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The PHILIPPINES RECOMMENDS for MANGROVE CRAB

Department of Science and Technology (DOST)
PHILIPPINE COUNCIL FOR AGRICULTURE, AQUATIC AND NATURAL RESOURCES RESEARCH AND DEVELOPMENT (PCAARRD)

About DOST-PCAARRD

ISO 9001:2015

The Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) is one of the sectoral councils under the Department of Science and Technology (DOST). It was formed through the consolidation of the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) and the Philippine Council for Aquatic and Marine Research and Development (PCAMRD) on June 22, 2011 pursuant to Executive Order No. 366.

Originally established on November 10, 1972 as the Philippine Council for Agricultural Research (PCAR), it became the Philippine Council for Agriculture and Resources Research (PCARR) to include mines research in 1975. Affirming the role of S&T in development, PCARR changed its name to Philippine Council for Agriculture and Resources Research and Development (PCARRD) in 1982. The Council was tasked to provide a unified and focused direction for the country's agricultural research. It then became an apex organization that supports and manages the national network of government and higher education institutions involved in crops, livestock, forestry, fisheries, soil and water, mineral resources, and socio-economic research and development (R&D). In 1987, the Council was renamed the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development but retained the acronym PCARRD. On January 30 of the same year, the Philippine Council for Aquatic and Marine Research and Development (PCAMRD) was created from the Fisheries Research Division of PCARRD with functions focused on aquatic and marine sectors.

With expanded coverage, functions, and responsibilities, the Council formulates policies, plans, and programs for science and technology-based R&D in the different sectors under its concern. It coordinates, evaluates, and monitors national R&D efforts in the agriculture, aquatic, and natural resources (AANR) sector. It also allocates government and external funds for R&D and generates resources to support its program.

As the apex Council of the AANR sector, PCAARRD is engaged in active partnerships with international, regional, and national organizations and funding institutions for joint R&D, human resource development and training, technical assistance, and exchange of scientists, information, and technologies. The Council is implementing its program primarily through its Regional Consortia, which are located all over the country.

It also supports the National Agriculture, Aquatic and Natural Resources Research and Development Network (NAARRDN) composed of national multi- and single-commodity and regional R&D centers, cooperating stations, and specialized agencies.

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Dear Reader:

Mangrove crabs locally known as ‘alimango’ is one of the most traded species of crustaceans in the country. Being a favorite delicacy of Filipinos, it commands a high price in the market and is being consumed year round. However, the inadequate supply of crablets and broodstock remains to be a problem in the industry.

As a priority commodity of DOST-PCAARRD, the development of technologies increasing the supply and availability of the species in the market was given attention. In fact, the establishment of the Mangrove Crab Industry Strategic Science and Technology (S&T) Program (ISP) was to increase the survival rate of the mangrove crab in the hatchery, nursery, and grow-out stages.

PCAARRD is proud to add **The Philippines Recommends for Mangrove Crab** to the list of its banner publication line. Some interventions contained in this book will help ensure the supply of crablets to increase production of marketable size mangrove crabs.

We hope that you will find this publication useful as you venture into your own business whether in the hatchery or in the grow-out culture of mangrove crabs.

Very truly yours,

REYNALDO V. EBORA, PhD
Executive Director
DOST-PCAARRD

The Philippines Recommends for **Mangrove Crab**

PCAARRD Philippines Recommends Series No. 100/2021

Department of Science and Technology (DOST)
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Foreword

It is with great pride that PCAARRD adds **The Philippines Recommends for Mangrove Crab** to its banner publication line. This is the first time that the technologies in mangrove crab aquaculture, from larval rearing in a hatchery for juvenile crab production up to the growing of marketable-sized crabs, have been put together in one volume.

The mangrove crab, locally known as 'alimango,' is a high-value seafood that is greatly sought after in the Philippines or abroad. With the dwindling crab resources due to human encroachment into mangroves, the crabs' natural habitat, and the real threat of climate change, mangrove crab farming is the only way to sustain and increase its availability.

The full potential of the mangrove crab industry to generate jobs and livelihood as well as increase export earnings can only be realized by transforming it from one that is largely dependent on the use of seedstock caught from the wild to that which utilizes abundant seedstock from hatcheries. Moreover, high survival and rapid growth of crabs in brackishwater fishponds should be assured through proper preparation, water management, and good nutrition.

This book contains technologies generated under PCAARRD's Industry Strategic Science and Technology Plans (ISP) for Mangrove Crabs. It aims to ensure the economic viability of all aspects of crab aquaculture from the production of crab seedstock or crablets in hatcheries to grow-out in brackishwater fishponds. With these technologies available to the general public, we hope to see more investments in crab hatcheries. With more hatcheries, the crab industry can attain the same status as milkfish and tilapia and perhaps even surpass shrimps both in volume and in value.

With this publication, we hope that you will find all the necessary information you need for a successful crab hatchery and/or grow-out operation. If you are already into crab production, we hope the information contained in this book will help increase your production several times over.

REYNALDO V. EBORA, PhD
Executive Director
DOST-PCAARRD

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Glossary of Terms

berried crab - a female crab that has released eggs, which are attached to the hairs of the abdominal flap; egg mass appears like berries

brackishwater - water having a higher salinity (~17 parts per thousand [ppt]) than freshwater but not higher than seawater

cannibalism - an individual eating the flesh of its own species

carapace - hard layer that covers and protects the animal

cheliped - one of the pairs of legs that bears the large claw in decapod crustaceans

dactylus - the movable part of the claw that makes up the nipper or chela of crabs

ecology - branch of biology that studies the interactions among organisms and their environment

exoskeleton - external covering of the body providing support and protection

eyestalk ablation - commonly practiced in crustaceans to induce maturation. The production and storage sites of the gonad inhibiting hormone (GIH) which prevents ovarian maturation is found in the eyestalk. Eyestalk ablation reduces the GIH to a level at which ovarian maturation can take place

genetics - a branch of biology involved with the study of genes, genetic variation, and heredity in organisms

gonopod - appendage in many arthropods modified to serve as a copulatory organ

hemacytometer - a glass chamber with specific depth developed for counting blood cells but can also be used to count algal cells

hemolymph - a fluid, similar to the blood in vertebrates, that circulates in the interior of the arthropod body and remains in direct contact with the animal's tissues

hepatopancreas - a glandular structure that combines the digestive functions of the vertebrate liver and pancreas

maxilliped - one of the three pairs of appendages situated immediately behind the maxillae of crustaceans

mRNA - refers to the messenger ribonucleic acid (RNA). An mRNA molecule carries a portion of the deoxyribonucleic acid (DNA), also known as the hereditary material, to other parts of the cell for processing

mollusk - any invertebrate of the Phylum Mollusca that has a soft body and usually protected by a hard shell as it has no spines/bones

molt - shedding of old skin or exoskeleton to make way for new growth

nauplii - the first larval stage of many crustaceans, having an unsegmented body and a single eye

omnivore - an organism that is naturally able to eat food from both plant and animal sources

pheromone - a chemical substance that is usually produced by an animal and functions as a stimulus to other individuals of the same species for one or more behavioral responses

phototactic - movement of an organism toward or away from a source of light

physiology - branch of biology that deals with the normal functions of living organisms and their parts

polymerase chain reaction - a technique used to quickly and accurately make numerous copies of a specific segment of DNA

RNA-Seq (RNA sequencing) - a method for revealing the presence and quantity of RNA in a biological sample at a given moment. The process involves next generation sequencing (NGS) and the data generated are used in gene expression studies

salinity - concentration of dissolved salts

spermathophore - a sperm ampulla (ball of sperm) or a protein capsule containing spermatozoa produced by male

spermathecae - a sac for sperm storage in the female reproductive tract of various lower animals

spermatozoa - mature non-motile male sex cell of crab, specific output of the testes

sternites - ventral part of each segment of an invertebrate's body.

thoracic sternite - the segmented chest cavity located on the ventral side of the crab

List of Abbreviations and Acronyms

ABW	average body weight
ARMM	Autonomous Region in Muslim Mindanao
BAFS	Bureau of Agriculture and Fisheries Standards
BCR	Benefit to Cost Ratio
BFAR	Bureau of Fisheries and Aquatic Resources
°C	degree Celsius
$Ca(ClO)_2$	calcium hypochlorite
CAP	Corrective Action Plan
cfu	colony forming unit
CL	carapace length
cm	centimeter
COR	Certificate of Registration
CW	carapace width
DNA	deoxyribonucleic acid
DTI	Department of Trade and Industry
ERK	extracellular signal-regulated kinase
FAO	Food and Agriculture Organization
FHO	Fish Health Officers
g	gram
h	hour
H	height
ha	hectare
HUFA	highly unsaturated fatty acid
IHHNV	Infectious Hypodermal and Haematopoietic Necrosis Virus
IRR	internal rate of return
ITS	internal transcribed spacer
kg	kilogram
L	length
LGU	local government unit
LTP	local transport permit
m	meter
MIH	molt inhibiting hormone
min	minutes
mL	milliliter

mm	millimeter
MRL	maximum residue limit
mRNA	mitochondrial ribonucleic acid
NaOCl	sodium hypochlorite
PCR	polymerase chain reaction
PNS	Philippine National Standards
ppm	parts per million
ppt	parts per thousand
PVC	polyvinyl chloride
RAS	recirculating aquaculture system
SEAFDEC	Southeast Asian Fisheries Development Center
SEC	Securities and Exchange Commission
SSOP	Sanitation Standard Operating Procedure
µm	micrometer
UV	ultraviolet
W	width
WSSV	white spot syndrome virus

Introduction

The mangrove crab, widely known in the Philippines as alimango is known under different names in English language. In the Food and Agriculture Organization (FAO) Species Fact Sheet, it is known as Indo-Pacific swamp crab while in the Smithsonian collection, it is referred to as serrated swimming crab, giant mud crab, edible mud crab, and mangrove crab. During the First National Mud Crab Congress, held on November 16–18, 2015 in Iloilo City, the participants unanimously agreed on and signed a resolution adopting "mangrove crab" as the preferred English common name for the species to highlight the mangrove habitat where these are commonly found.

The taxonomy of mangrove crabs is not any less confusing. Originally classified under one species as *Scylla serrata*, Estampador (1949) recognized 3 species and 1 subspecies. Keenan et al. (1998), using genetic methods on a greater number of specimens collected from several locations in the Indo-Pacific, determined that Estampador was correct in recognizing four distinct groupings but considered all four groups as distinct species: *S. serrata* (Forskål 1775), *S. olivacea* (Herbstm 1796), *S. tranquebarica* (Fabricius 1798), and *S. paramamosain* (Estampador 1949).

However, Keenan et. al. questioned Estampador's use of nomenclature especially with regards to which of the four groupings should be *S. serrata*. Taxonomic details and nomenclature are important in both the academe and in aquaculture since mangrove crabs are widely traded and priced differently among species.

The classification of Keenan et al. (1998) has been widely accepted. *S. serrata* is known in the Philippines as king crab, 'bulik' and 'kinis' and the most expensive and sought after species. It is generally found along the eastern seaboard of the Philippines (Pacific Ocean side) such as Camarines, Albay, Sorsogon, Catanduanes, Samar, and Surigao.

Along the western seaboard (West Philippine Sea, Sulu Sea and waters between the islands), *S. olivacea*, known locally as 'pulahan,' 'amamakhaw,' 'manabigui,' or 'tabiguion' and *S. tranquebarica* or 'lawodnon' are the dominant species (Fig. 1). *S. olivacea* is "probably the most common species in many markets of Southeast Asia" according to the FAO Species Fact Sheet. The fourth species, *S. paramamosain*, may have dwindled to a very small population and have become very rare in the Philippines. Nevertheless, *S. paramamosain* is the mangrove crab species that is dominant in Vietnam, Thailand, Indonesia, and China.

The mangrove crabs are widely distributed from East and South Africa to Southeast and East Asia (from southeast of China to Sri Lanka), and Northeast Australia as well as around the Marianas, Fiji, and Samoa Islands (FAO Cultured Aquatic Species Fact Sheet, www.fao.org/fishery/culturedspecies/Scylla_serrata/en). It is found in the Red Sea, which is considered the original type locality of *S. serrata* where Forskål obtained his specimen. It was introduced in the Hawaiian islands where it is now known as Samoan crab as well as in Florida where its population status is currently unknown (Smithsonian species inventory, www.sms.si.edu/irlspec/scylla_serrata.htm).

