AQUACULTURE EXTENSION MANUAL NO. 42 APRIL 2009

Seed production and grow-out of mud crab (*Scylla paramamosain*) in Vietnam

Nguyen Co Thach

Government of Japan
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Aquaculture No. 3 - Vietnam

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FOREWORD

SEAFDEC Aquaculture Department is proud to produce this manual on the culture of mud crab (*Scylla paramamosain*) that comes from our counterpart researchers from Vietnam, a member country of SEAFDEC. This is made possible by the funding support of the Government of Japan Trust Fund (GOJ-TF).

Most of the mud crab studies at AQD, which started as early as 1977, were focused on another mud crab, *Scylla serrata,* with the breakthroughs in developing seed production techniques brought about by collaborative projects between AQD and Australian Centre for International Agricultural Research (1996-1999) and in culture & management of *Scylla* species by AQD and the European Union project (2001-2004; with co-proponents University of Wales Bangor in the United Kingdom, University of Ghent in Belgium, and Can Tho University in Vietnam). Recently, the Government of Japan Trust Fund (GOJ-TF) has funded the domestication of mud crab at AQD.

These collaborations enabled AQD to begin packaging mud crab culture technologies, and conducting international training courses and onsite technology demonstrations as well as the publication of extension manuals. To date, AQD has a twice-revised manual on the biology and hatchery of mud crabs; another manual on pen culture of mud crab in mangroves; and a book on the diagnosis, prevention and control of diseases of farmed *Scylla* spp.

AQD acknowledges the efforts of its Deputy Chief, Dr. Hiroshi Ogata, co-manager of the GOJ-TF, in bringing this publication about. We also give support to Vietnam's Research Institute for Aquaculture (RIA-3) in disseminating science-based aquaculture technologies.

To you, our readers, we would welcome your feedback on this technology. Its refinement would ensure that the mud crab industry in Southeast Asia fulfills its promise of helping alleviate poverty and provide food security to the people of this part of the world.

Joebert D. Toledo, D. Agri.
Chief
SEAFDEC/AQD

PREFACE

Adopting sustainable aquaculture technologies could help abate the rapid degradation of resources. As one of the important crustacean commodities in Southeast Asia, mud crab continues to be of significant interest to many aquaculturists and farmers. The successful culture on a mass scale of any aquaculture species depends on the reliable supply of seed, and to this end, both Philippines and Vietnam have developed the technology for mass seed production. Already, the technology for hatchery and pond culture has been extended to stakeholders through publications, seminars, conferences and training courses. However, access to available technology is still lacking.

The commissioning of the preparation of this manual was funded by the Government of Japan Trust Fund on the basis of the approved implementation of the project on the **promotion of sustainable aquaculture** in the ASEAN region under the ASEAN-SEAFDEC Fisheries Consultative Group mechanism. This is part of the activity to transfer viable technologies and address needs relevant to sustainable aquaculture in the areas of broodstock development, genetic improvement, seed production, and culture systems of various priority species for aquaculture. Mud crab is one of the priority species under the aquaculture component of this project.

Hiroshi Ogata, Ph.D.
Deputy Chief
SEAFDEC/AQD

PREFACE

The Research Institute for Aquaculture No. 3 (RIA 3) in Vietnam is a government institution that develops long-term sustainable aquaculture and fisheries. The institution has put a great effort on the understanding of shrimp, crabs, echinoderms and molluscs with emphasis on biology and aquaculture.

To maintain the mud crab industry in Vietnam, the government through RIA 3 has conducted projects to understand the biology and to develop hatchery and grow-out technologies. Moreover, a project to develop cost-effective formulated diets for mud crab was implemented in collaboration with the Australian Centre for International Agricultural Research (ACIAR). After 10 years of research and development, the large scale mud crab hatchery technology has been developed and applied successfully in Vietnam. Mr. Nguyen Co Thach, who spearheaded the development of the technology in Vietnam, has received the World Intellectual Property Organization (WIPO) 2005 award.

The manual on **Seed production and grow-out of mud crab (*Scylla paramamosain*) in Vietnam** provides information on the biology and techniques in the larval rearing, nursery and grow-out of mud crab. We hope that this manual will provide useful information to researchers, biologists, hatchery and pond operators/managers, and students who are interested in fisheries and aquaculture of mud crabs.

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CONTENTS

STATUS OF MUD CRAB CULTURE IN VIETNAM

There has been no available technology on the commercial production of mud crab using hatchery-reared seeds for farming in Vietnam until 1998. Responding to the need of the mud crab industry, the Vietnam Government under the State program coded KC 06 NN started investing in on-farm research trials to improve the production.

Mud crab has been cultured for a long time along the coastal provinces of Vietnam. The wild seeds are stocked at low density from 0.1 up to 0.2 crab/m^2 with a production of approximately 137 kg/ha. Since the development of mud crab hatchery and nursery technology, pond culture activity has increased significantly. At present, monoculture of crabs in ponds and mangroves, and polyculture of crabs and shrimps are being practiced.

