong aeration. The suspension can be applied to a 2-ton *Artemia* culture twice daily.

4. Feed to *Artemia* frequently or in continuous drips. Avoid overfeeding to maintain good water quality. Use a secchi disc to determine water transparency. Maintain transparency at 10-15 cm during the first three days and 20-25 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 flowthrough removal everyday.

6. Harvest the *Artemia* after 5-7 days depending on the desired size. *Artemia* reach adult size in about 2 weeks at 25-29 °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 Breeders

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. 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.

Mated females are difficult to determine 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 death of eggs during incubation.

To select and transport breeders

1. Choose active crabs that have clean and hard shell, and complete limbs. The minimum recommended body weight is 450 g (12.5 mm CW) for *S. serrata* broodstock, and 320 g for *S. tranquebarica* (12.2 mm CW) and *S. olivacea* (11.5 mm 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), plastic box, or cardboard box with holes for ventilation. Line the bottom with damp cloth, paper, or leaves.

5. Put berried crabs in pails or styrofoam box with clean sea water, preferably from the source where crabs are collected. Put enough sea water 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 dehydrate 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.

To acclimate and disinfect breeders

1. Prepare two basins, one empty and the other containing 150 ppm formalin (3 ml formalin for every 20 liters of sea water).
2. Put crabs in the empty basin and pour sea water 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.
3. Transfer crabs to basin containing 150 ppm formalin for 30 minutes to disinfect.
4. Untie crabs and stock in broodstock tanks. Put crabs in hatchery tanks. Aerate moderately.

Eyestalk Ablation

The hormone inhibiting gonad maturation in crabs is found in the eyestalk. By ablating one eyestalk, the production of the hormone is reduced to a level at which maturation can proceed. Females with immature ovaries may be ablated for faster maturation.

To ablate females

1. Allow crabs to recover from handling and transport stress for 2-3 days before ablation.
2. Tie crabs just before eyestalk ablation.
3. Ablate crabs by either of the following methods:
   a. Incise the eyestalk with a sharp and sterilized blade (Fig. 16). Squeeze out contents. Apply terramycin ointment on the ablated eyestalk.
   b. Heat forceps until red hot. Clip off eyestalk by clamping the base with the red-hot forceps.
4. Put the crabs in a basin with only a small amount of sea water so as not to wet the ablated eyestalk.
5. After 30 minutes, transfer the crabs into a broodstock tank at 1 crab/ m^2. Cover the tank to avoid disturbance and leave only a small opening for air circulation.

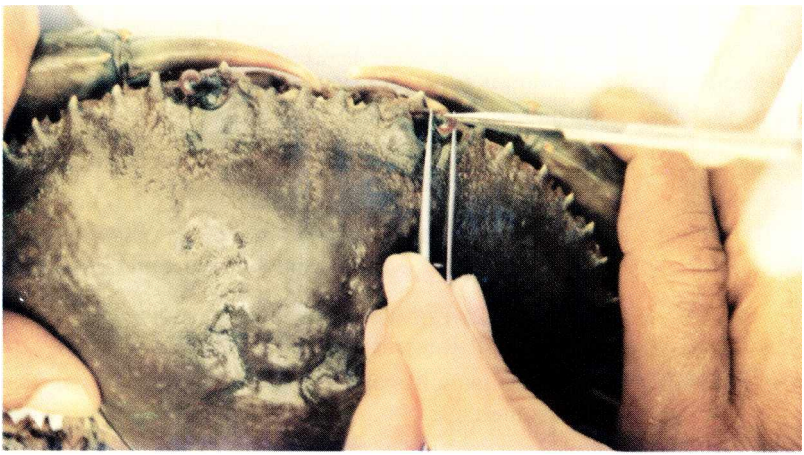


Fig. 16. Incision of eyestalk with blade

Feeding

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

To feed broodstock

1. Determine the feeding rate based on current food consumption and crab biomass.

2. Feed crabs with mussel meat, marine worms, or squid in amounts equal to 10-15% of crab biomass 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.

Water Management

About 80% of water is changed daily. Water depth is maintained at 30-40 cm. Water temperature and salinity are maintained at 26-29 °C and 30-34 ppt. The sand bottom is cleaned twice a week. A recirculating water system may also be used.