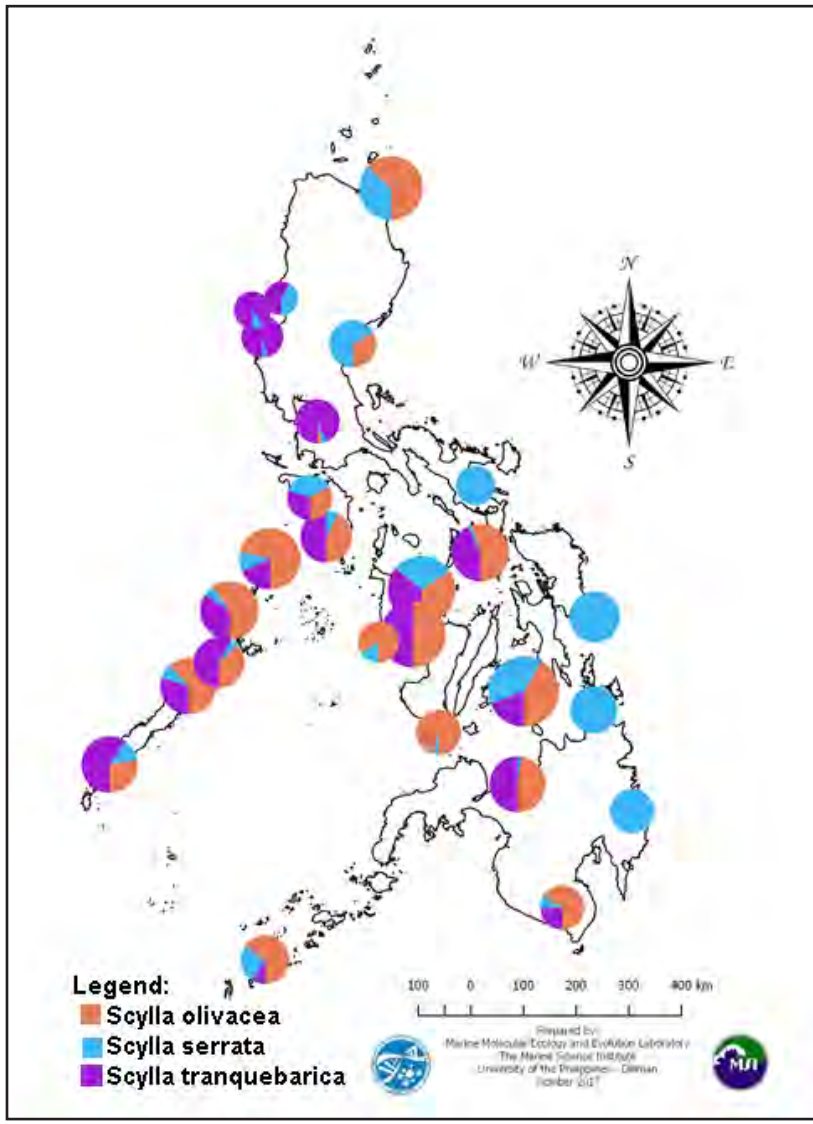


Fig. 1. Distribution of mangrove crabs by species in the Philippines showing their relative abundance based on 1,033-individual samples in 26 sites covering 6 marine biogeographic regions. (Source of map: Ravago-Gotanco et al. unpublished data).

Commodity Profile

The mangrove crab is just one among nearly 40 species of crabs that are traded commercially, but many are not classified as to species in trade statistics (Globefish 2015). The blue swimming crab is the most important among those classified, accounting for 7% of the total volume landed, followed by tanner crabs (4%), and dungeness crab (2%). As a commodity, the mangrove crab may be considered a class in itself at least within Southeast Asia because it is always traded, displayed, and sold live while most other species are traded chilled or frozen or as crab meat.

Scylla mud crabs are distributed from East and South Africa to Southeast Asia and Australia. The most widely distributed is *S. serrata*, which, having been introduced in Hawaii, can also be found in the Pacific Island Network.

The total production of mangrove crab from aquaculture in the Philippines is relatively small when compared with the other farmed species. Mangrove crab ranks 9th after seaweeds, milkfish, tilapia, tiger shrimp, and four other species by quantity. However, it is 4th after milkfish, tilapia, and tiger shrimp in terms of value. This shows the value of the species and its potential in reducing poverty in coastal areas. Furthermore, the growth in annual production in the Philippines is on an upward trend. During the last 10 years, total production of mangrove crab from aquaculture grew from 11,618 tons (t) valued at P2.9 billion (B) in 2008 to 18,098 t valued at P7.3B in 2017 (Fig. 2). While production grew at an average of 5.5% annually by quantity, the average annual growth by value during the same 10-year period was 149.2%. The massive increase in its value during the last 10 years reflects the surging demand for live mangrove crabs especially of king crab or *S. serrata*. Domestic and export market demand is so high that the mangrove crab industry is essentially a seller's market at present and has been for some time.

While mangrove crabs are farmed in many coastal regions in the Philippines, production is highest in Northern Mindanao (8,669 t), followed by Central Luzon (4,355 t), and Western Visayas (2,096 t) (Fig. 3). The three regions produced 83.5% of farmed crabs in 2017, particularly in the Panguil Bay area which is bounded by three provinces: Misamis Occidental, Lanao del Norte, and a very small portion technically along Zamboanga del Sur, which is part of the Autonomous Region in Muslim Mindanao.

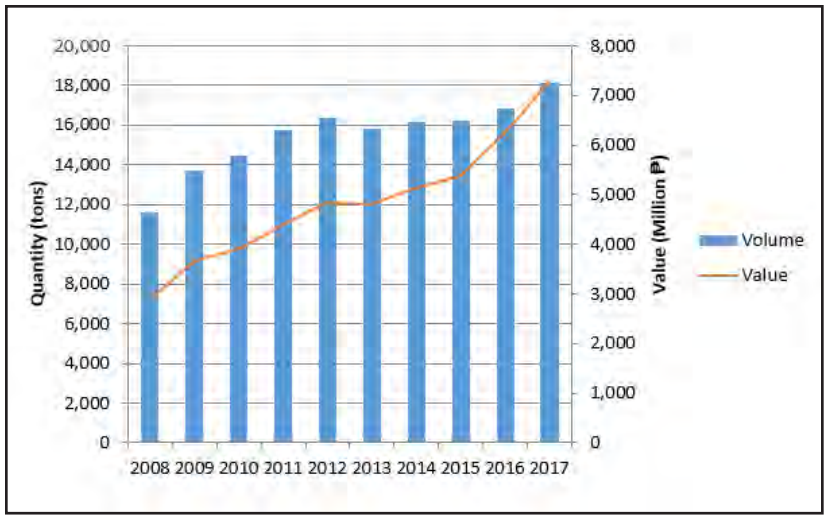


Fig. 2. Annual quantity and value of mangrove crabs from aquaculture in the Philippines, 2008–2017 (PSA Countrystat).

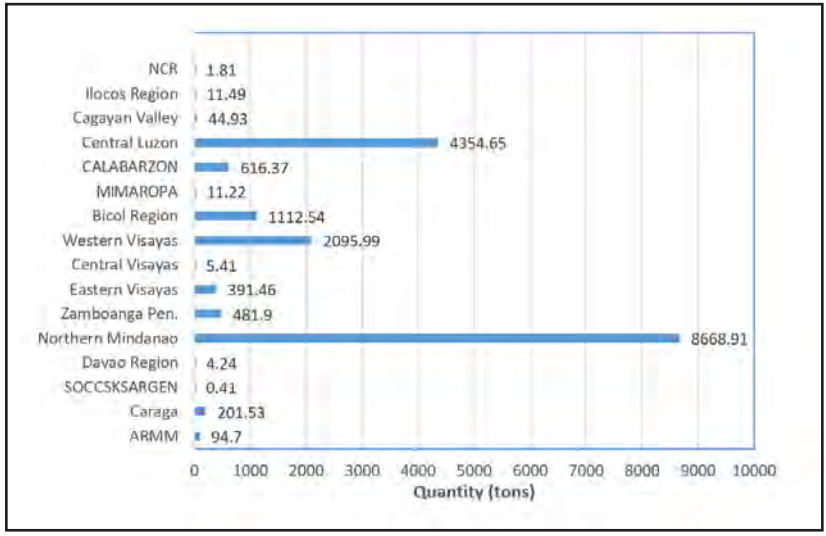


Fig. 3. Mangrove crab production by region in the Philippines, 2017 (PSA Countrystat).

Traded live crabs have a very complicated pricing scheme at the farm gate, which varies widely in terms of species, sex (male, female, immature female or 'bakla'), size, reproductive stage, and season. *S. serrata* fetches a higher price than *S. olivacea* and *S. tranquebarica*. Crabs over 500 grams (g) are sold at premium price. Among crabs of the same size, the female crab with orange gonads or 'aligue' are sold at a higher price than those without aligue. The mangrove crab is too expensive for the crab meat market, which consists mainly of wild-caught blue swimming crabs (*Portunus* sp.). The only products from mangrove crabs are the soft shell crabs and sometimes, the claws of males.

Among the countries producing the Indo-Pacific swamp crab from aquaculture, the Philippines with 16,857 t was second only to Vietnam with a production of 59,857 t in 2016 (most recent figures available). However, it is known that Vietnam produces only *S. paramamosain*, which does not occur naturally in the Philippines. China is listed as having produced 148,977 t of *S. paramamosain* in 2016, while Bangladesh and Myanmar produced 13,160 t and 3,151 t of *S. olivacea*, respectively.

The Bureau of Agriculture and Fisheries Standards (BAFS) of the Department of Agriculture (DA), in partnership with relevant government and research agencies, academe, and stakeholders developed the Philippine National Standards (PNS) for live mangrove crabs and soft-shell crabs. This PNS describes the food safety and quality requirements for live and soft-shell mangrove crabs to safeguard the health of consumers and make the product globally competitive.

Biology of Mangrove Crab

Information on the biology of the animal for culture is important to be able to understand its characteristics, structure, development, physiology, and ecology. This knowledge coupled with skills in optimal husbandry and breeding techniques will ensure success in crab aquaculture operations.

Parts of a Crab

Mangrove crabs have a flat and broad body covered by a carapace (Fig. 4). The front margin of the carapace has 6 spines between the eyes and 9 spines on each side of the anterolateral margin. Carapace width (CW) and carapace length (CL) are used to measure the size of the crab. The crab possesses 1 pair of claws, 3 pairs of walking legs, and 1 pair of flattened swimming legs. The walking legs in males are used for embracing the female during mating while females use these for scratching the eggs off before hatching.

The claws have enlarged segments and are used for crushing shells and bringing food to the mouth. The mouthparts collect and process food. The eyes, antennules, antennae, dactylus, and maxillipeds are used for sensory perception.

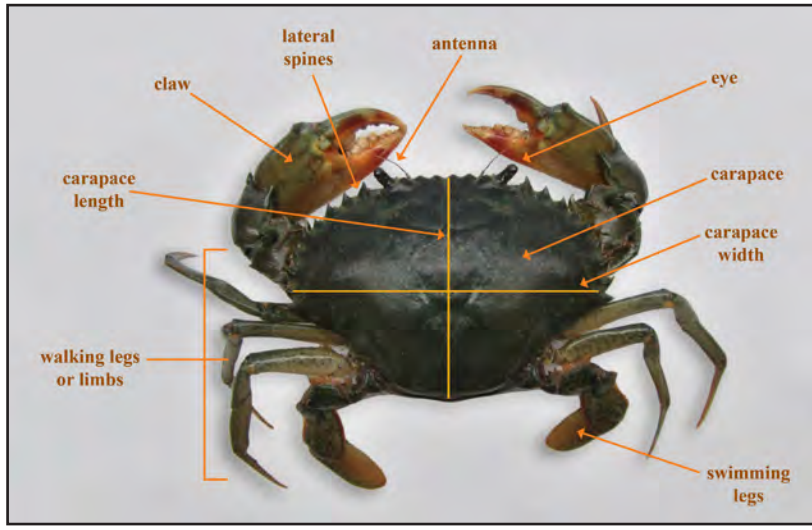


Fig. 4. Top view of an adult mangrove crab showing major external parts.

The sex of mangrove crabs can be recognized externally. Females and males are differentiated by the shape of their abdominal flaps. Immature females have a small triangular-shaped abdominal flap (Fig. 5A) and as they mature the flap becomes semi- circular and wide (Fig. 5B and 5C). Males have a triangular-shaped abdominal flaps (Fig. 5D). Mature males have bigger claws than females of the same carapace size.

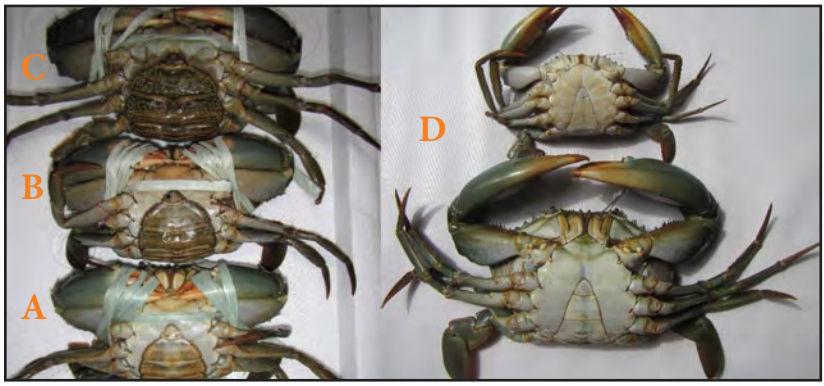


Fig. 5. Appearance of the abdominal flap at different stages of maturity: (A) immature, (B) maturing and (C) mature female, and (D) immature and mature male.

Intermediate morphological features have been observed and mangrove crabs having this intermediate phenotype are locally called bakla, and are sold at a higher price due to their larger size, higher flesh content, and less fatty vitellogenic tissue.