Seed production

In 2008, there are about 250 mud crab hatcheries in Vietnam and over 100 million crablets have been produced. A total of 540,000 ha shrimp farms was recorded by the end of 2004. In many cases, economic losses were due to disease outbreaks forcing farmers to convert monoculture (shrimp) ponds into polyculture (shrimp and crab or fish) ponds. However, the major constraint at present is the availability of seedstock for grow-out ponds. If 50% of the existing area is converted to monoculture of crabs, 133 to 220 million crablets are needed annually to meet the average stocking density of 0.5-1 ind/m^2.

Vietnam has the technical capability for the seed production of mud crab. The number of hatcheries is the highest in Southeast Asia and is increasing in most coastal provinces. However, the supply of seeds from both the wild and hatcheries (100 million/year) is not sufficient to meet the requirement. The annual seed requirement for farming to produce market size crabs for both domestic and export market can be adequately provided once the existing 2,600 shrimp hatcheries are used for crab seed production in conjunction with shrimp.

Farming in brackishwater and marine areas

The Red River and Mekong River systems have created a vast wetland next to brackish and marine waters. The total water surface area that can be utilized for brackish and marine aquaculture is around 858,000 ha (Lindner 2005). The potential regions for crab and shrimp culture are shown in Table 1 (see also Fig. 1).

Table 1. Potential sites for mud crab and shrimp farming in Vietnam

Province	Shrimp farming area for monoculture and polyculture (approximate total ha)	Crab farming area (approximate total ha)
Ca Mau	240,000	65,000
Bac Lieu	117,267	33,838
Ben Tre	4,466	103
Tra Vinh	935	335
Khanh Hoa	5,300	100
Binh Dinh	2,440	100
Phu Yen	2,403	100
Hai Phong	6,929	6,000
Quang Ninh	10,440	10,000

In the northern provinces, the climatic condition and the high price of market-sized crabs are ideal for the development of crab farming. Most of the brackish and marine waters are suitable for tiger shrimp and mud crab on a rotation basis. Crab production for export may range from 480 to 800 tons (Lindner 2005).

In the south, especially the provinces lying along the Mekong River Delta, the large area of brackish and marine waters combined with favorable climatic condition is suitable for aquaculture development in general, and crab farming in particular.

The narrow strip of brackish and marine waters in central Vietnam with the salinity of 30-35 ppt, sand and gravel, and good benthic growth are appropriate for seed production but not for grow-out of mud crab.

Fig. 1. Potential sites for mud crab farming are mostly concentrated in the southern provinces of Vietnam (indicated by a red rectangle).

BIOLOGY OF MUD CRAB

Taxonomy

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

Fig. 2. *Scylla paramamosain,* the most common mud crab in Vietnam

Many authors used to believe that mud crab belongs to only one species *Scylla serrata* (Forskal 1775). However, Estampador (1949) identified three species: *S. serrata* (Forskal), *S. oceanica* (Dana), and *S. tranquebarica* (Fabricius) and one variety *S. serrata var. paramamosain*. Based on the samples collected from south Vietnam, Serene (1952) categorized four species namely, *S. oceanica*, *S. tranquebarica, S. serrata* and *S. crassimana*. Starobogatov (1972) affirmed that the species found in Tonkin Gulf of Vietnam was *S. oceanica*. Keenan et al (1998), reclassified the *Scylla* species into *S. serrata* (Forskal 1775), *S. tranquebarica* (Fabricius 1798), *S. olivacea* (Herbst 1796) and *S. paramamosain* (Estampador 1949) based on morphological and genetic features. Following the classification of Keenan et al (1998), mud crabs obtained from central Vietnam consisted of *S. paramamosain, S. olivacea* and *S. tranquebarica,* in which *S. paramamosain* (Fig. 2) accounted for more than 90% of over 3,000 crab samples. Hence the focus of this manual is on *S. paramamosain*.

Habitat

Scylla paramamosain inhabit estuaries, mangroves and coastal marine waters, where salinity is between 5 and 30 ppt. Small crabs are normally found in areas with low salinity, and move to higher salinity when they mature, mate and spawn.

Morphological characteristics

The transversely ovate carapace is flat and smooth with ridges. It is light to muddy green. The abdomen is yellowish. The back side of the chelipeds is muddy green while the underside is yellowish with dark green spots.

The frontal margin has 6 sharp teeth and the anterolateral margin has 9 pointed teeth on each side. The mouthparts consist of 6 pairs of feeding appendages. The abdominal plate has seven segments which are held to the carapace. In female, the abdominal legs or pleopods are branched with bristles and used to carry the eggs after spawning. In male, the pleopods are modified into gonopods that are used for copulation. There are five pairs of legs. The first pair is the cheliped with fixed pollex and movable dactylus at the tip. The 2nd to 5th pairs are the walking legs, the last two segments of the 5th pair are paddle-like (Ng, 1998).

Crabs with 250-600 g body weight (BW) have corresponding carapace width (CW) of 10-12.5 cm.

Scylla species are difficult to distinguish from each other when still small in size. The morphological structures used to distinguish the differences among species include the following:

- Shape and height of frontal spines
- Number and height of propodus and carpus spines on the chelipeds
- Color of body and markings on legs

Reproductive biology

Sexual maturity. Adult male and female can be distinguished by the shape of their abdominal flap, triangular in males while semi-circular in females.

Ovary is transparent to white in immature female. As the crab matures, the white ovary turns light yellow. The size of oocytes increases as the nutrients begin to accumulate in the cytoplasm. The ovary turns light to dark orange at full maturity. Almost all crabs with 350 g BW (10 cm CW) are sexually mature.