Spawning

Crabs that spawn in broodstock tanks are easy to recognize from the abdominal flap extended 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.

To care for 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 sea water.
3. Feed crabs mussel meat, fish, marine worms, or squid at 10-15% of biomass 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 water every other day to prevent fungal infection.
7. Cover the tank with plywood.
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.

Larval Rearing

The SEAFDEC/AQD protocol for mud crab seed production in the hatchery described in the succeeding pages.

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 50-80 zoeae/liter. Only the zoeae from the first two spawnings are recommended for larval rearing.

*Mention of a product brand does not mean endorsement by authors.

To collect and stock 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 weakly flowing sea water (Fig. 17).

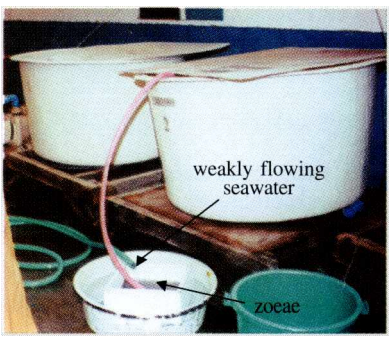


Fig. 17. Siphoning of zoeae into a harvesting box with 150 µm mesh size net. The net retains the zoeae while allowing the water to pass through.

4. Scoop out the zoeae with a bowl and put in 50-100-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:

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

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 computed amount of 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 and basin are similar. Allow the water to overflow in the basin and slowly release the zoeae into the rearing tank.