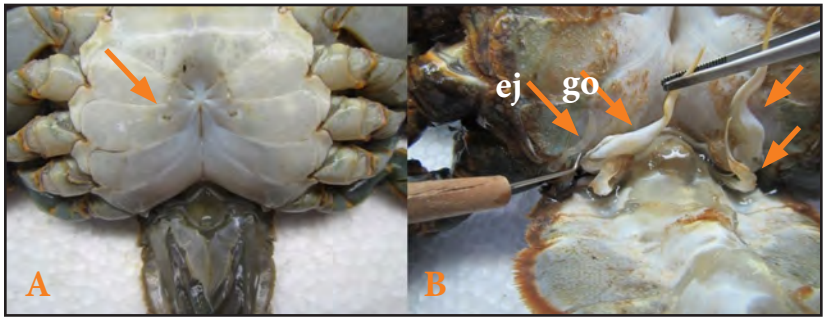


Fig. 6. Structures in crabs involved in mating: (A) vulvae of female and (B) gonopods of male (ej - ejaculatory duct; go - gonopods).

Identification of Crab Species

The four species of *Scylla* are *S. serrata*, *S. tranquebarica*, *S. olivacea*, and *S. paramamosain* (Fig. 7). Except for *S. paramamosain*, the three species are commonly found in the Philippines. *S. paramamosain* is common in Thailand, Vietnam, and Indonesia. Table 1 shows the distinguishing characters of the four species.

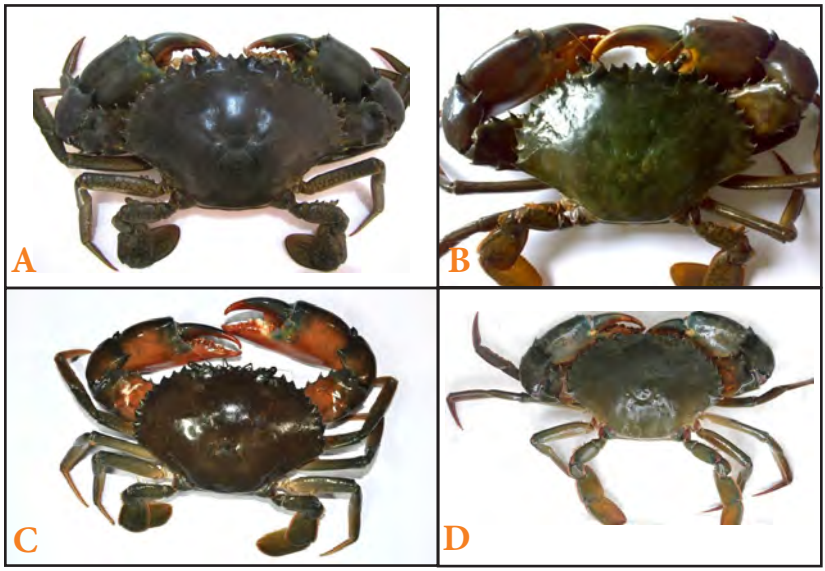
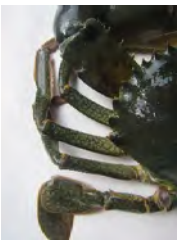
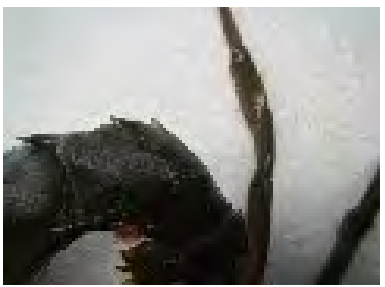
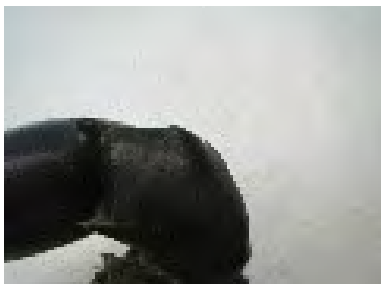


Fig. 7. The four species of *Scylla*: (A) *S. serrata*, (B) *S. tranquebarica*, (C) *S. olivacea*, and (D) *S. paramamosain*.

Table 1. The distinguishing characters of the *Scylla* species (modified from Keenan et al. 1998) as summarized by Quinitio et al. (2018).

Species (English name)	Frontal spines		Claw spines		Color and Markings
	Shape	Height	Carpus	Propodus	
Scylla serrata (Giant or king mangrove crab) Local names: alimango, kinis, 'banhawan,' bulik	pointed	high	both obvious	obvious	green to almost black carapace, polygonal pattern obvious on claws and legs of both sexes and on abdomen of mature female 
					
S. tranquebarica (Purple mangrove crab) Local names: alimango, lawodnon	blunt	moderate	both obvious	obvious	green to almost black carapace, polygonal pattern obvious on last two pairs of legs but weak on chelipeds and other legs of both sexes 
					

Species (English name)	Frontal spines		Claw spines		Color and Markings
	Shape	Height	Carpus	Propodus	
S. olivacea (Orange mangrove crab) Local names: alimango, lawodnon, pulahan, amamakhaw	rounded	low	inner absent, outer reduced	reduced	brownish to brownish green carapace, rusty brown claws and legs, polygonal pattern absent
					
S. paramamosain (Green mangrove crab) Local name: alimango	triangular	moderately high	inner absent, outer reduced	obvious	green to light green carapace, weak polygonal pattern on claws and legs in both sexes
					

Life Cycle

Scylla species inhabit muddy estuaries in mangroves and soft-bottom shallow intertidal water. Crabs are commonly collected using cylindrical bamboo tubes or 'bubo', meshed-net box traps, lift nets or 'bintol', or hooked pole aided by bare hands.

The life cycle of the mangrove crab is illustrated in Fig. 8. Courtship and mating occur in brackishwater. Mature *S. serrata* females migrate offshore to spawn. *Scylla* spp. prefer 25-32 parts per thousand (ppt) salinity depending on the species. Spawned eggs attach to the hairs of the abdominal flap. Egg hatches into zoea and undergoes five stages, zoea I to V that float in the water. Zoea V becomes megalopa that molts after 5–7 days to appear as minute crab (4 millimeters [mm] wide). Small crabs (juveniles or popularly known as crablets) are found in estuaries, tidal flats, and mangroves where they burrow in mud or sand, or hide under fallen leaves, stones/rocks, and other shaded areas during the day. About a month after hatching, the crablets move to the estuary and settle in sheltered areas. The crabs undergo several moltings until they reach full maturity.

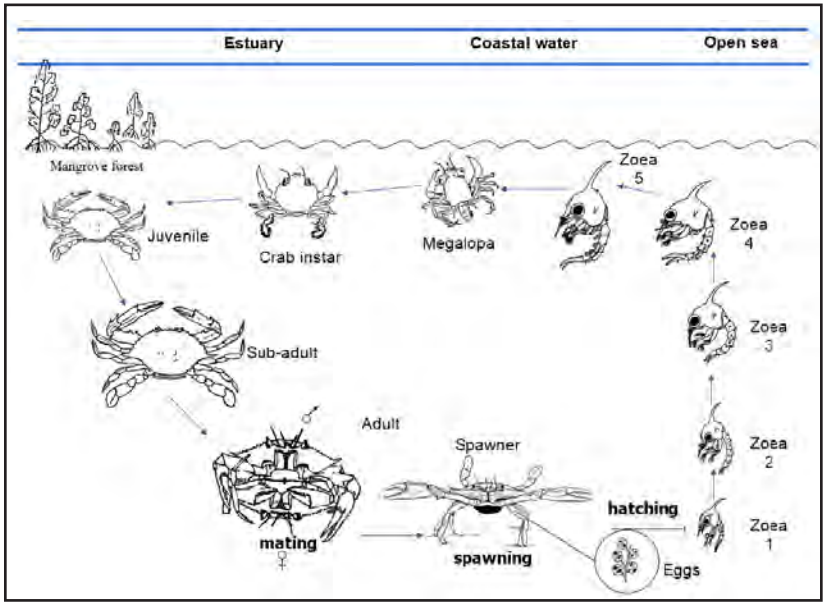


Fig. 8. Life cycle of mangrove crab (not drawn to scale, Quinitio et al., 2018).

Food and Feeding

The zoea and megalopa feed on zooplankton. Small crabs are omnivorous, feeding on sessile or slow-moving benthic invertebrates such as crustaceans, mollusks, worms, fish, and plant matter. The sub-adult and adult crabs feed on burrowing and attached bivalves and small crabs.

Molting

Mangrove crab has an exoskeleton or shell, which requires molting (shedding of hard exoskeleton) to grow and develop. The exoskeleton is soft immediately after molting. The crab expands its body and limbs by taking in water before the new shell hardens. The crabs molt frequently when small, but less often when bigger. The different stages of the molt cycle are as follows:

- Postmolt - The newly molted crab is soft and inactive. It expands its body and limbs by taking in water prior to the hardening of the new exoskeleton. Feeding starts when shell hardens.
- Intermolt - The carapace is slightly hard during the early part of intermolt stage. Exoskeleton becomes completely hard after several days depending on the crab size.
- Premolt - Exoskeleton becomes papery. The hard outer layer of the exoskeleton separates from the membranous layer and causes an evident mottled appearance of the old exoskeleton. Activity is reduced and feeding ceases as the crab loses its muscle insertions.
- Molting - The crab quickly gets out of the old exoskeleton (Fig. 9). Water and air are taken up to expand the new exoskeleton. The crab increases in size by 30–50%. This stage is the most stressful part of the molt cycle.

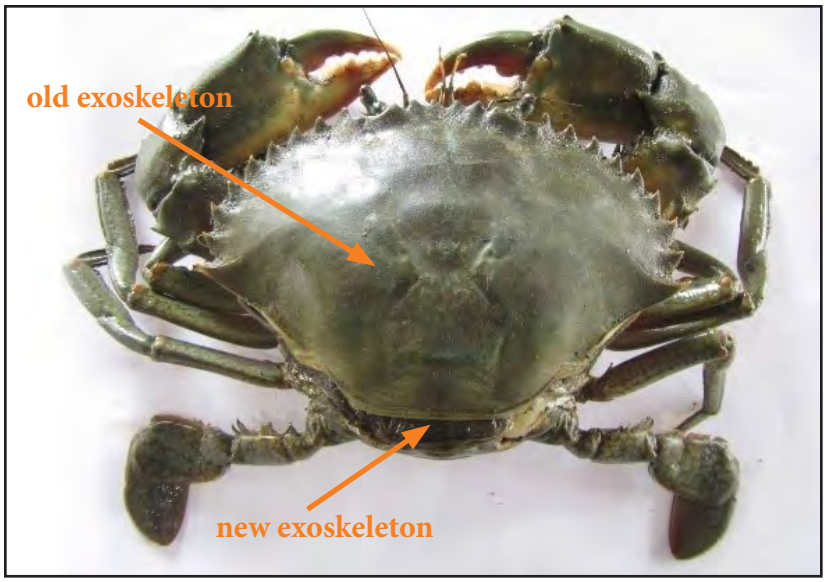


Fig. 9. The old exoskeleton is separated from the crab during molting.

The newly molted crab is vulnerable to cannibalism; hence, it seeks shelters or burrows to escape predation. A crab is able to snap off its legs at the base when it is seized by other animals or when its leg is damaged. However, crabs are able to regenerate lost limbs.

Mating

Mature females release a chemical attractant called pheromone in the water to attract males. The male climbs on top of the female and clasps the female using his hind legs. The male carries the female around for up to several days and releases the female that is ready to molt. After the female has molted, the male mounts itself at the back of the female and turns the female around. Their under surfaces meet with their abdomens extended. The male deposits a capsule of sperm called spermatophores inside the genital openings or vulvae of the female with the aid of the gonopods. After mating, the male flips the female upright and holds her under him for a few more days while her shell hardens. The spermatophores are stored in the spermathecae for several months until the developing ova (eggs) are ready to be fertilized.

The spermatophores can be retained in the spermathecae even after molting. Multiple spawning after a single mating can be observed in females. The sperm in the spermatophores are usually viable for more than 4 months.

Spawning

Mangrove crabs spawn throughout the year in captivity. A female ready to spawn raises its body away from the bottom and opens its abdominal flap to facilitate release of the eggs. The eggs are fertilized as they pass through the spermathecae. The eggs pass through the opening and attach to the hairs of the abdominal flap. Females with spawned eggs are sometimes referred to as berried females. The orange egg mass darkens to grayish orange and finally to gray as the embryo develops (Fig. 10).

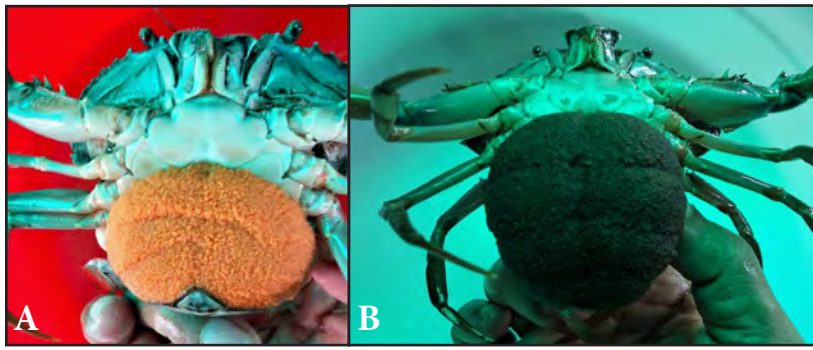


Fig. 10. Newly spawned eggs are orange (A) and become gray (B) as they develop.