Copulation. Crabs tend to migrate to higher salinity (30-35 ppt) to copulate and breed. Copulation can also occur in pens where water depth is at least 0.5 m and salinity is 30-35 ppt. A few days before moulting, female secretes a hormone to attract the male. The male grabs the female and then they move together for several days. Copulation takes place right after the female has molted (soft-shelled). The male turns the female body upside down, opens and presses its abdomen. The copulating organs of the male are inserted into the female's opening (vulvae) on the sternum.

The male organs (sharp as a point of a sword) are located at the base of 5th pair of legs. After copulation, the male carries the female along for a few days until the female shell hardens. Subsequent to copulation, the sperm are kept for 1-2 months in the chambers (spermathecae) deep behind the female's heart.

Fertilization and spawning. Fertilization occurs in the spermathecae inside the body of the female before the eggs are released. The process is controlled by the central nervous system, and there is concerted interaction between the eggs and sperm.

Crabs with fully mature ovary may start to spawn if conditions are favorable. The female rests on the ground, leans on the walking legs and opens the abdomen backwards. Its two pairs of legs turn upright and the bristled pleopods of the abdominal flap are arranged in a position to receive the sticky eggs. The eggs pass through the oviducts and move along to the vulvae. The eggs attach to the hairs of the abdominal flap.

The fecundity depends largely on the size and weight of the female crab. Each female may spawn up to 2 million eggs.

Breeding season. Mud crabs may spawn throughout the year along the south central coast of Vietnam where the annual average temperature is high. The peaks of spawning are from February to March and from July to August. In the south, mud crabs start migrating from the brackish water areas to seawater from July to August, and the peak of spawning season is from October to February (northern Vietnam) and from April to July (central and south Vietnam). In general, the breeding season is influenced by temperature; therefore, it varies in different areas of Vietnam.

Embryonic development. The egg has two membrane layers. The external layer is believed to create stalk to cling to hairs and act as protective shield. The inner layer is thin and is separated with the external layer over a slit. The fertilized eggs start to divide 45-60 min after spawning. The embryo develops normally in 26-30 °C, 30-35 ppt and pH 7.0-8.6, and >5mg/L dissolved oxygen. The embryonic development is shown in Table 2. Figure 3 shows the color change in the egg mass.

Table 2. Embryonic development of *Scylla paramamosain*

Embryonic development	Description	Days after spawning	Embryo average size (µm)
Cell division	Yellow to orange	About 1 hour	270
Gastrulation	Orange	5-7	290
Nauplius	Orange; abdominal legs and eye spots start to develop	7-10	330
Nauplius with dark pigments	Gray; star-shaped spots and black oval compound eyes	10-12	340
Pre-hatching	Dark gray; heart apparent and beats getting higher over time; episternites, anterior legs, thoracic sternal segments are apparent; muscles begin pulsating, and other organs gradually become complete; activities inside the embryo increases until the shell breaks to release the larva	12-15	350

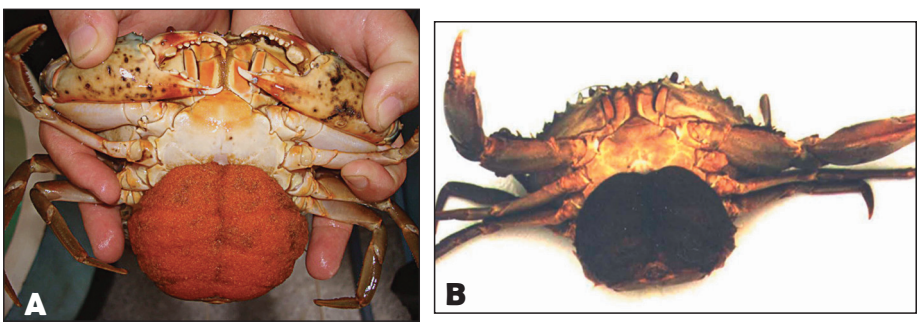


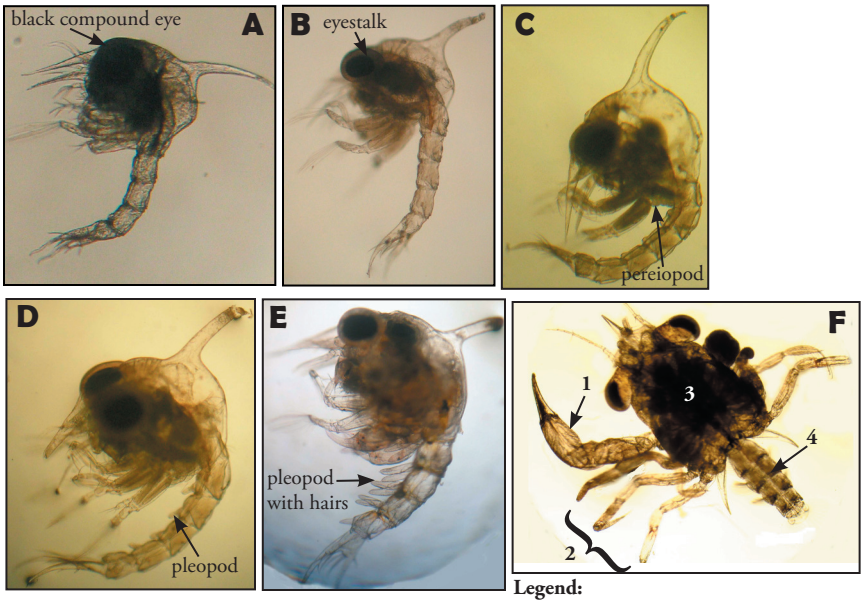
Fig. 3. Color change from orange immediately after spawning (A) to gray prior to hatching (B) in the egg mass of *Scylla paramamosain*