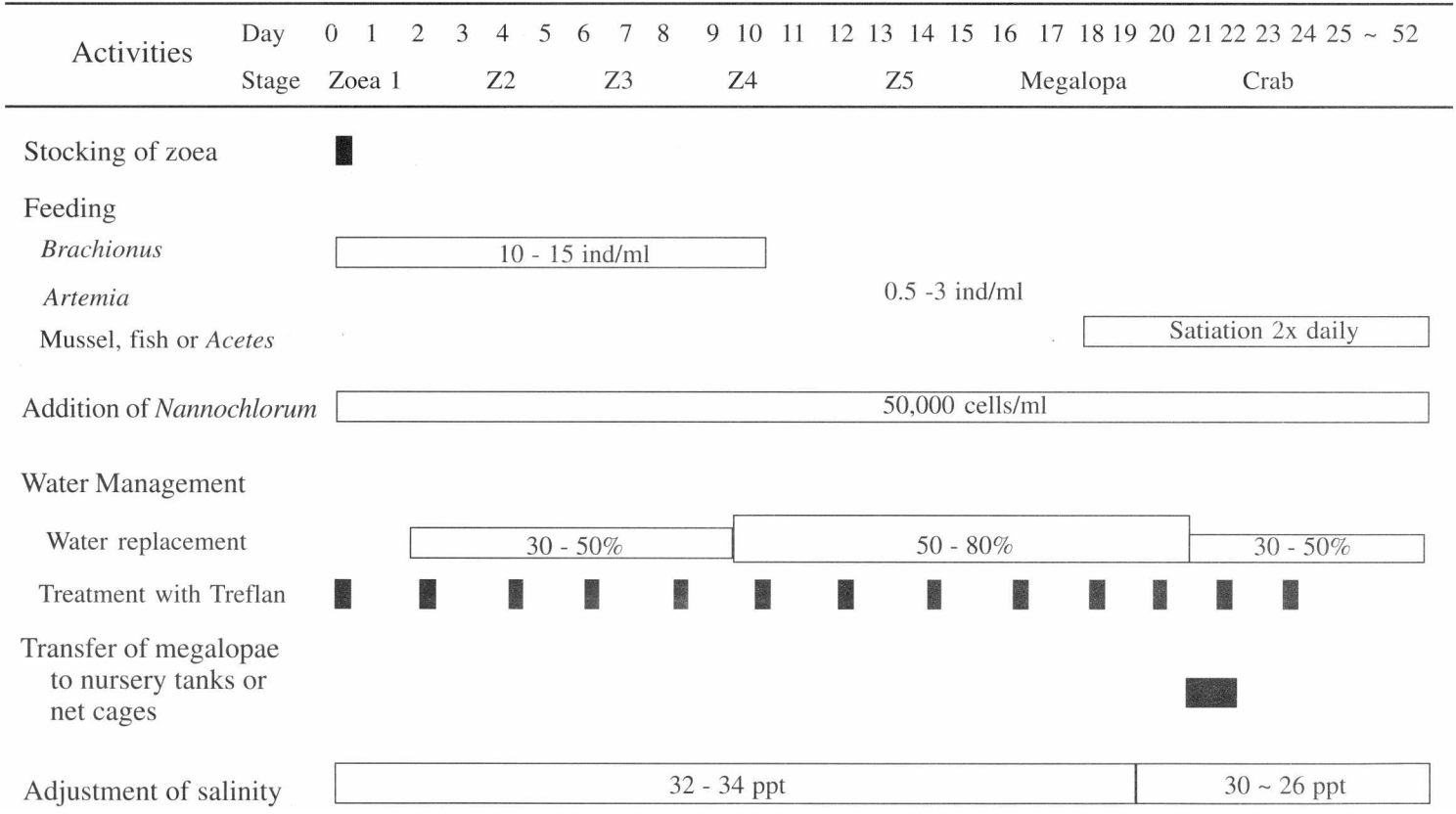


Fig. 18. Feeding and water management during a mud crab hatchery operation

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, copepods and oyster larvae are fed to crab larvae at different feeding levels. Rotifers are commonly fed to larvae because they are easy to propagate. The density of rotifers to be maintained in the rearing tank is 10-15/ml (Fig. 18). Newly hatched *Artemia* are given to late zoea 2 and larger larvae at 0.5-3/ml. Larger 5-7 day old *Artemia* are fed to zoea 5 and megalopa at 0.5-1/ml.

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, fish, or the small shrimp *Acetes* at 30-50% of biomass daily or to satiation. Crabs are fed twice a day.

To estimate algal density

1. Take samples from the algal tank and rearing tanks. Use clean test tubes.
2. Place a cover slip at the center of a hemacytometer (Fig. 19).
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).

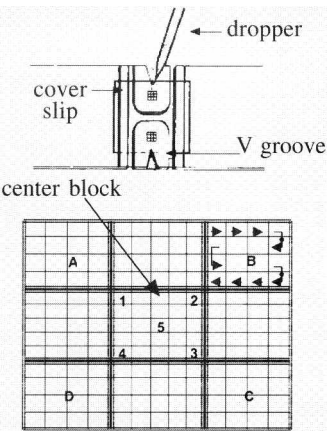


Fig. 19. Top view of a hemacytometer for counting algae

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.*

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

   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)

To estimate rotifer density

1. Get rotifer samples from the rearing tank and from the harvesting container. Put samples separately in clean 5-10 ml test tubes or beakers.

2. Pipet a 1 ml sample to each well of a modified Sedgewick Rafter counting chamber (Fig. 20).

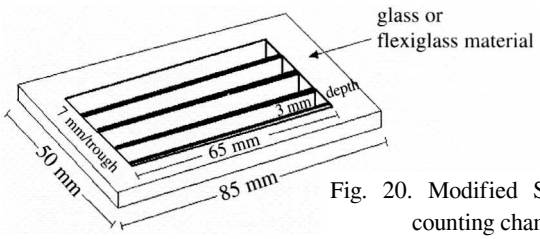


Fig. 20. Modified Sedgewick Rafter counting chamber for rotifers

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 the 1 ml sample.

5. Compute the volume of rotifers to be added to rearing tanks by the following formula:

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

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 sea water is used in rearing the zoeae to megalopae. The rearing water is replaced at 30% daily starting day 3 and up to 80% as larvae grow larger and when high levels of luminescent bacteria (1×10^2) are detected in the water (Fig. 18). Regular water change dilutes the concentration of toxic metabolites in the tank. Unchlorinated sea water can be used 1-2 weeks after the megalopae have molted to crab stage.

The suitable ranges of temperature and salinity for crab larvae are 27-31 °C and 25-34 ppt. Salinity may be reduced gradually from ambient (32-34 ppt) to 26 ppt at 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 at low stocking density. Using several tanks to rear megalopa up to juveniles at low density is not cost-effective because these tanks are better used for rearing the zoeae. Megalopae are better stocked in ponds which have wider surface area for dispersion. The ponds must be predator-free and have substantial zooplankton growth.