The zoeae produced by a female in a single spawning range from 0.5 million (M) to 6.0 M in *S. serrata* (480–915 g), 0.30–3.5 M in *S. tranquebarica* (300–480 g), and 0.30–2.7 M in *S. olivacea* (250–465 g). A female can produce at least three batches of eggs with an interval of 34–59 days between spawnings.

Embryonic and Larval Development

Newly released eggs measure 0.31–0.32 mm in *S. olivacea* and *S. tranquebarica* and 0.32–0.35 mm in *S. serrata*. The eggs are almost spherical and hatch within 7–10 days. The duration of embryonic development varies with egg quality, temperature, salinity, and other factors. After 15–18 days, zoea becomes megalopa. It will take another 7 days for the megalopa to develop into the first crab stage (instar) or crablet (Fig. 8).

Hatchery Operations

Hatchery is the first phase in the culture of crab and has become essential to meet the increasing seedstock requirements for farming. Establishment of crab hatcheries is important in sustaining the industry. The advantages of hatchery-produced crablets include conservation of wild resources, certainty in species identification, uniformity in size, and availability throughout the year.

This section describes the principles and procedures for spawning mature *S. serrata*, *S. tranquebarica*, and *S. olivacea* and rearing the zoea to crablet. Hatchery conditions should satisfy the ecological requirements of the crab larvae.

Site Selection

The important criteria in selecting a site for the crab hatchery are as follows:

- Seawater supply - The hatchery should be adjacent to sandy and rocky or coralline shores where quality seawater can be obtained readily;
- Availability of electric power – Electricity is necessary to operate life support systems and other hatchery equipment. In case of electric power interruptions, a stand-by generator should be available;
- Accessibility - The hatchery should be accessible to good roads for ease in the transport of crabs, equipment, supplies, and other materials; and
- Freshwater supply - Freshwater is essential for washing and rinsing tanks and other implements.

Hatchery Layout

The size of mangrove crab hatchery is based on the target production and financial capability of the investor. Figure 11 shows a sample layout of a hatchery with a total rearing tank capacity of 80 t. This size can produce about 96,000 crablets (<1.0 cm CW/run). The ratio of rearing tanks to natural food tanks is 1: 2–2.5. However, the number of natural food tanks can be reduced when commercially available algal paste is used as feed for the mass production of rotifers or when umbrella stage or small strain *Artemia* is used as food for the zoeae.

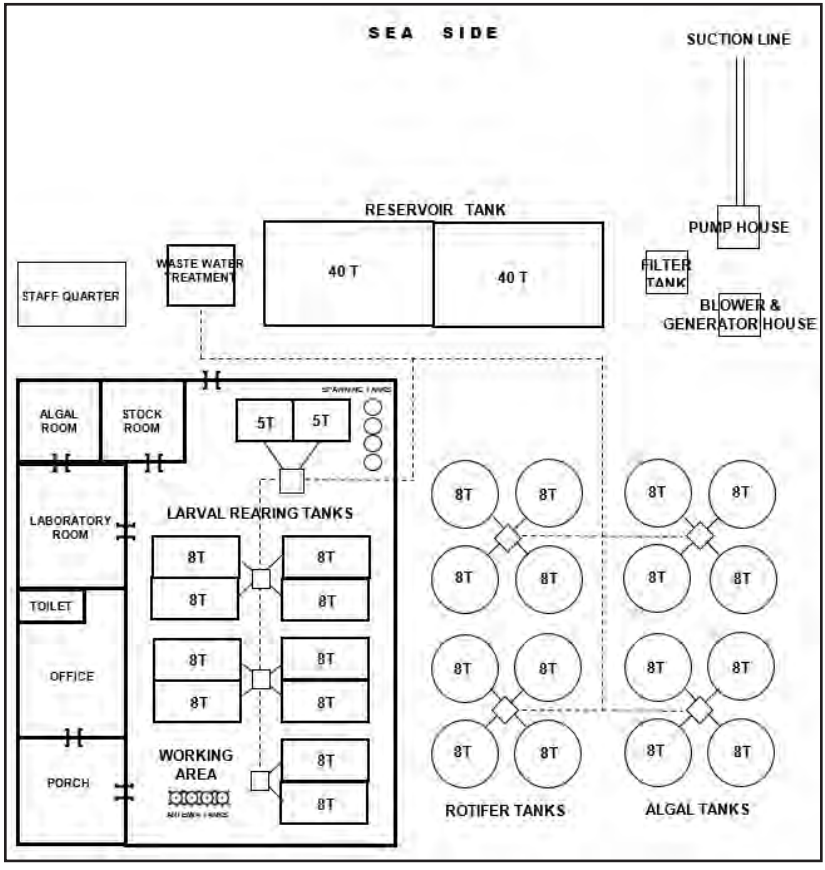


Fig. 11. A sample layout of a mangrove crab hatchery. T - ton, which is equivalent to 1,000 liters (L) of water.

Tanks

Tanks can be made of concrete, fiberglass, plastic, or marine wood with rubberized canvas lining. Circular or square/rectangular tanks with rounded corners are suited for better water circulation in the hatchery. Tank bottom should be flat and sloping towards the drain. Wall and bottom surfaces should be smooth and painted. Tanks for broodstock, spawning, larval rearing, natural food production, Artemia hatching, and water storage (reservoir), as well as life support systems (aeration, seawater, and freshwater supply) are crucial in hatchery operations.

An aquaculture engineer or hatchery expert should be consulted in the preparation of the layout and construction of the hatchery.

Tank Preparation

Hatchery tanks should be cleaned and disinfected with 200-parts per million (ppm) hypochlorite prior to use. The tanks, aeration hoses, airstones, and other implements should also be cleaned and dried after each run. Aeration hoses (with airstones) should be placed 1 meter (m) apart in tanks.

Water Disinfection

Water for algal culture, broodstock, and larval rearing should pass through a water filtration system. Water disinfection can be done by chlorination with 10–15 ppm calcium hypochlorite overnight in the reservoir, ozonation, or ultra violet treatment, or a combination of any two or all three methods.

Seawater chlorination

Hypochlorite is an oxidizing agent that kills the growth of harmful microorganisms. This chemical is also toxic to crab, hence, the chlorinated water should be strongly aerated to release the chlorine residues or treated with sodium thiosulfate to deactivate the residues before use. There are two forms of hypochlorite namely, sodium hypochlorite or bleach (NaOCl or NaClO) and calcium hypochlorite ($Ca\ ClO)_2$. Calcium hypochlorite, available in dry granular form, is more commonly used because it is easy to store and is more stable. The application is as follows:

1. Pump seawater into the reservoir after filtration.
2. Compute the amount of calcium hypochlorite required for disinfection as follows:

$$Wt = \frac{Ch \times Vsw}{Ph}$$

Where: Wt = weight of calcium hypochlorite (in g)
Ch = desired concentration (ppm) of hypochlorite (usually 10–15 ppm)
Vsw = volume of seawater to be treated (in t)
Ph = percentage of hypochlorite in the product

3. Dissolve calcium hypochlorite in a pail containing water. Mix or aerate.
4. Add the solution to the water in the reservoir. Aerate vigorously for uniform mixing.
5. Aerate the water strongly or add sodium thiosulfate after 12–24 hours.

Residual chlorine determination

1. Obtain 10 milliliters (mL) of chlorinated water from the reservoir.
2. Put 3–4 drops of orthotoluidine solution, a chlorine level indicator ($CH_3C_6H_4NH_2$), to the chlorinated water sample and shake.
3. After 10–15 seconds, if the water sample remains white, the chlorine level is zero. However, if it turns yellow, chlorine is still present (Fig. 12).

4. To remove the residual chlorine, subject the treated water to vigorous aeration overnight and test again using the chlorine indicator.
5. If the water is immediately needed, neutralize the chlorine by using sodium thiosulfate.
6. Dissolve the same amount of sodium thiosulfate as the amount of calcium hypochlorite used.
7. Put the sodium thiosulfate in a small amount of freshwater and aerate for 30–60 minutes (min). Add the dissolved sodium thiosulfate to the chlorinated water and aerate vigorously.
8. Repeat Step 2 after 30 mins. Residual chlorine should be zero before using the water.

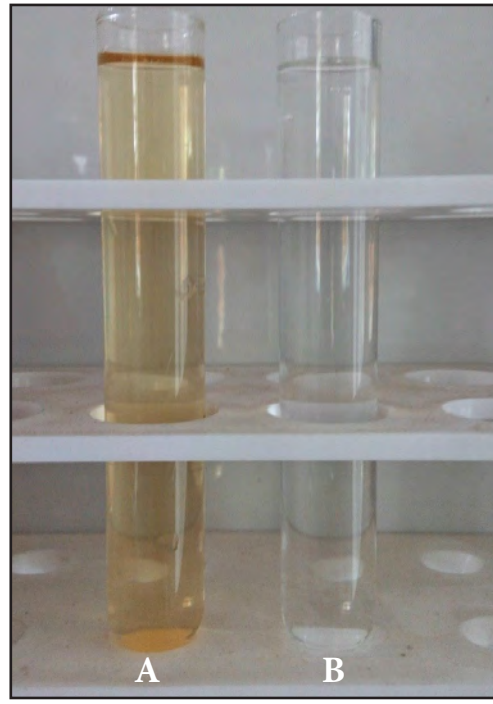


Fig. 12. Water treated with chlorine turns yellow (A) but becomes clear (B) when chlorine has been removed through strong aeration or neutralization using sodium thiosulfate.

Culture of Natural Food

Rotifers or *Brachionus* (Fig. 13) are fed to zoeae for growth and survival. However, green microalgae such as *Tetraselmis* (Fig. 14A), and *Nannochloropsis* or *Nanochlorum* (Fig. 14B), have to be cultured as feed to the rotifers. *Nanochlorum* is more commonly used in most crab hatcheries.

Rotifers should be made available as soon as the eggs hatch. To determine the number and volume of tanks to be used, a scale-up schedule for the initial culture of *Nanochlorum* and *Brachionus* must be made. Since it takes about 3–4 days for both to attain peak density, three sets of tanks must be available for the scale-up culture. About 20% of the culture is needed as starter. Figure 15 shows a sample production schedule for scaling up microalgae and rotifers for use as larval food for an 80-t capacity hatchery. This schedule represents one set of culture and another set should be cultured on Day 2 and the third set on Day 3 so that food will be available daily.

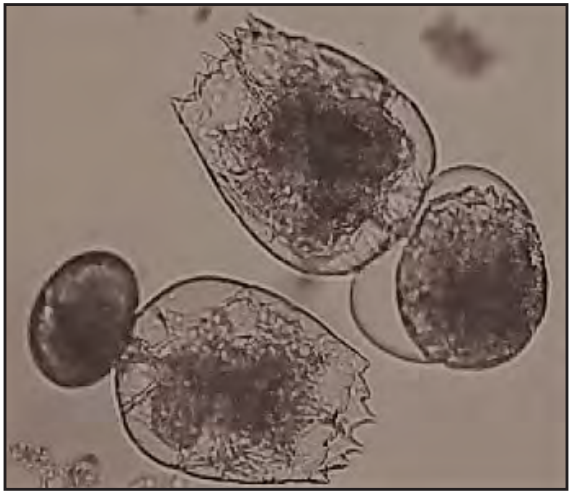


Fig. 13. Adult rotifers *Brachionus rotundiformis* (190–215 µm).

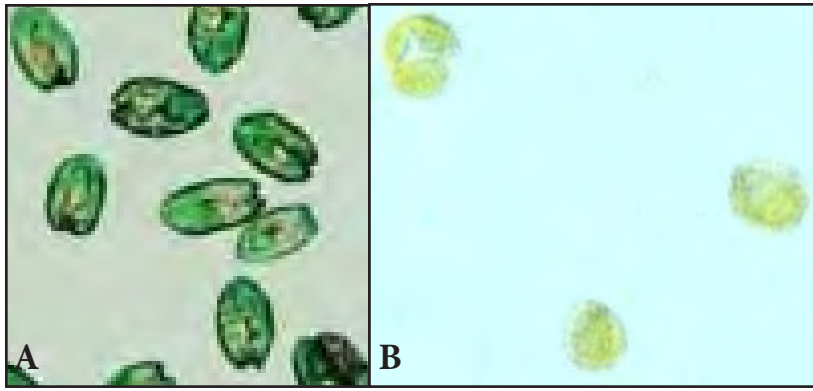


Fig. 14. The unicellular algae *Tetraselmis* (10–16 micrometers [µm]) (A) and *Nanochlorum* sp. (4–8 µm) (B).