Larval development

Zoea. The body of newly hatched zoea consists of the cephalathorax and abdomen. The cephalathorax is almost oval shape, with long rostral and dorsal spines, short lateral spines, compound eyes, antennules, and mouth parts.

The abdomen is made up of six segments, in which the last segment is split into two spines. Zoea moults five times (Fig. 4A-E) after which it moults to megalopa (Fig. 4F). The identification of stages (Table 3) is important in the management of larvae.

Fig. 4. Zoea and megalopa stages: Zoea 1 through 5 (A-E) and megalopa (F)



Legend:
1 - cheliped
2 - walking legs
3 - carapace
4 - abdomen

Table 3. Morphological characters of zoea and megalopa stages

Stage	Morphological characters	Duration (days)	Average size (mm)
Zoea 1	Black compound eyes without stalks	5-6	1.25
2	Eyestalks apparent	4-5	1.53
3	Pereiopods apparent	3-4	1.93
4	Pleopods apparent	3-4	2.75
5	Pleopods with hairs distinct	3-4	3.67
Megalopa	1st walking legs develop to become chelipeds; carapace broader, segmented abdomen becomes folded to the ventral side of carapace at the later stage	7-8	3.9

Megalopa. For the first five days, megalopa leads a floating life and becomes benthic two days before moulting to crab instar. The suitable salinity for megalopa is 27-29 ppt. Megalopa lasts for 7-8 days prior to moulting to the crab instar stage (Fig. 5).

Fig. 5. Crab instar

Moulting

The carapace width increases as the crab moults. However, the frequency of moult becomes less as crab grows.
The increase in carapace width is smaller than in body weight during the succeeding moults. Daily increase in carapace of mud crab in commercial farms slows down gradually until the end of the crop, while the daily weight gain continuously increases, notably when crabs reach the marketable size. Daily average weight gain can be at 3.4 g in the grow-out phase. Crab with an initial body weight of about 0.7 g can grow to marketable size of ≥300 g after 4-6 months.

SEED PRODUCTION OF MUD CRAB

Site selection

The technical requirements for a suitable site for mud crab hatchery are as follows:

Water source. Marine water source should not be contaminated with domestic, agricultural and industrial wastes, and other toxic substances. The physical and chemical characteristics of the water should be within the optimum range shown below (Table 4):

Table 4. Optimum physical and chemical characteristics of water for the culture of mud crab larvae

Parameter	Optimum range
Temperature	27-31°C
Salinity	18-35 ppt
Alkalinity	80-140 ppt
pH	7.5-8.6
NH_3/NH_4	<0.01 ppm
NO_2-N	<0.01 ppm
Fe^{+2}	<0.001 ppm

Clear and clean freshwater supply should always be available.

Geological terrain. Flat terrain that is conveniently close to the marine water supply should be selected. It should be far from tide- and wave-induced erosion.

Accessibility. The hatchery should be accessible to the source of electricity, markets, suppliers, service providers and other types of support.

Hatchery facilities and design

Crablets can be produced year-round. However, the production period depends on the market demand. In northern provinces, the season is from April to September while in central and southern provinces, it is February to October. Hence, production of crablets should coincide with these seasons.

The capacity of the hatchery depends on the seed requirement. The tanks for the culture of crabs and hatching of *Artemia* should be housed in a building where desired temperature can be maintained. Tanks for natural food are better located outside the building where there is sufficient sunlight. The following facilities are required for larval rearing of crabs.

Broodstock tanks. These tanks are used to hold the mature crabs until they spawn. Cement tanks with a capacity of 1 to 6 m^3, depth of 1.0-1.2 m and bottom area of 12 to 24 m^2 sloping towards the drain are required. One-third of the tank bottom is covered with 15-20 cm deep sand where crabs can burrow.

Fig. 6. Larval tanks for zoea to megalopa culture

Hatching tanks. Berried crabs are held individually in hatching tanks until their eggs hatch. Circular fiberglass tanks of 150-200 L capacity are needed as hatching tanks.

Larval tanks. The tanks for rearing zoea is preferably 1,000 L with 1.0-1.2 m depth, circular in shape with smooth, inner surface (Fig. 6).

Fig. 7. Nursery tanks for megalopa to crab instar culture

Nursery tanks. The nursery tanks for megalopa to crab instar can be made of cement with a dimension of 2.5 x 2.5 x 1.4 m (Fig. 7).

Natural food tanks. Rotifer and algal culture tanks may range from 1 to 5 m^3. Movable fiberglass tanks are more convenient to use. Conical tanks of 100-150 L are needed for the incubation of *Artemia* cysts and 2 m^3 tanks for the culture of *Artemia*.