Healthy megalopae (4-5-day old or 21-22 days after hatching) may be harvested, packed, and transported with extra care.

To harvest, pack, and transport 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 by siphoning with a small hose (2-3 cm diameter) into a basin.

3. 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 4 if megalopae are to be stocked in ponds.

4. Place megalopae in double plastic bags (50 x 90 cm) at a loading density of 50 ind/liter in cool sea water (24-25°C). This density allows high survival in transport up to 9 hours.

5. Fill the inner bag with oxygen and tie the two bags separately with rubber bands.

6. Load bags in styrofoam boxes or woven pandan bags.

7. Transport megalopae early in the morning, late afternoon or during cool weather.

8. Acclimate the megalopae to the water temperature and salinity of the ponds before release.

NURSERY OF MUD CRABS

Culture of Megalopae to Juveniles

In Tanks

The megalopae can be stocked at 1-2/liter in 10-ton tanks. Black nets and cut PVC pipes are distributed as shelters on the tank bottom when megalopae become crab instars. Some nets are installed and suspended in the water column. Sand bottom may be provided when megalopae are grown until the juvenile stage. Megalopae can tolerate a salinity range of 20-34 ppt.

Artemia (5-7 day old, ≥2 mm long) are fed to megalopae. Small crabs are fed minced trash fish, mussels, small shrimps (*Acetes*), or bivalves ('agiis') twice daily to satiation (Fig. 18): Feed ration should be given 30% in the morning and 70% in the late afternoon. The amount and size of feeds are adjusted based on the consumption and size of crab. About 30% of the volume of the rearing water is replaced daily during the first 5 days and every two days thereafter.

In Net Cages

Net cages of 1 mm mesh size and 20 m^2 bottom surface area are set in ponds (Fig. 21). 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.

Artemia (5-7 days old) are fed to megalopae during the first 2 days in cages. Food is then changed to minced fish and mussel, placed on feeding trays with fine mesh net, or broadcasted. Daily ration can be divided into two feedings.

Water depth is maintained at 80-100 cm. About 50% of the water is replaced weekly. Feeding of crabs is similar to those in tanks. Nets and seaweeds (*Gracilaria*) can be used as shelters.

Fig. 21. Net cages set in earthen brackishwater pond for culture of megalopae

Harvest, Packing and Transport of Juveniles

Crabs can be transported even without water. A 40 x 20 x 10 cm cardboard box can be half filled with crabs as long as it has enough ventilation holes. The crabs should be transported early in the morning or late afternoon.

To harvest, pack and transport juveniles

1. In tanks, drain water and collect crabs. Remove crabs from shelters.
2. In ponds, lift net cages, but leave one end submerged in water (Fig. 22). Collect the crabs from the net. Lift the entire net and collect the remaining crabs.
3. Tie or trim pincers to prevent fighting among crabs.
4. Pack crabs inside woven bags, cardboard boxes, or bamboo baskets with ventilation holes. Put moist leaves, cloth, or newspaper in between layers of crabs.

Fig. 22. Harvest of juveniles in net cage

5. Sprinkle the crabs with water to keep them moist and cool. Partly cover the crabs with moist materials.

COMMON PROBLEMS AND SOLUTIONS

The common problems encountered in the crab hatchery include:

1. egg loss in berried females
2. shell disease in breeders
3. diseases of larvae
4. incomplete molting
5. cannibalism

Egg Loss in Berried Females

Eggs are sometimes detached from the flap due to fungal 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 increase mortality. Berried females are bathed in 150 ppm formalin for 30 minutes to prevent fungal and bacterial infections. The egg mass should be submerged in the solution. During incubation (between spawning and hatching), 0.1 ppm Treflan can be applied every 2 days.

Shell Disease

Shell disease, characterized by the presence of lesions or softened and darkened areas on the exoskeleton (Fig. 23), is the most common problem in crabs held in tanks. Erosion 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 wiped gently to keep the exoskeleton smooth and glossy.