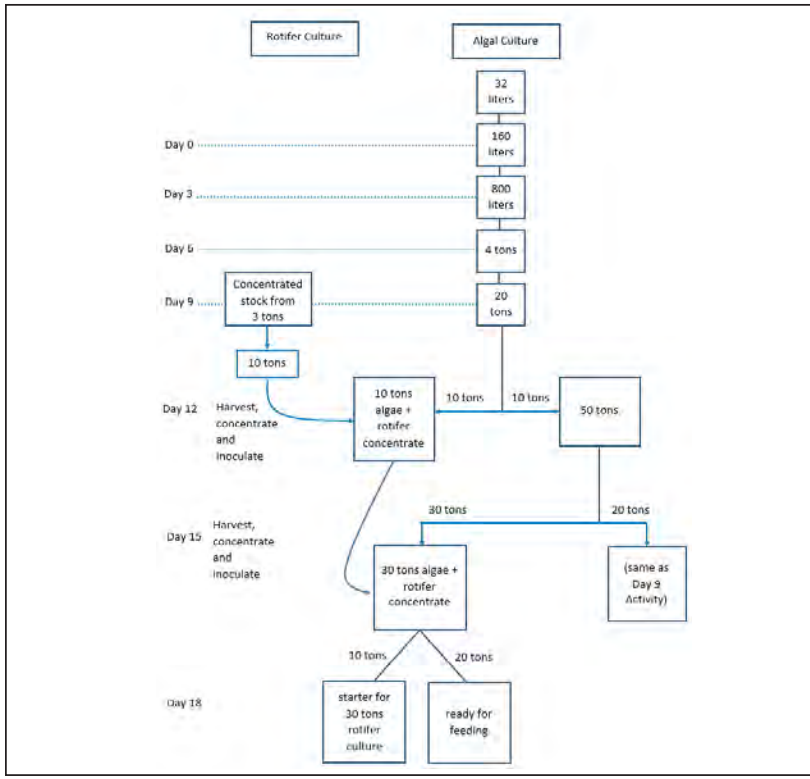


Fig. 15. Example of production schedule or scaling up microalgae and rotifer cultures in the hatchery. This schedule represents one set of culture. Another set of culture needs to be prepared on Day 2. (Quinitio et al. 2018)

Culture of Marine Algae (*Nanochlorum* or *Nannochloropsis*)

1. Get the initial starter (inoculum) of marine microalgae *Nanochlorum* sp. or *Nannochloropsis* sp. from the Natural Food Laboratory of SEAFDEC/AQD or nearby hatchery. About 32 liters (L) for 160-L initial culture is needed.
2. Put 80% of the desired volume of seawater in a clean tank and add the starter.
3. Dissolve the following fertilizers in clean water:

21-0-0 (ammonium sulfate)	10 g/t of culture
16-20-0 (ammonium phosphate)	15 g/t
46-0-0 (urea)	40 g/t

4. Add the dissolved fertilizers to the culture tank. Provide aeration. *Nanochlorum* sp. or *Nannochloropsis* sp. will be ready for use after 3 days.
5. Scale up the culture (follow Steps 2–4) until the desired volume is attained for starters and food for the rotifers.

Culture of Rotifers (*Brachionus*)

1. Acquire rotifers as starter from known sources (e.g. the Southeast Asian Fisheries Development Center/Aquaculture Department [SEAFDEC/AQD] or nearby crab or marine fish hatchery). The volume of starter should be at least 30% of the total volume. The rotifer starter should be concentrated to 10–30 L for ease of transport. A daily requirement of 20 t of rotifer culture can be attained after 18 days from the start of natural food culture.
2. Put the concentrated rotifers into the microalgae *Nanochlorum* sp. or *Nannochloropsis* sp. culture and the resulting density of rotifers should not be lower than 15 rotifers/mL.

3. Add baker's yeast at about 1 g yeast/M rotifers per day if microalgae are not enough. Continuous drip or frequent feeding is recommended to avoid deterioration of water quality. However, rotifer-fed algae are more beneficial for crab larvae than rotifers that are yeast-fed. Highly unsaturated fatty acid (HUFA) can be used to enrich rotifers 6–12 hours before feeding to the larvae. There are several commercially available enrichment diets for rotifers. Likewise, commercially available algal paste or concentrate can also be used to feed the rotifers.
4. Concentrate the rotifers using a 45–65 µm mesh plankton net. Use 30% of the harvested rotifers to start the next set of culture and the rest (70%) as food for the crab larvae.

Hatching and Culture of Brine Shrimp (*Artemia*)

The brine shrimp, *Artemia*, is used as food for marine finfish and crustacean larvae. *Artemia* cysts are packed in cans. Within 15–24 hours of incubation in seawater, the cysts hatch into free-swimming nauplii and can be fed directly to zoeae and megalopae. After 16–18 hours, an umbrella-like stage occurs in which the embryo hangs underneath the shell.

Hatching of Artemia cysts

1. Determine the hatching efficiency of the *Artemia* cysts and total volume of the larval tanks where *Artemia* will be introduced using the following equation:

$$Wt = Fr \times He \times Vlt$$

Where: Wt = weight of *Artemia* cysts (in g) to be incubated
Fr = feeding rate (0.5–1.0 *Artemia*/mL)
He = hatching efficiency of given batch (g cysts/ million nauplii)
Vlt = total volume of larval tanks (in t)

2. Dissolve 0.3 g calcium hypochlorite/L of seawater (60% hypochlorite concentration) in *Artemia* hatching tank to disinfect cysts. Provide aeration.
3. Put 3–5 g *Artemia* cysts/L of water in the hatching tank. Harvest and wash the cysts after 30 mins.
4. Put the disinfected cysts in a hatching tank (preferably cone-shaped) with clean seawater. Provide aeration to suspend all the cysts. Incubate for 18–24 hours as indicated on the product label. Provide artificial lighting atop the *Artemia* incubation tank to ensure efficient hatching.

Harvesting of Artemia nauplii

1. Remove aeration and cover the tank leaving a small portion open to allow some light to get into the tank. *Artemia* nauplii will converge in the lighted area as these are phototactic.
2. Siphon the nauplii with a hose (1.5–2.0-cm diameter) into a 110–150 µm mesh size collecting net.
3. Wash the nauplii with seawater or freshwater. Put the nauplii in a pail with seawater and feed to crab larvae.

Culture of Artemia

1. Wash the newly hatched *Artemia* nauplii with clean water by letting them pass through a 150-µm mesh net and stock at 1,000–3,000 *Artemia*/L in a 1-t tank with seawater.
2. Provide the tank with strong aeration using an airlift system.
3. Prepare a rice bran suspension by soaking 1 kilogram (kg) rice bran in 4 L seawater. Provide aeration for 1 hour. Put the suspension in a 60 µm plankton net and squeeze to obtain the particle sizes appropriate for *Artemia*. Aerate the suspension vigorously.
4. Feed the *Artemia* frequently with rice bran suspension. Feeding by continuous drip is another option. Avoid overfeeding to maintain good water quality. The transparency

of water should be 10–15 cm during the first 3 days and 20 cm thereafter.

5. Change 30–50% of the water 2–3 times a week. Siphon the waste materials from the bottom and/or allow daily removal by flowthrough system.
6. Harvest the *Artemia* after 3–5 days depending on the desired size. *Artemia* may be fed with green algae *Tetraselmis* or enriched with HUFA emulsion 6–12 hours before harvest. Several enrichment diets for *Artemia* are commercially available.

Management of Broodstock

Selection and Transport

Mature female crabs with dark orange ovaries obtained from either ponds or estuaries are held in tanks until the eggs are released or spawned. The eggs are released and they attach to the hairs of the crab's abdominal flap. This stage is known as berried females. Berried females are 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 longer than 3 weeks. Ovarian maturation can be induced by performing eyestalk ablation. There are several methods of eyestalk ablation but cautery is preferred (Fig. 16A). In cautery, one eyestalk is crushed with a pair of red-hot forceps (Fig. 16B) or an electric cauterizer. Cautery closes the wound and allows the scar tissue to develop faster.

Fig. 16. Red-hot forceps (A) used in eyestalk ablation by cautery (B).

Mated female crabs are hard to determine because the spermathecae (sperm pockets) are not visible externally. Thus, it is recommended that several females be sourced to get a higher percentage of mated females that will give viable eggs. Berried females sourced from ponds or estuaries may sometimes carry eggs that are heavily infested with protozoans and other microorganisms resulting in egg mortality.

1. Select crabs that are active with clean and hard shells, and complete claws and legs. The minimum body weight should be 500 g (12.5 mm CW) for *S. serrata*, 350 g for *S. tranquebarica* (12.2 mm CW), and *S. olivacea* (11.5 mm CW) broodstock.
2. Select berried crabs with brown or gray egg mass (colors of which indicate fertilized eggs). The egg mass should be clean and intact.
3. Tie claws to prevent fighting among crabs, but do not tie those that are berried.
4. Place non-berried crabs in woven bags ('bayong'), carton, or plastic box with holes for ventilation. Line the bottom with damp cloth or leaves.
5. Place berried crabs in a styrofoam (polysterene) box or pail with clean seawater, preferably seawater from where the crabs were collected. Put sufficient seawater to submerge the crabs and prevent drying of eggs which may cause mortality. Provide aeration using portable battery-operated aerators.
6. Do not expose the crabs to direct sunlight and strong wind to avoid dehydration which may cause death.

Acclimation and Disinfection

Mangrove crabs may die from mishandling or exposure to unsuitable conditions. An abrupt change in environmental conditions such as salinity and temperature may weaken the crabs hence, acclimation should be done.

1. Place non-berried crabs in a basin and add seawater gradually for about 30 mins. For berried crabs, acclimate them until the salinity and temperature levels are similar with the water in the hatching tank.
2. Place crabs in a basin with 150 ppm formalin for 30 mins to disinfect.
3. Tag crabs using an engraver for identification and to determine the reproductive performance of each crab.
4. Untie crabs and stock them in broodstock tanks with sand bottom. For berried crabs, place them in hatching tanks at one crab per tank. Provide moderate aeration.

Feeding

Crabs are given natural food such as mussel, clam, oyster, marine worm (polychaete), fish, or squid with or without formulated diet. The food is given separately to avoid selective feeding on preferred food.

1. Compute the feeding rate based on food consumption and crab biomass.
2. Feed crabs with natural food at 3–5% of crab biomass daily. Give 30–40% of the daily ration in the morning and the remaining amount in the afternoon.
3. Place food on perforated feeding trays. Remove uneaten food before the next feeding since excess food encourages growth of harmful fungi and bacteria.

Water Management

1. Maintain water depth at 50 cm and water temperature and salinity at 27–30 degrees Celsius (°C) and 30–34 ppt, respectively.
2. Change 30–50% of water volume 3–4 times a week. Clean the sand bottom at least once a week during water change.

Spawning

Crabs that spawned (berried females) in broodstock tank are easy to identify by looking at the abdominal flap which are extended outward (Fig. 17). These crabs are taken from the broodstock tank and transferred in hatching tanks for easy monitoring of egg development and collection of newly hatched zoeae. Berried crabs are maintained using the following:

1. Disinfect berried crabs in 150 ppm formalin bath for 30 mins.
2. Put each crab in a 500-L tank (without sand) provided only with aerated seawater.
3. Feed crabs with natural food at 3–5% of biomass daily. Remove uneaten feeds after 4 hours. Stop feeding when eggs turn brown.
4. Siphon out excess food and detached eggs before changing the water. Change 50–80% of the total water volume in the tank daily. Always retain water in the tank to prevent drying of eggs attached to the flap.
5. Take a small amount of egg samples 2–3 times during the incubation period (7–10 days) to examine embryonic development, infestation, infection, and other abnormalities.
6. Cover the tank to minimize disturbance.
7. Examine for hatching and remove the crab after all the eggs are shed.
8. Return the crabs that have hatched their eggs to the broodstock tank for the next spawning.

Fig. 17. Berried female with extended abdominal flap.

Larval Rearing

Stocking of Zoeae

Zoeae should be collected from the spawning tank within an hour after hatching to avoid microbial infection. The initial stocking density in the larval rearing tank is 80–100 zoeae/L. Only the good quality zoeae from the first two spawnings of a female crab are recommended for larval rearing. The quality of the larvae can be determined by exposing a sample of the newly hatched zoeae in 40 ppm formalin/L for 3 hours. A batch of zoeae is of good quality if the mortality is only 0–18% in 3 hours of formalin exposure. To determine the quality of the batch, perform the following steps:

1. Turn off the aeration to allow dead zoeae, unhatched eggs, feces, and other waste products to settle. Siphon them out. Active zoeae remain near the water surface.
2. Cover the tank but leave a small opening. Allow the zoeae to concentrate in the lighted area for about 20 mins.