At present, most mud crab hatchery operators in Vietnam do not use rotifer and *Artemia* biomass for larval rearing. Instead, they use *Artemia* nauplii and artificial food.

Reservoir. This tank is used for chlorination and holding of seawater for daily use.

Equipment and tools

- 2,000 L plastic tanks for holding filtered water
- 1.5 CV marine water pumps
- 0.5 CV freshwater pumps
- 500-watt aerators
- 3.5 kW electric generator
- refractometer
- pH meter
- digital weighing scale

- optical microscope
- thermometers (°C)
- plastic tubes of Ø34, 100 Ø21 and 100 m Ø27
- other materials such as plankton net, airstones, buckets, plastic dippers, pails, etc.

Water treatment

Water used for rearing should be treated with chlorine to kill harmful organisms that may cause disease problems. To treat water:

1. Pump 20 to 35 ppt marine water into the reservoir
2. Pump the water into the hatchery tanks after settling for 36-72 h
3. Treat the marine water with 15-30 ppm chlorine
4. Aerate the water for 48-72 h to remove the chlorine residues
5. Pump the treated water into a clean storage tank
6. Check for harmful microorganisms and chemical residues
7. Filter the water twice through a 5µm bag and fill the larval rearing tanks

Tank preparation

Maintenance of hygiene in the hatchery is necessary to avoid disease problems. Tanks and implements are disinfected prior to larval rearing runs.

1. Clean the tanks and other implements with detergent and then soak in 100-200 ppm chlorine for 12-24 h
2. Wash and dry the tanks
3. Fill the tanks with marine water and aerate moderately

Culture of natural food

Zoeae feed on rotifers while rotifers feed on microalgae. Both the rotifers and microalgae are mass produced and maintained even before the eggs hatched to zoeae so as to ensure the availability of rotifers for zoeae.

The time needed for the microalgae, *Chlorella* and *Chaetoceros,* to reach maximum cell density of 5-10 x10^6 cells/mL is 2 to 3 days.

Microalgae

1. Get 1 L pure starter of *Chlorella* or *Chaetoceros*
2. Culture the algae in 10 to 100 L glass jug
3. Fertilize using the chemicals as follows:

Chlorella

Chemicals	Amount (ppm)
KNO_3	50-100
K (Na) H_2PO_4	10
Citric acid	20
Fe^{3+}	4
Micro-element	0.5

Chaetoceros

Chemicals	Amount (ppm)
KNO_3	10-100
KH_2PO_4	5-10
Na_2SiO_3	1

4. Scale up the algae to 500-1,000 L after 2-3 days and fertilize

Rotifers

1. Inoculate the *Chlorella* culture with rotifers one day before the maximum algal cell density is achieved
2. Start with an initial density of about 20 rotifers/mL
3. Harvest rotifers after 3 to 4 days of culture when 200-250 ind/mL has been obtained
4. Remove protozoans from the harvested rotifers by washing with filtered freshwater several times
5. Enrich the rotifers with squid oil, vitamins and other sources of docosahexaenoic acid (DHA) for 10-12 h
6. Wash rotifers prior to feeding to early zoeae

***Artemia* hatching**

1. Select *Artemia* strain, preferably produced by Can Tho Shrimp and *Artemia* Center
2. Determine the hatching rate and incubation period of the *Artemia* cysts
3. Decapsulate the *Artemia* cysts with 100 ppm chlorine for 2-5 minutes
4. Wash the cysts with freshwater several times after decapsulation
5. Incubate the cysts in filtered 20-35 ppt water for 16-20 h
6. Turn off aerator and heater and allow *Artemia* nauplii to settle for 5-7 minutes
7. Collect nauplii with a hand net (100-150 microns mesh size) and transfer to a clean bucket containing filtered marine water
8. Allow to settle for another 5 minutes and remove cysts
9. Place the nauplii into a bucket containing freshwater and allow remaining cysts to settle for another 5 minutes
10. Remove remaining *Artemia* cysts and collect nauplii
11. Feed some nauplii to crab larvae
12. Culture remaining nauplii for up to 7 days as feed for older zoea and megalopa

Selection and transport of broodstock

Adult crabs sourced from the wild are selected as broodstock. The egg and larval quality depend on the broodstock quality. Select broodstock that are:

- ≥400 g BW and ≥12 cm CW
- Healthy with complete legs
- Copulated
- Mature with orange-colored ovary

Tie the broodstock. Load 20-30 crabs (10-15 kg) in 40 x 30 x 20 cm insulated container with moist sponge material. The number of crabs depend on the duration and means of transport (airplane, train, car or motorbike). Keep broodstock in a moist condition at 22-25°C during transport. Do not transport crabs for more than 48 h.

Maintenance of broodstock

1. Upon arrival, stock broodstock in tanks with aerated marine water at a density of 2-3 ind/m^2
2. Feed broodstock with fish (e.g. *Gazza minuta*) at 50% and shrimp, squid or shellfish at 50% of the daily ration. Enrich feeds with vitamins and minerals prior to feeding
3. Feed broodstock twice a day at around 0500h and 1700 h. Remove uneaten feeds prior to feeding. Adjust amount of feeds depending on the consumption based on the previous feeding
4. Change 30% of the water volume daily with new marine water. Change water completely after 3 to 5 days
5. Maintain the following water quality parameters in the tank:

Parameter	Optimum range
Temperature	27-31°C
Salinity	30-35 ppt
pH	8.0-8.5
H_2S, NH_3-N and NO_2-N	<0.01 ppm

6. Hold broodstock in tanks until they spawn

Spawning and incubation

Spawning may occur in 10-30 days after full ovarian maturation. Eggs hatch 13-15 days after spawning.