Fig. 23. Mud crab with brown patches on the exoskeleton

Diseases of Larvae

The most serious disease of larvae is luminous vibriosis due to *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, sea water should be disinfected by chlorination or by other means. Since luminous bacteria are present in nearshore sea water, 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 prophylactic methods through application of 0.1 ppm Treflan can be done.

Fouling organisms like sessile ciliated protozoans and filamentous bacteria may cause problems if they attached 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 other substances shed upon molting. Water change should be done to remove organic matter and minimize growth of fouling organisms.

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.

Cannibalism

Strategies to reduce cannibalism include provision of sufficient shelters, size grading, trimming of dactylus and pollex, and removal of chelipeds (Fig. 24). However, chelipeds are removed only in smaller crabs (< 5 cm CW) because growth may be affected. Trimming of dactylus and pollex and removal of chelipeds are tedious and applicable only for a small population of crabs.

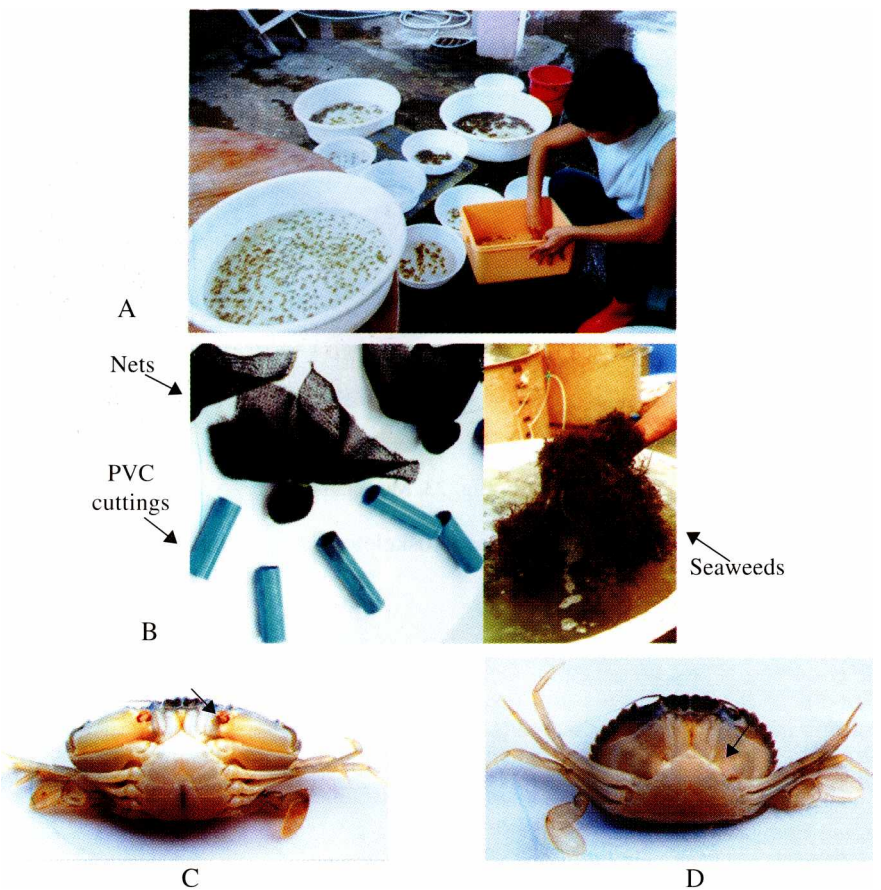


Fig. 24. Strategies to reduce cannibalism in juveniles : A) size grading, B) provision of enough shelters, C) trimming of dactylus and pollex, and D) removal of chelipeds

ECONOMICS OF HATCHERY AND NURSERY

The acceptability of a new technology like the mud crab hatchery depends on its profitability. The economics of producing juveniles is shown below. The assumptions (Table 3) are based on the runs that have been conducted at the SEAFDEC/AQD crustacean hatchery, where 10-ton larval tanks are used.

The technology in this manual starts with the sourcing of females as breeders and ends with the production of juveniles. Costs and returns of the following scenarios are shown: 1) hatchery phase alone where megalopa is the final product; 2) an integrated hatchery-nursery complex where the final product is juveniles; and 3) nursery phase alone where megalopae bought from the hatchery are stocked in ponds and grown to juveniles.