3. Siphon the zoeae with a 2-cm diameter hose into a harvesting net box placed in a basin with gently flowing seawater (Fig. 18).
4. Scoop out the zoeae with a bowl and put in an aerated 50–100-L bucket.
5. Get three 100 mL subsamples from different sections of the bucket and count the zoeae individually. Get the average count and multiply by 10 to get the number of zoeae per liter in the bucket.
6. Determine the volume of zoeae suspension (in L) to be placed in each larval rearing tank with the following formula:

$$Vz = \frac{Dst \times Vlt}{Dz}$$

Where: Vz = volume of zoeae suspension (in L)
Dst = desired stocking density (100 zoeae/L)
Vlt = volume of larval rearing tank (in L)
Dz = density of zoeae in the bucket (zoeae/L)

7. Monitor the water temperature in the rearing and hatching tanks. If the temperature difference is 1°C or less, stock zoeae directly into the larval rearing tank.
8. Place the larvae in basins if the temperature difference is more than 1°C. Allow the basins to float on the rearing water for 10–20 min (Fig. 19). Pour water from the rearing tank into the basin every 5–10 mins until conditions in the tank and in the basin are the same. Allow the water in the basin to overflow and slowly release the zoeae into the rearing tank.

Fig. 18. Siphoning of newly hatched zoeae into a net box in a basin using a 2-cm diameter hose.

Fig. 19. Newly-hatched zoeae in basins for acclimation prior to release in larval rearing tank.

Feeding Management

The newly hatched zoeae should be fed immediately since their egg yolk has been used up. Crab larvae may consume phytoplankton but these cannot sustain the growth and survival of the larvae. Rotifers are commonly fed to larvae because they are easy to propagate. The density of rotifers to be maintained in the larval rearing tank is 15–30 individual/mL (Fig. 20). Newly hatched *Artemia* are given to late zoea 2 or early zoea 3 until megalopa at 0.5–1.0 ind/mL. However, umbrella stage *Artemia* or small strain *Artemia* nauplii may be fed to zoeae if rotifers are not readily available. Larger 3–5-day old *Artemia* are fed to late zoea 3 until early megalopa. Minced fish, mussel, or other mollusk meat can be fed to megalopae. Use a blender to finely mince the food stuff.

The amount of rotifers and *Artemia* in the larval tanks are maintained by regular addition of these food organisms. A sufficient amount of food increases the chance of larvae to see and ingest food organisms. Green microalgae may also be added in the rearing tank at 100,000–200,000 cells/mL as food for rotifers and to improve water quality. Crablets are fed minced fish, mussel, or other mollusk meat twice a day to satiation or 40–50% of their biomass.

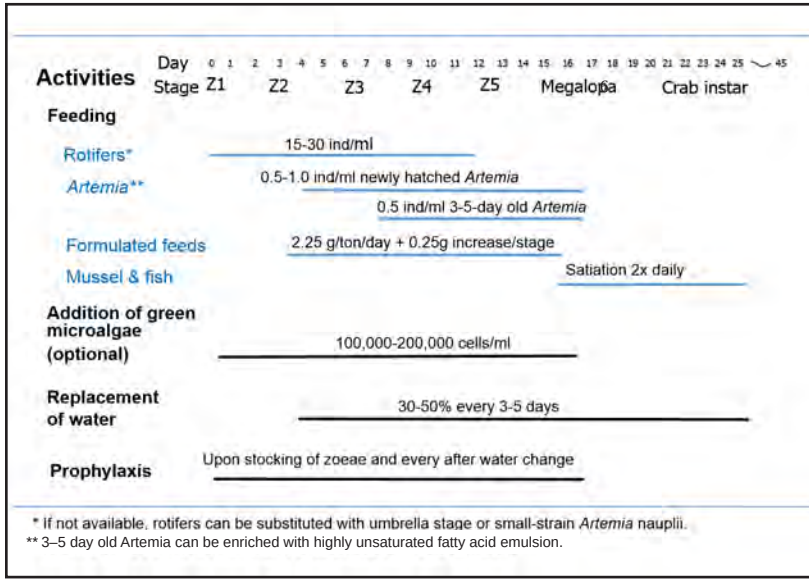


Fig. 20. Feeding and water management during a mud crab hatchery operation.

Counting of algae

1. Use test tubes or small containers (5–10 mL) to obtain water samples from the algal tank and larval rearing tanks.
2. Put a cover slip at the center of a hemacytometer (Fig. 21A).
3. Put a small amount of the sample in the V groove of the hemacytometer. Allow the algal cells to settle for 1–2 mins. The cells should be evenly distributed. Discard the sample if the cells are not evenly distributed. Clean the hemacytometer and reload with new sample.
4. Count the cells using a microscope, examining left to right and top to bottom (Fig. 21B).
5. Compute using the formula:

    a. Use areas A, B, C, and D for bigger cells such as *Tetraselmis* (Fig. 21B).

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

    b. Use the center blocks (1, 2, 3, 4, and 5) in counting small cells (>1 million cells/mL) such as *Nannochlorum and Nannochloropsis* (Block E, Fig. 21B).

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

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

$$\text{Vas} = \frac{\text{Dad-Cad} \times \text{Vrt}}{\text{Sad}}$$

Where: Vas = volume of algal stock (in L) to be added
Dad = desired algal density in rearing tank (cells/mL)
Cad = present algal density in the larval tank (cells/mL)
Vrt = water volume in rearing tank (in L)
Sad = algal density in stock (cells/mL)

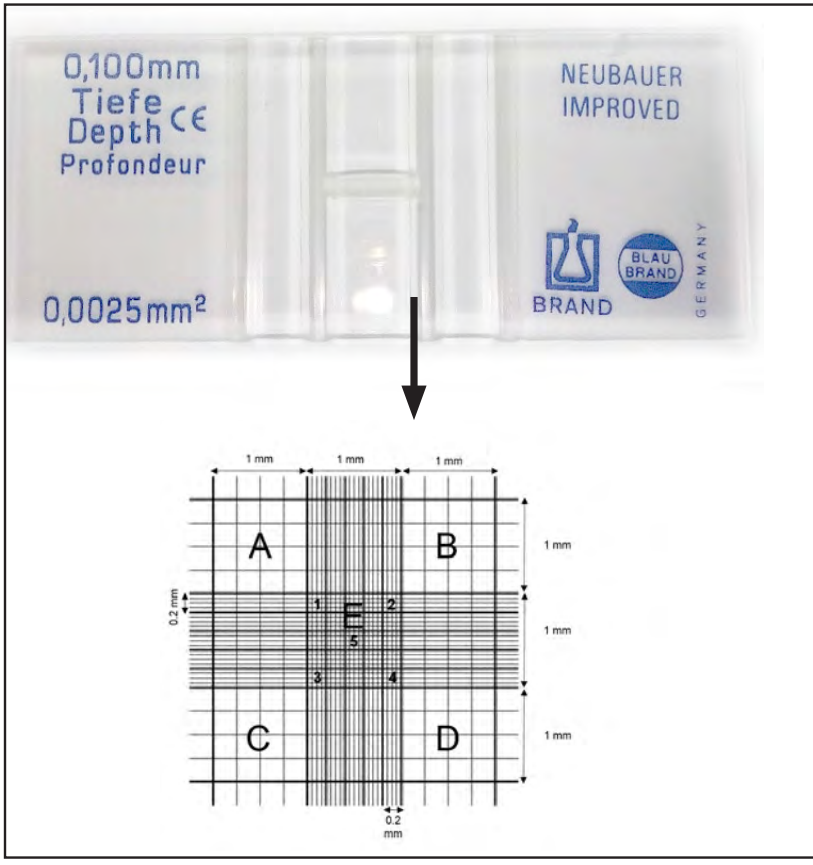


Fig. 21. Top view of a hemacytometer (A) for counting algae under the microscope and one of the counting chambers (B) inset.

Counting of rotifers

1. Use small containers (5–10 mL) with wide opening to get water samples from the harvesting container (where concentrated rotifers are held after harvest) and rearing tanks separately.
2. Pipet 1 mL sample from each well of a modified Sedgewick Rafter counting chamber (Fig. 22).
3. Determine the quality of rotifers. Rotifers should be actively swimming.

4. Count the rotifers by adding a drop of Lugol's solution in each well and mix thoroughly. The Lugol's solution will kill the rotifers so that counting can be done.
5. Prepare Lugol's solution as follows: Dissolve 2 g potassium iodide and 1 g iodine crystals in 100 mL water. Keep solution in a dark bottle.
6. Count the number of rotifers in 1 mL sample. Afterwhich, count another 1 mL from the same water sample and get the average.
7. Compute the volume of rotifers to be added to rearing tanks using the following formula:

$$Vr = \frac{(Drd - Prd) \times Vrt}{Srd}$$

Where: Vr = volume of rotifers to be added to rearing tanks (L)
Drd = desired density of rotifers (15–30 ind/mL) in rearing tanks
Prd = present density of rotifers (per mL) left in rearing tank
Vrt = volume of rearing tank (L)
Srd = density of rotifers (per mL) in stock tank (where harvested rotifers are held)

Fig. 22. A modified Sedgewick Rafter for counting rotifers.

Water Management

Zoeae to megalopae are reared using treated seawater. Regular water change dilutes the concentration of toxic metabolites in the tank. The suitable ranges of water quality for mangrove crab larvae are shown in Table 2. To maintain water quality in the tanks, the following steps may be done:

1. Change water in the larval rearing tanks at 30–50% every 3–5 days (Fig. 20) depending on the water quality.
2. Maintain the temperature and salinity of the larval rearing water at 27–30°C and 28–32 ppt, respectively. Maintain natural photoperiod, light intensity, and other water quality parameters at optimum levels (Table 2)
3. Provide moderate aeration throughout the rearing period.

Table 2. Suitable ranges of water parameters for the larval rearing of crab.

Parameter	Range
Temperature	27–30 C^{o}
Salinity	28–32 ppt
Dissolved oxygen	≥ 5 ppm
pH	7.5–8.5
Unionized ammonia	≤ 1 ppm
Nitrite	≤ 0.1 ppm

Transfer of Megalopae or Crab Instar

Megalopae are cannibalistic, hence they should be transferred to bigger tanks or split them into two or more tanks. They may also be transferred to net cages (hapa) installed in ponds. However, megalopae for stocking in net cages should be at the benthic stage (5–6 days old). If the megalopae are cultured in tanks, they should be disposed once they reach crab instar stage or crablet stage (0.6–0.8 cm CW) for faster turnover of tanks. The salinity in the larval rearing tank should be gradually adjusted to the salinity of the nursery pond prior to harvest and transport.

Health Management

The success of mangrove crab hatchery operations relies on the ability to produce high numbers of good quality crablets for stocking in nursery and grow-out ponds. Effective health management goes beyond procedures aimed at preventing disease and implementing protocols for treatment and control when they occur. It involves close monitoring of the crabs to observe changes in their appearance and behavior, and appropriate use of diagnostic tools and treatment regimens. One should be familiar with the condition of a healthy crab so that any change from the norm that may indicate a disease problem can be recognized easily.

Possible sources of infection are as follows:

- hatchery facilities;
- broodstock and larvae ;
- water supply;
- natural food and formulated feeds;
- staff coming in and out of the facility; and
- other animals (dogs, cats, etc.).

Management of infections

All live crabs brought into a hatchery facility carry microbes that may include pathogens. Prophylaxis or quarantine of broodstock and berried crabs should be done to prevent introduction of new pathogens. Microalgae and rotifers should be free from contaminants like saprophytic protozoans. Bacterial populations associated with rotifers and *Artemia* can be examined for opportunistic pathogens by microbial culture. Rinsing in clean seawater before use can reduce microbial load of natural food. Artificial feeds should be refrigerated to prevent rancidity, fungal growth, or its toxic byproducts.

Effluents from the hatchery should not go directly to the incoming source of water or to the sea. Hatchery design should incorporate an effluent treatment system such as a sedimentation pond, a bio-pond, and aeration pond.

The following steps prevent contamination from possible pathogens:

Vibrio

1. Disinfect seawater and facilities to be used for broodstock, larvae, and natural food (microalgae, rotifers, and *Artemia*). Pass seawater through sand filter and treat using chlorine (dechlorinate with sodium thiosulfate or through strong aeration), or ozone or ultraviolet (UV) treatment prior to use.
2. Siphon unconsumed food, feces, dead larvae, exuviae, and other debris from the tank bottom regularly to prevent build-up of organic substrates for bacteria.
3. Scrub tank sides after each run to prevent formation of bacterial biofilms that are difficult to remove or eradicate with disinfectants.
4. Treat luminescent bacteria with antibiotics following the recommended dose published in the guidelines for food standards (GESAMP 1997) or as determined empirically considering the maximum residue limits of the product.
5. Dispose antibiotic-treated wastewater properly prior to release into other body of water.

Shell Disease/Chitinolytic Bacteria

1. Maintain low organic load by siphoning out excess feeds, dead larvae, and natural food and debris that settle at the bottom.
2. Minimize handling and overcrowding of larvae and crablets to avoid mechanical injuries.

Virus

White spot syndrome virus (WSSV) and infectious hypodermal and hematopoietic virus (IHHNV) may be transmitted vertically from berried females to larvae.

1. Apply prophylaxis to broodstock and disinfect seawater, equipment, and implements.

2. Screen natural food for broodstock (live polychaetes, squid, mollusks, fish, etc.) and for larvae (microalgae, rotifers, and *Artemia*) for the presence of pathogens by polymerase chain reaction (PCR) and culture in microbiological media. Use only those that are free of pathogens.
3. Install footbaths at entry and exit points, and provide hand disinfectant or spray.
4. Provide footwear and clothing for hatchery staff and visitors, which must be worn when entering the hatchery and removed upon exit.