1. Check ovarian development every 3 days by pressing the first abdominal segment just below the carapace. Mature ovary is orange
2. Adjust the salinity and water flow to stimulate spawning when the ovary of the crab is orange
3. Retrieve crab carrying eggs (berried) using a hand net
4. Rinse the berried crab before moving it to the hatching tank with 100 to 150 L of seawater
5. Provide the hatching tank with a false bottom made of mesh grid to minimize bacterial and parasitic infection (Fig. 8)

Fig. 8. Berried crab in tank with mesh grid

6. Feed crabs once daily but cease feeding two days before the eggs are ready to hatch
7. Provide aeration during the entire incubation period
8. Change total volume of water daily. Maintain the water quality parameters similar to that in the maturation tank

Larval rearing

Collection of zoeae. The crab eggs hatch to zoea between 0630 and 0800 h in the morning but may be delayed if the quality of the eggs is poor. The zoeae should be collected immediately after hatching.

1. Turn off aeration in the tank. Good quality larvae will move towards the light, migrating to the water surface where these can be easily gathered
2. Discard the remaining zoeae that stay on the bottom
3. Siphon the zoeae from the water surface and place in a plastic bucket with 100 L water. Complete the collection of larvae within 10-15 min
4. Estimate the total number of zoeae. Get three 100 mL subsample from the bucket and count zoeae individually. Get the average count and multiply by 10 to obtain the number of zoeae per liter. Multiply by the number of liters in the bucket to get total zoeae count
5. Compute for the volume of zoeae to be stocked in larval tanks
6. Stock zoeae in the tanks

Culture of zoea$_1$ to zoea$_5$

1. Introduce rotifers and *Artemia* in the tank
2. Release zoeae into the tank at 100-200 ind/L
3. Feed zoeae 2-3 times per day at 0500-0600 h, 1700-1800 h and 2400-0100 h using the following feeding regime:

   - Rotifers at 15-20 ind/mL or *Artemia* (preferably umbrella stage) at <10 ind/mL from Z_1 to late Z_2
   - *Artemia* nauplii from Z_3 to late Z_5 at 10-15 ind/mL

4. Maintain the quality of the water by siphoning the dead zoeae, excess feeds and other sediments regularly since there is no water change. About 70% will die during the early zoea stages
5. Maintain the following water quality parameters in the tank:

Parameter	Optimum range
Temperature	28-30°C
Salinity	30 ± 1 ppt
pH	8.0-8.6
NH_3-N and NO_2-N	<0.01 ppm
Fe^{+2}	<0.01 ppm

Culture of zoea$_5$ to crab instar (C)

1. Start the biomass of *Artemia* 5 to 7 days before feeding the megalopa
2. Turn off the aeration and allow Z_5 and megalopa to swim on the surface and collect by siphoning into other containers
3. Stock in nursery tank at 50 ind/L
4. Feed megalopa with ≥ 5 day-old *Artemia* at 20-25 ind/L at 0500-0600 h and 1700-1800 h daily
5. Give processed feeds starting on the last 2-3 days of megalopa stage to C_2- C_3
6. Maintain water salinity of 25-27 ppt
7. Siphon the excess feeds, dead animals and other sediments daily
8. Provide mussel shells in the tank as shelters when megalopae molt to crab instar

Harvest and transport of crab instar

1. Drain the water, retaining around 20 cm and remove the shelters
2. Drain the water totally and collect the crablets with a 2 mm mesh scoop net
3. Count and transport using plastic containers with 1.0-1.5 cm moist sand over the bottom (Fig. 9)
4. Load crablets (< 1 cm CW) at 2-3 ind/cm^2. Do not exceed transport duration of 30 h. A survival rate of 90% can be attained

Fig. 9. Transport of crab instar in plastic containers with wet sand (A) and loading of the containers in plastic bags (B)

NURSERY

Nursery systems

Crab instar$_2$-C$_3$ measuring 0.3-0.5 cm CW are grown to 1.2-2.0 cm CW in rectangular net ponds (10 x 3 x 1.2 m or 10 x 5 x 1.2 m) (Fig. 10) or net cages set in earthen ponds before stocking in grow-out ponds. A survival rate of 60-80% can be attained in 15-20 days nursing period.