The capital assets and the depreciation schedule are given in Table 4. The straight line method has been used to compute for annual depreciation.

Table 3. Assumptions used in the computation of costs and returns for the hatchery and nursery of mud crab

Broodstock		
% of broodstock that will survive and mature	35	
Average zoea produced / female	1,200,000	
Average body weight of broodstock	0.5 kg	
Hatchery		
Stocking density of larvae	60	larvae/liter
% of zoea that will survive to the megalopa stage	4	
% of megalopa that will survive to juvenile stage	50	
Number of runs/year	6	
Nursery		
Stocking density for megalopae	50	megalopae/m^2
Number of runs/year	6	

Table 4. Depreciation schedule of capital assets in a mud crab hatchery and nursery

Item	Cost (₱)	Economic life (years)	Depreciation/ year (₱)
Hatchery phase			
Hatchery building	570,000	10	57,000
Tanks	730,000	10	73,000
Equipment	175,000	2	87,500
Aeration system	200,000	10	20,000
Electrical system	50,000	10	5,000
Reservoir	200,000	10	20,000
Miscellaneous	10,000	2	5,000
Total	1,930,000		267,500
Depreciation/ run for hatchery	44,583		
Nursery phase			
Nets	124,800	1	124,800
Pump	30,000	2	15,000
Total	154,800		139,800
Depreciation/ run for nursery	23,300		

Table 5. Costs and returns of a hatchery with a total larval tank capacity of 80 tons. The final product is megalopa, assumed to be sold at P2 each.

Item	Quantity	Unit cost (₱)	Total cost (₱)
SALES	192,000	₱2.00	₱ 384,000
Variable Cost (per run)			
Broodstock (kg)	6	300	1,800
Broodstock feeds (kg)	144	25	3,600
Artemia (can)	11	2,000	22,000
Natural food starters			500
Fertilizers			240
Other chemicals			7,843
Other supplies (nets, hoses, etc.)			20,000
Electricity (kwh)	2,000	6	12,000
Marketing (2% of revenue hatchery)			7,680
Miscellaneous (5% variable cost)			3,783
Labor (30% profit less expenses)			91,366
TOTAL VARIABLE COST			₱ 170,812
Fixed Cost			
Depreciation			44,583
Rent on land			3,000
Interest on investment cost (12%)			45,432
Repair and maintenance (5% of fixed assets)			11,542
TOTAL FIXED COST			₱ 104,557
Total production cost per run			275,370
Total production cost per year (6 runs/year)			1,652,218
Net income per year			651,782
Less: income tax (30%)			195,535
PROFIT AFTER TAX			₱ 456,247
Capital assets			1,930,000
Working capital for 2 runs			461,573
Total investment			₱2,391,573
Payback period	3.3 years		
Return on investment	27.61%		
Variable cost/ megalopa	₱ 0.89		
Break-even price	₱ 1.43		
Break-even quantity	137,685 megalopae		

It takes about 3.3 years (payback period) to recover total investment if the hatchery produces megalopae (refer to Table 5). Furthermore, the market for megalopae has yet to be developed. Table 6 shows that greater profits can be made if megalopae are stocked in hapa nets set in ponds and reared for one more month before they are sold as juveniles.

Existing prawn or fish hatcheries may also be rented and used for production of megalopae. Given a rental of P30,000/run for an 80-ton (for larval rearing only) hatchery, the payback period for megalopae production can be shortened from 3.3 years to 1.6 years. An integrated hatchery-nursery business will have a payback period of 0.72 years if the hatchery is rented.

A nursery operator who buys megalopae from hatcheries and grows them for a month in net cages will get back his investment in 1.3 years as shown in Table 7.

Table 6. Cost and returns of an integrated hatchery-nursery system for mud crab. Megalopa used are those produced from the hatchery.