Fungus

1. Follow Steps 1 to 4 under *Vibrio* Section.
2. Disinfect broodstock or berried crabs in 150 ppm formalin for 30 mins. Transmission of fungus from eggs to newly hatched larvae can be prevented by placing berried crabs in formalin bath. Formalin treatment inactivates zoospores without harming the eggs. Motile zoospores of *Lagenidium* are inactivated by 10–15-minute dips in 7–15 ppt salinity.
3. Monitor larvae daily by microscopic examination for early detection of fungal infection. Discard larvae with severe infection and disinfect facilities used.

Parasites

1. Follow steps 1 to 4 under *Vibrio* Section.
2. Use antiparasitics (e.g., formalin) and potassium permanganate ($KMnO_4$) for protozoans and algal foulers to prevent parasitic infections. Formalin can be used at a concentration of up to 150 ppm for 30 mins and 50–100 ppm for a longer bath exposure. Most sessile and saprophytic protozoans can be eliminated by formalin treatment.

Biofoulers and debris

Biofoulers include filamentous bacteria, protozoans, and nematodes (Fig. 23).

1. Disinfect broodstock or berried crabs in 150 ppm formalin for 30 mins upon arrival in the hatchery.
2. Use treated seawater for broodstock or berried crabs and larvae.
3. Monitor berried crabs and larvae regularly by examining representative samples under the microscope.
4. Maintain good water quality by avoiding overfeeding and by siphoning uneaten feeds, dead larvae, and other sediments from the tank bottom.

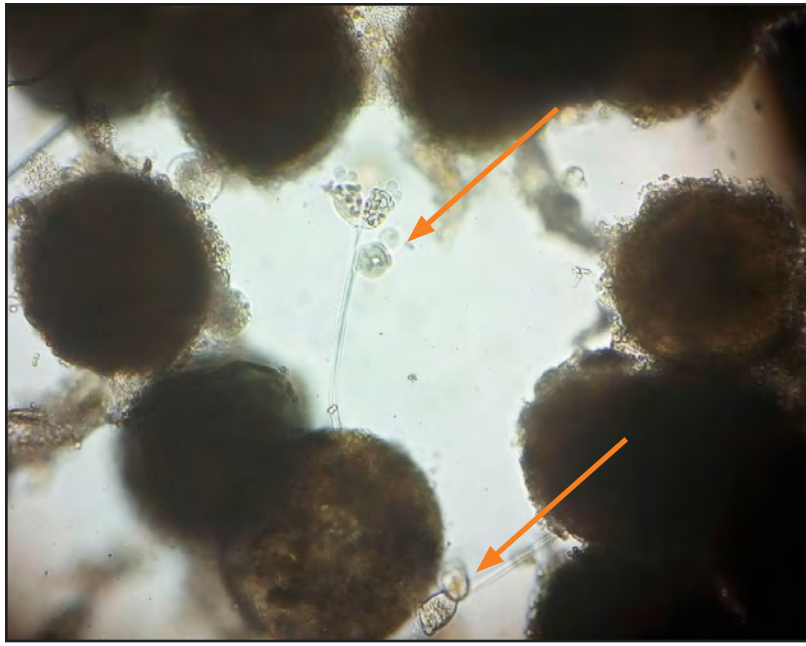


Fig. 23. Eggs infested with protozoans (arrows).

Other treatments

Antibiotic treatment should be the last resort. Proper dosage, withdrawal periods, proper disposal of treated wastewater, and other procedures to ensure safety to personnel, environment, and consumers should be implemented when using antibiotics. Oxytetracycline is the most commonly used antimicrobial but may lead to abnormalities in larvae if the dose administered is too high. It may also cause depressed immunity and susceptibility to other infections or lead to the development of tetracycline-resistant strains of bacteria. For larval rearing, oxytetracycline can be used at 3–6 ppm from zoea 1 to zoea 5, which results in better survival than when no antibiotic is used. Oxytetracycline has a half-life of 101–364 days. Approved antibiotics for aquaculture use are Ormethoprim and Trimethoprim and can be used at a dose of 50 ppm for the control of *Vibrio* infections. The extract of *Terminalia catappa* ('talisay') leaves can be used as substitute for antibiotics. Crude methanolic extracts of *T. catappa* at 200 ppm can be added in the water during crab larval rearing. It has an efficacy comparable to that of antibiotics. Aside from being antimicrobial, it also reduces the virulence in *Vibrio harveyi*.

Probiotics have been popularly used in grow-out ponds and can also be used in the hatchery in view of the growing concerns about the negative consequences of antibiotic use. A locally isolated or commercial probiotic may be used. Probiotics are usually added in the larval rearing tanks at a 10^7–10^8 cfu/mL after every water change to maintain the desired concentration. *Bacillus* sp. can also be added at 10^7–10^8 cfu/mL but water management has to be modified to allow the probiotic to function. *Bacillus* sp. can prevent *V. harveyi* from proliferating by competing with it for space and nutrients in the rearing water as well as in the gut of the crab larvae. It takes about 24–48 hours for probiotics to be found in the gut of crab larvae. It can also secrete *Vibrio*-inhibiting antimicrobial compounds as well as digest polysaccharides in the gut to serve as additional source of nutrients for the larvae.

Health monitoring and record keeping

Careful monitoring and record-keeping provide data on the most profitable operational protocols that result in highest possible production. Details on water quality, stocking, feeding and water management, and harvesting provide a means of evaluating the performance of each production run.

Costs and Returns Analysis

The information needed in the computation of the viability of hatchery operation is shown in Table 3. The cost and return for hatchery operation can generate a net income of P428,384/run. A total of at least six successful runs for a period of 1 year can be performed and can reach an annual profit of P2.57M (Table 4). The calculated return on investment is 56% and in 2 years' time the cost of investment can be recovered. However, to start the business, it would require a P4.55M capital investment. The capital cost includes supervision and management of the project to assist the investor and make sure that the operation is running smoothly (see Table 5).

Table 6 shows the financial analysis of a crab hatchery over a 5-year duration.

Table 3. Technical information used in the computation of costs and returns for the mangrove crab hatchery (Quinitio et al. 2018).

TECHNICAL ASSUMPTIONS	
Total larval rearing capacity	80
Broodstock	
% broodstock that will survive and mature	45
Average zoae/female	1,200,00
Average BW of broodstock (g)	600
No. of sucessful spawners needed	5.33
Kg broodstock to be purchased	8
% of body weight to be used as basis of feeding	5
Hatchery	
Stocking density of larvae/L	80
Total no. of zoea to be stocked at max cap	6,400,000
% of survival from zoea to C1C2	3.0
No. of crab instar produced	192,000
No. of runs/year	6
Pick up price (P)	4

Table 4. Costs and returns/run of a new hatchery.

Revenue	Quantity	Unit Price (P)	Total (P)
	192,000	4 pick up price	768,000
Variable cost/run			
Broodstock			6,000
Broodstock feeds (fish, annelids, mollusks,etc)			783
Artemia (can)			19,908
Natural food starters & medium			465
Chemicals (chlorine, thiosulfate, etc)			4,302
Other supplies			38,500
Electricity			30,000
Marketing (2% of revenue)			19,200
Miscellaneous (5% of variable cost)			5,958
Total Variable Cost			**125,116**
Fixed Cost/Run			
Labor			
Aides	2		19,200
Technician (overall in charge)	1		20,000
Hired labor (daily basis)	20		6,000
Depreciation			55,800
Repair (5% of fixed cost)			113,500
Total Fixed Cost			**214,500**
Net Income/Run			**428,384**

Annual net income (6 runs x net income/run) 2,570,304.

Table 5. Investment items, cost and schedule of depreciation of capital assets in a new crab hatchery (Quinitio et al. 2018).

Item	Quantity	Unit	Total Cost (P)	Economic Life (in years)	Depreciation/Year (P)	Salvage Life After 5 Years
Larval tanks, concrete, 8-t capacity	10	units	320,000	10	32,000	160,000
Algal and rotifer tanks, canvas, 8-t capacity	16	units	240,000	5	48,000	0
Broodstock tank , concrete, 5-t capacity with 2 compartments	1	unit	75,000	10	7,500	37,500
Spawning tank, fiberglass	4	units	32,000	15	2,133	21,333
Artemia tanks , 60-100-L	4	units	28,000	15	1,867	18,667
Reservoir with filter tank, 40-t capacity	2	units	300,000	10	30,000	150,000
Hatchery building and shed	1	lot	500,000	10	50,000	250,000
Staff house	1	lot	300,000	10	30,000	150,000
Blower and generator house	1	lot	50,000	10	5,000	25,000
Pump station structure	1	lot	25,000	10	2,500	12,500
Aeration lines	1	lot	50,000	10	5,000	25,000
Seawater lines	1	lot	125,000	10	12,500	62,500
Freshwater lines	1	lot	25,000	10	2,500	12,500
Drainage and settling pond	1	lot	200,000	10	20,000	100,000
Air blower	2	units	120,000	5	24,000	0
Seawater pump	2	units	100,000	5	20,000	0
Freshwater pump	1	unit	25,000	5	5,000	0

Item	Quantity	Unit	Total Cost (P)	Economic Life (in years)	Depreciation/Year (P)	Salvage Life After 5 Years
Refrigerator	1	unit	18,000	10	1,800	9,000
Generator set	1	unit	200,000	10	20,000	100,000
Electrical works	1	lot	150,000	10	15,000	75,000
Total			2,883,000		334,800	1,209,000
Depreciation/ run			55,800			
General requirements (mobilization, demobilization, plans, permits, etc.			200,000			
Siteworks and earthworks cleaning (cleaning works, lay-out, staking, etc)			600,000			
Total cost of materials, labor, equipment siteworks, general requirements, operation cost/run, etc.			3,683,000			
Supervision and management of project (10% of project cost)			368,300			
Contingencies			500,000			
Total Investment			**4,551,300**			

Table 6. Financial analysis of a crab hatchery over a 5-year duration.

	Year 0 (P)	Year 1 (P)	Year 2 (P)	Year 3 (P)	Year 4 (P)	Year 5 (P)	Total (P)
Gross Revenue		5,760,000	5,760,000	5,760,000	5,760,000	5,760,000	28,800,000
Investment	4,551,300	0	0	0	0	0	4,551,300
Cost		2,037,695	2,037,695	2,037,695	2,037,695	2,037,695	10,188,477
Net Income	(4,551,300)	3,722,305	3,722,305	3,722,305	3,722,305	3,722,305	14,060,223
NPV 12%	(4,551,300)	3,323,486.25	2,967,398.44	2,649,462.89	2,365,591.87	2,112,135.60	8,866,775
IRR							58%
BCR							3
ROI							81.79
Payback period							0.76
Operational cost per run							339,616
Operational cost per year							2,037,696

Culture of Crablets

Site Selection

The site for crab culture in nursery and grow-out in ponds, cages, or pens should have the following characteristics:

- Clay, clay-loam, or sandy-clay soil to retain water;
- Sufficient source of clean brackishwater;
- Free from possible sources of pollution;
- Protected from strong waves, typhoon, flood, and siltation;
- Accessible to transportation and market;
- Located 1 m above the highest tide level to allow drainage and harvest, specifically for ponds; and
- For pens and cages in estuaries, good water inflow and outflow with at least 0.3 m of water at the lowest tide and with mature mangroves.

Pond Layout and Construction

Pond layout and design are done with the assistance of an aquaculture engineer or experienced pond operator. The pond layout depends on the site's size and shape, water source, target species, construction means, culture systems, and financial capability of the pond owner/operator. Many existing brackishwater fishponds are suitable for crab culture provided that the dikes are not less than 1 m deep and clean brackishwater is readily accessible.

Pond Preparation

Prepare the rearing pond to ensure that the soil quality is suitable for the crabs, especially since they burrow in the soil. Furthermore, the soil condition largely affects the quality of the rearing water. Before using the ponds, the following should be undertaken:

1. Drain the pond totally.
2. Make all dikes watertight and seal the gates with soil.

3. Install screens (0.5–2.0-cm mesh size) at the gates to prevent entry of undesirable organisms.
4. Level the pond bottom for ease in water management and harvest. Remove dried muck layer.
5. Apply a small amount of lime mixed with topsoil and plow the pond bottom. Plowing or tilling is one way of eradicating burrowing predators.
6. Dry for at least 1 week to eliminate waste products and obnoxious gases from decomposing organic matter.
7. Add water into the pond up to a level of 30–50 cm. Let this stand for 1–2 days.
8. Flush the water out to remove toxic substances produced by decomposition of organic matter.
9. Repeat the drying process.
10. Apply one of the following to eradicate predators and other unwanted species:

    - 10–40 kg derris roots/ha;
    - 150–200 kg tea seed powder/ha after soaking overnight in brackishwater;
    - 1.5–2.0 kg tobacco dust/10 cubic meters (m^3) of pond water; or
    - A combination of organic pesticide or inorganic chemical and lime, such as 5.0–6.5 kg tea seed powder/m^3 and 1.5 calcium oxide/100 m^3, or 10 g ammonium sulfate (21-0-0) and 50–60 g quicklime/m^2 pond water (5 cm deep).