Fig. 10. Nursery net pond

Pond preparation and stocking

1. Drain and dry pond for at least 5-7 days. The pond should have a slope of around 2% towards the drain for easy draining
2. Level the pond bottom and repair the dikes
3. Apply fish killing substance (Saponin) at a rate of 10-15 g/m^3 for 24-36 h if total drain is not possible
4. Apply lime ($CaCO_3$) at a rate of 1.0-1.5 ton/ha to correct acidity and eliminate predators
5. Use either of the following:
    - *net enclosures* - install 2-mm mesh size net around the pond and bury more than 1 cm of the net bottom into the mud. Each pond compartment can hold 4 to 6 net enclosures measuring 10 x 5 x 1.2 m or 10 x 3 x 1.2 m (Fig. 10) or
    - *net cages* - install 10-15 net (2 mm mesh size) cages measuring 30-50 m^2 in ponds
6. Introduce brackishwater with salinity of 10-20 ppt and 7.5-8.6 pH into the pond
7. Use a 2 mm mesh size net to filter the water in the inlet and outlet gates. Maintain water level at 70-80 cm deep

Nursery rearing

Stocking

1. Select healthy crablets (0.3-0.7 cm CW) and acclimatize prior to stocking
2. Stock at 15 to 50 ind/m^2 depending on the size of the crablets

Feeding and water management

1. Feed the crablets with the following formulation:

Ingredients	Amount (%)
Chicken eggs	30
Mixture of shrimp, crab and oyster	50
Squid intestine	5
Wheat flour	15
Vitamin	0.01

2. Mix the ingredients, grind and steam
3. Feed crabs with the feed mixture for the first 3-5 days
4. Shift to trash fish, mollusks and shrimp on day 4 onwards. Steam all feed ingredients and cut into small pieces or pass through a 5 mm net and mix in water
5. Feed crabs to satiation or 100 g feeds per 1,000 crabs daily at 0800-0900 h and 1700-1800 h
6. Change 30% of the pond water 5 days after stocking to stimulate the crabs to moult. Thereafter, change 50% of the water after another 5 days
7. Harvest crablets (1.2-2.0 cm CW) in net enclosures using lift nets after 15-20 days. Place feed on the lift nets to attract the crablets, then quickly pull the nets up to select individuals that are large enough for farming. Drain the pond for total harvest of crablets. Handpick crablets
8. To harvest crablets in net cages, drain 70-80% of pond water. Lift one end of the cage and allow all crablets to go to the other end for easy collection. Use scoop net to collect crablets

Transport. If the grow-out pond is far from the nursery site, the crablets are transported using the transport system described in pages 16-17.

GROW-OUT

Polyculture

Polyculture of mud crab and tiger shrimp has been applied in most provinces in north and south Vietnam with a production of approximately 1.0 ton/ha. This type of farming applies to collective units and households engaged in aquaculture. The pond (Fig. 11) ranges from 3,000 m^2 to more than 1 ha with 1 or 2 water gates depending on the pond area.

The culture of mud crab with tiger shrimp or herbivorous fish species such as mullet or siganid gives better economic gain.

Site selection. Select a site with the following criteria:

- Mid- or low tidal areas, where there is easy inflow and outflow of water
- Sandy muddy soil with compactness of 10-15 cm depth
- Water source free from pollution
- Salinity of 15-25 ppt
- Accessible to transportation, feed suppliers and market

Fig. 11. Grow-out pond

Pond preparation and stocking

1. Follow nos. 1 to 4 in page 18 for pond preparation
2. Introduce water into the pond and maintain depth of 0.8-1.0 m for the first two months and increase to 1.0-1.4 m thereafter
3. Acclimate crabs and shrimps prior to stocking
4. Stock shrimp postlarvae $(PL)_{15}$ at 10 ind/m^2 and crablets (0.8-1.0 g BW; 1.2-2.0 cm CW) at 0.5 ind/m^2
5. Release crabs 45 days after stocking shrimp postlarvae

Feeding and water management

1. Feed crabs and shrimps with chopped trash fish, mollusk meat, crustaceans and mixed feed balls (50% trash fish, 40% mollusk and 10% small crustaceans)
2. Use feeding rate of 10-15% of the body weight of small crabs and adjust to 3-5% as the crabs grow bigger
3. Feed crabs at 0700-0900 h and 1700-1800 h
4. Put feeds in trays distributed throughout the pond with 4-7 m distance from each other
5. Monitor water parameters such as temperature, dissolved oxygen, salinity and pH daily
6. Take water for biochemical oxygen demand (BOD), chemical oxygen demand (COD), NH_3, and NO_2 analyses when unusual behavior of crabs is observed such as loss of appetite. Examine for the presence of harmful microorganisms

7. Take remedial actions immediately after observing abnormal conditions to reduce mortalities
8. Change 30-40% of the pond water every 3 to 5 days during high tide. Maintain water depth of 0.8 to 1.5 m
9. Maintain water quality as follows:

Parameter	Optimum range
Temperature	26-30°C
Dissolved oxygen	about 6 ppm
pH	7.0-8.6
NH_3-N, NO_2-N and H_2S	<0.02 ppm

Harvest

1. Harvest crabs 4-6 months (2-3 pcs/kg) and shrimps 3.0-3.5 months (25-30 pcs/kg) after stocking
2. Harvest crabs (preferably males first) using feeding trays and lift nets after 4 months to reduce density. Harvest the remaining crabs after the majority of the population has attained marketable size
3. Harvest shrimps using current method
4. Tie crabs and hold in a cool wet place. Provide crabs with water every 7-10 h. Shrimps can be held in containers provided with aerated water for 2-4 days

Farming in mangroves

The farming of mud crabs has been successfully done in Ngoc Hien District, Ca Mau province with a production of 1.0 ton/ha. Farming of crabs in mangroves can be conducted all throughout the year with two cropping seasons. Seeds (either from the wild or hatchery) are stocked from February to March and from August to September.