Item	Quantity	Unit cost (₱)	Total cost (₱)
SALES	96,000	₱ 7.00	₱672,000
Additional Variable Cost for the Nursery			
Feeds (kg)	670	15	10,050
Fertilizers			1,200
Lime	7	100	700
Electricity			4,500
TOTAL Additional Variable Cost			₱18,950
Additional Fixed Cost for the Nursery			
Repair and maintenance			3,333
Labor			9,000
Depreciation			23,300
Rent	0.17	15,000/ha	2,500
Interest on Investment (12%)			3,754
TOTAL Additional Fixed Cost			₱35,633
Total cost/run (hatchery + nursery)			329,953
Total cost/ year			1,979,718
Net income/ year			2,052,282
Less: Income tax (30%)			615,685
PROFIT AFTER TAX			₱ 1,436,597
Capital assets			2,084,800
Working capital for 2 runs			524,139
Total Investment			₱2,608,939
Payback period	1.4 years		
ROI	55.06%		
Variable cost/ juvenile	₱ 1.95		
Break-even price	₱ 3.44		
Break-even quantity	47,136 crablets		
NPV discounted at 12% over 5 years	₱3,537,035.00		
Profitability Index	141.9%		

Table 7. Cost and returns of a mud crab nursery system using megalopae produced from an 80-ton hatchery

Item	Quantity	Unit cost (₱)	Total cost (₱)
SALES	50,000	₱7.00	₱350,000
Additional Variable Cost for the Nursery			
Feeds (kg)	670	15	10,050
Fertilizers			1,200
Lime	7	100	700
Electricity			4,500
Megalopa	100,000	2	200,000
TOTAL Additional Variable Cost			₱216,450
Fixed Cost for the Nursery			
Repair and maintenance			3,333
Labor			9,000
Depreciation			23,300
Rent	0.17	15,000	2,500
Interest on Investment Cost (12%)			11,754
TOTAL Fixed Cost			₱49,887
Total cost/run			266,337
Total cost/ year			1,598,024
Net income/ year			501,976
Less: Income tax (30%)			150,593
PROFIT AFTER TAX			₱351,383
Capital assets			154,800
Working capital for 2 runs			486,075
Total Investment			₱640,875
Payback period	1.3 years		
ROI	54.83%		
Variable cost/ crablet	₱ 4.33		
Break-even price	₱ 5.33		
Break-even quantity	38,048 crablets		
NPV discounted at 12% over 5 years	₱1,008,688.00		
Profitability Index	157.4%		

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Some useful Unit Equivalents

1 gram (g)	= 1 ml or cc water
	= 1,000 mg
	= 1,000,000 (or 10^6) µg
1 kilogram (kg)	= 1000 g
	= 1,000,000 mg
1 micron (µm)	= 1000 ng or nannogram
1 millimeter (mm)	= 1000 µm
1 centimeter (cm)	= 10 mm
1 meter (m)	= 100 cm
	= 1,000 mm
	= 1,000,000 µm
1 liter (L)	= 1000 ml
	= 1,000,000 ml
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

About SEAFDEC

The Southeast Asian Fisheries Development Center (SEAFDEC) is a regional treaty organization established in December 1967 for the purpose of promoting fisheries development in the region. Its member countries are Japan, Malaysia, the Philippines, Singapore, Thailand, Brunei Darussalam, the Socialist Republic of Vietnam, Union of Myanmar, Indonesia, and Lao PDR.

Representing the Member Countries is the Council of Directors, the policy-making body of SEAFDEC. The chief administrator of SEAFDEC is the Secretary-General whose office, the Secretariat, is based in Bangkok, Thailand.

Created to develop fishery potentials in the region in response to the global food crises, SEAFDEC undertakes research on appropriate fishery technologies, trains fisheries and aquaculture technicians and disseminates fisheries and aquaculture information. Four departments were established to pursue the objectives of SEAFDEC.

- The Training Department (TD) in Samut Prakan, Thailand, established in 1967 for marine capture fisheries training
- The Marine Fisheries Research Department (MFRD) in Singapore, established in 1967 for fishery post-harvest technology
- The Aquaculture Department (AQD) in Tigbauan, Iloilo, Philippines, established in July 1973 for Aquaculture research and development
- The Marine Fishery Resources Development and Management Department (MFRDMD) in Kuala Terengganu, Malaysia, established in 1992 for the development and management of the marine fishery resources in the exclusive economic zones (EEZs) of SEAFDEC Member Countries

SEAFDEC/AQD is mandated to:

- promote and undertake aquaculture research that is relevant and appropriate for the region
- develop human resources for the region
- disseminate and exchange information on aquaculture