Site selection. Select a site with clean and unpolluted brackishwater (15-25 ppt) in mangrove area that is accessible to transportation, feed suppliers and market.

Farming crablets to marketable size

1. Install net around the pond perimeter to prevent crabs from escaping
2. Select healthy crablets (about 2.0 cm CW) from the nursery pond
3. Stock crablets at 0.5 to 1 ind/m^2 early morning or evening
4. Feed crabs with chopped fish and mollusks after 15 days. The crabs also feed on the available natural food in the pond

5. Put feeds in feeding trays distributed throughout the pond (one feeding tray/100 m^2) as follows:

Average body weight (BW) of crab (g)	<1.5	1.5 to 10	10 to 30	30 to 90	90 to 150	>150
Amount of feed (g) based on % BW	0	20-25	15-20	10-15	5-10	About 5

6. Remove feed residues early morning and evening prior to each feeding. Feed twice daily
7. Change 30-50% of water every 3 to 5 days; increase to 60-80% if water quality is poor

Harvest

1. Harvest crabs when >300 g/crab is attained
2. Collect crabs using feed trays and lift nets
3. Drain the pond and handpick all remaining crabs

CONSTRAINTS

The survival rate from zoea 1 to C_2-C_3 (less than 1 cm) is about 10%. Crablets having this size can already be stocked in grow-out ponds and culture to marketable size attaining a survival rate of 40 to 70%. The constraints in mud crab culture are cannibalism, availability of commercial formulated feeds and diseases.

Cannibalism

Cannibalism results to low survival rate. High stocking density and lack of feeds may induce cannibalism. When space is limited, the encounter among crabs is high. The lack of feeds may lead to incomplete nutrient accumulation for growth, thus producing unequal sizes of crabs. The stronger and bigger crabs cannibalize the smaller ones.

Cannibalism can be minimized by:

Reduction of stocking density. Crabs to be stocked are preferably of similar size and age. Stocking density is less than 0.5 ind/m^2 for extensive polyculture and 1.0-1.5 ind/m^2 for monoculture.

Provision of shelters. Water tubes, seagrass and empty mollusk shells can be used as shelters. Newly moulted crabs can easily hide from other crabs if pond is provided with many shelters.

Provision of high protein and lipid feeds. Aside from trash fish, it is necessary to feed the crabs with high-protein and lipid pellets.

Feeds

There are no available commercial pellets for crabs at present. Based on previous studies, pelleted feeds can be used for crab farming. Crabs fed both live and pelleted feeds grow well with a daily weight gain up to 4.84 g and survival rate up to 89%. The substitution for trash fish will reduce the risks of disease outbreak and deterioration of pond bottom. It is important to formulate a diet with good attractability and nutritive value.

Diseases

The common diseases in mud crabs are:

Disease	Signs	Effects
Brown-spot disease (carapace spot disease) caused by the *Vibrio* bacteria	Spots (1-10 mm) that are reddish-brown, white, yellow to brown on the carapace are apparent. In some cases, black spots may be found on walking legs	Chitin layer becomes thinner and the crab experiences difficulty in moulting. Mortality occurs in serious cases.
Black-gill disease	Dead crabs with black gills which carry various pathogens (bacteria, parasites and fungi). Infection incidence of *Fusarium semitectum* in the gills is rather high (72.9%), and may be the major cause of black-gill disease	Injuries to the respiratory system adversely affect oxygen supply in the body. As a result, the crab stops feeding, moves slowly and gradually becomes feeble. The incidence of mortality is low.
White-spot disease	The disease is hard to identify at the beginning of infection. White spots (some times yellow-brown) are only visible when the infection is serious	Mortality is quick, and epidemic outbreak may be possible, causing up to 100% mortality
Bitter crab (dinoflagellate blood) disease	Crab body turns opaque white with fishy smell. The external part is greasy, legs are injured, and abdomen becomes milky white. The crab moves slowly and stops feeding	Some dead crabs can be observed at the beginning of infection but mass mortality may occur in serious cases
Loss of limbs	The crab becomes weak, feeds little, lies near the pond dikes. Leg muscles degenerate and when taken out of the water, walking and swimming legs easily fall apart from the body	Infected crabs die rapidly at high incidence
Chronic soft-shell disease	The shell (carapace) remains soft several hours after moulting. The crab is fragile and unable to defend itself	The crab feeds little or nothing, so it grows slowly and gets infected easily

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SEAFDEC conducts research on fisheries problems; generates appropriate fisheries technologies; trains researchers, technicians, fishers and aquafarmers, and managers; disseminates information on fisheries science and technologies; and recommends policies pertaining to the fisheries sector.

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

SEAFDEC/AQD is mandated to:

- Conduct scientific research to generate aquaculture technologies appropriate for Southeast Asia
- Develop managerial, technical and skilled manpower for the aquaculture sector
- Produce, disseminate and exchange aquaculture information

SEAFDEC/AQD maintains four stations: the Tigbauan Main Station and Dumangas Brackishwater Station in Iloilo province; the Igang Marine Station in Guimaras province; and the Binangonan Freshwater Station in Rizal province. AQD also maintains a Manila Office in Quezon City.