11. Apply 1–2 t calcium carbonate/ha or 200–300 kg calcium oxide/ha on pond bottom and dikes.
12. Three days after liming, apply 1–2 t dried chicken manure/ha, 25 kg/ha urea (46-0-0), and 50 kg/ha ammonium phosphate (16-20-0).
13. Fill the pond with water from the incoming tide to about 10 cm deep. Introduce water gradually until a water depth of 80–100 cm is attained.

14. If milkfish is to be stocked with the crabs in the grow-out pond, allow the 'lablab' to grow. Introduce water gradually (5–10 cm water level daily) into the pond until a water level of 40–50 cm is reached. After a few weeks, add water gradually and maintain water depth of 80–100 cm. If the lablab has been consumed, source from other shallower pond to feed the milkfish.

Other information on the guide to good aquaculture practices can also be applied to crab farming.

Nursery Phase

Crablets produced in the hatchery need to be grown further for them to adapt to the harsher conditions of the brackishwater pond where they will be grown to marketable size. This transitional stage, which links the hatchery to pond grow-out culture, is called the nursery phase.

Facilities

Net cages

Megalopae or early crab instars (crablets) are reared in net cages to protect them from prey and to make retrieval easier at the end of the nursery phase. The net cage usually rectangular or square is made of 1-mm mesh net (Fig. 24). It is sewn like an inverted mosquito net. Its bottom has a surface area of 12 square meters (m^2) (3 m wide and 4 m long) to 20 m^2 (4 m wide and 5 m long). It should be at least 0.8 m deep or deeper than the highest water level in the pond. The four corners of the cages should be tied to poles staked to the pond bottom (Fig. 25).

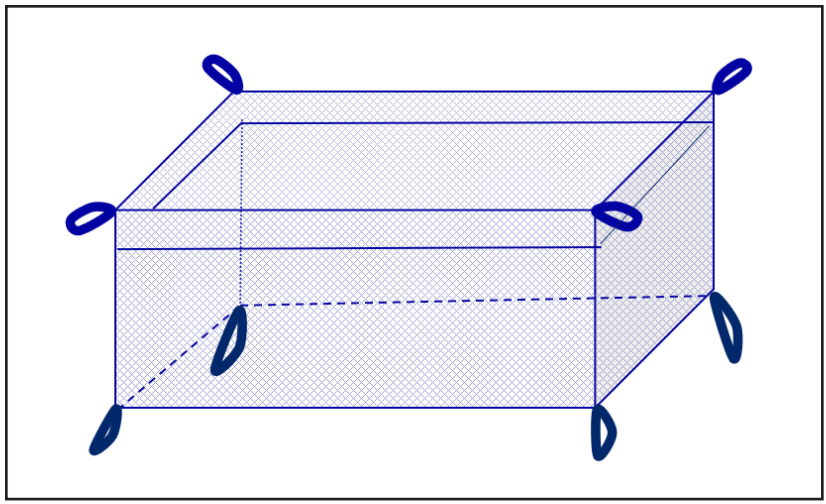


Fig. 24. Nursery cage (hapa) made of 1-mm mesh net like an inverted mosquito net.

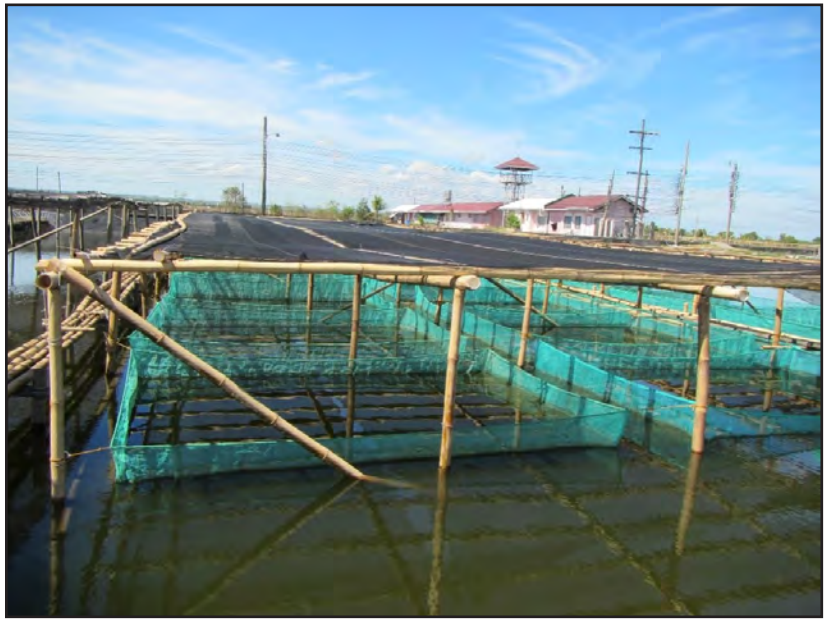


Fig. 25. Net cages installed in pond using bamboo poles as support.

Shade

The cages should be shaded from intense sunlight using nets. Dried coconut or nipa fronds may also be used as shades but doing so may make sorting of crablets at harvest difficult due to the debris from the fronds.

Shelters

Use of shelters is essential in the nursery. Immediately after molting, the exoskeleton is soft and the crab is prone to predation. The newly-molted crabs must hide in shelters so that they will not be eaten by hard-shelled crabs.

Several types of shelters have been tried in the nursery, these include macroalgae and used nets. Net shelters (Fig. 26) have been proven to be the most suitable. The fabrication of a shelter is described below:

1. Form a 50 cm x 50 cm square frame with 50-mm polyvinyl chloride (PVC) pipes.
2. Fit a 1-cm mesh net over the frame and secure by sewing or tying.
3. Cut about 3.5–5.0 cm-wide strips of nets, about 50 cm long.
4. Fasten each strip to the framed net about 10 cm from each other. Each square frame should hold at least 30 strips.

Fig. 26. Nets as shelters.

Stocking and Monitoring

The stocking density of crablets in the pond or the number of crablets in each cage greatly affects the growth of the crabs. Lower stocking density will result in faster growth. The following are the steps for the nursery rearing of crablets in net cages:

1. Install net cages before water is added into the pond.
2. In each cage, place 1 shelter/3 m^2 area.
3. Stock crablets (≥1.0 cm CW) at 30–50 ind/m^2.
4. Maintain the water depth to at least 80 cm.
5. Install at least one feeding tray (0.5 m x 0.5 m) in each cage for monitoring of feed consumption
6. Observe if crablets and leftover feeds are found in the tray 30–60 min after feeding to determine food consumption.
7. Sort crablets according to size on the third week. Bigger crablets may be sold or stocked in grow-out ponds while the smaller ones can be restocked at 20 ind/m^2. Use the weight measurements as basis in adjusting the feeding rate (refer to the next section).

Feeding Management

Crabs are omnivores and scavenge for a variety of food organisms. In culture conditions, these are provided mainly with low-value fish biomass (trash fish or fish by-catch) or fish trimmings or entrails and when available, a variety of food including boiled corn, mussel meat, small shells (‘agihis’), snails, and thoroughly cleaned chicken entrails. Inconsistent supply and increasing cost of unprocessed fresh food are main constraints in the nursery. As the quality and nutritive value of fresh food need to be preserved, proper storage or freezing facilities are necessary. Use of raw animal material is also prone to problems with deterioration of pond water quality due to fouling. Hence, cost-effective, nutritionally adequate dry formulated feeds can be used.

The feeding scheme and method for feeding the crablets in the nursery are as follows:

1. Determine the average body weight (ABW) of crablets just before stocking and multiply the ABW by the total number of crablets stocked. This will represent the mass weight of crablets in the net.
2. Feed about 2 cm x 2 cm pellets to crabs in the morning and late afternoon, and minced mussel meat at mid-day. Give minced mussel meat or low value fish to crablets at 30% of the mass weight. For formulated dry feed, use manufacturer's recommended feeding rate. Use this feeding rate for 3–4 weeks. Feed is broadcasted around the net cage with a portion placed on a feeding tray set inside each net cage to be able to monitor crab condition and feed consumption.
3. Take 20–30 crablets to get the ABW at the end of the second week and prior to harvest to monitor the growth.
4. Follow Step 7 under Stocking and Monitoring Section if crabs are cultured further.

Water Management and Harvesting

1. Replace 30% of the water every spring tide.
2. At harvest, drain 70% of the pond water.
3. Lift the net cage at the rib lines from one side and concentrate the crablets at the other end of the net cage.
4. Scoop out or handpick crablets.
5. Pack crablets in between moist cotton cloth. Place in shallow boxes (Fig. 27A–C) with perforations smaller than the size of the crablets for ventilation. Transport crablets early in the morning, late in the afternoon, or when temperature is low.

Fig. 27. Bottom of the box lined with plastic sheet (A) prior to putting the moist cloth (B) in the shallow box (C) for the transport of crablets.

Cost and Return Analysis

The nursery culture of mangrove crabs requires a relatively lower investment compared to the hatchery or grow-out. Crab instars produced from the hatchery are cultured for several weeks to achieve the size which is more tolerant to the harsher environment of the pond. To assess the profitability of this culture phase, data from actual runs at SEAFDEC/AQD have been used as basis. Technical assumptions are shown in Table 7. Here, the crab instar 1 are stocked first at a density of 50/m^2 or 1,000 per 20 m^3 cage. At this density, bigger sized crablets, assumed to be 50% of the survivors after 3 weeks culture, are sold. The remaining crablets are restocked at a much lower density and further cultured for another 3 weeks.

Initial investment consists mainly of the net cages, the nursery setup where the cages are tied to, and the shelters (Table 8). The annual depreciation is also shown. Costs incurred during each 3-week culture are shown in Tables 9 and 10. Total costs for a six-week run is PHP 140,711 while revenues total P199,920. Thus, gross income for 6 runs is P1,199,520 and net income is P355,248 (Table 11). Financial analysis projected for a 5-year operation (Table 12) shows that the discounted rate of return or IRR is 473% and Benefit to Cost Ratio (BCR) is 17, indicating that the nursery is a very profitable venture. Payback period or the time needed to recover investments is 1.02 years.

Table 7. Technical assumptions used in the economic feasibility of nursery culture.

Stocking density for first 3 weeks (crab instars/m^2)	50
Number of cages	24
Size of each cage (m^3)	20
Survival after first 3 weeks (%)	70
Crablets sold after 3 weeks (%)	50
Density for restocking crablets for the next 3 weeks (juveniles/m^2)	10
Survival after another 3 weeks (%)	80

Table 8. Capital outlay and depreciation schedule/run in the nursery culture of mangrove crabs.

Item	Quantity	Unit Cost (P)	Total Cost (P)	Economic Life	Depreciation/ Year
Hapa nets	24	1,600	38,400	1	38,400
Setup and catwalk	1	20,000	20,000	3	6,667
Substrates	96	100	9,600	5	1,920
Total			68,000		46,987
Depreciation/ run					7,831

Table 9. Cost and return after 3 weeks of nursery culture. Only 50% of the stock is sold. The rest are restocked for further rearing.

	Quantity	Unit Cost (P)	Total
Revenue	5,040	13	65,520
Variable Cost			
Lime (kg)	250	2.2	550
Ammonium sulfate			400
Feeds			756
Chicken manure			400
Crab instar	14,400	4	96,000
Hired labor (harvest)	2	500	1000
Total Variable Cost			99,106
Fixed Cost			
Labor			10,500
Rent			2,500
Depreciation			3,916
Total Fixed Cost			16,916
Total Cost After 3-Week Nursery Culture			116,022

Table 10. Cost at the end of another 6 weeks in the nursery.

	Quantity	Unit Cost (P)	Total
Revenue	6,720	20	134,400
Variable Cost			
Feeds			6,774
Hired Labor			1,000
Total Variable Cost			7,774
Labor			10,500
Rent			2,500
Depreciation			3,916
Total			16,916
Total cost for the next 3 weeks			24,690
TOTAL COST FOR 6-WEEK RUN			140,711
TOTAL REVENUE FOR 6-WEEK RUN			199,920
TOTAL NET INCOME FOR 6-WEEK RUN			59,209

Table 11. Summary of costs incurred for the nursery in a year.

	First 3 Weeks	Next 3 Weeks	Total for 6 Weeks	Annual At 6 Runs/Year
Revenue	65,520	134,400	199,920	1,199,520
Variable cost	99,106	7,774	106,880	641,280
Fixed cost	16,916	16,916	33,832	202,992
Total cost	116,022	24,690	140,712	844,272
Net income	(50,502)	109,710	59,208	355,248
Payback period: 1.02 years ROI: 522.42%				

Table 12. Financial analysis for a 5-year operation of a mangrove crab nursery.

	Year 0 (P)	Year 1 (P)	Year 2 (P)	Year 3 (P)	Year 4 (P)	Year 5 (P)	Total
Gross Revenue		1,199,520	1,199,520	1,199,520	1,199,520	1,199,520	5,997,600
Investment	68,000		38,400	48,000	38,400	38,400	231,200
Cost		844,272	844,272	844,272	844,272	844,272	4,221,360
Net Income		355,248	316,848	307,248	316,848	316,848	1,613,040
PV (r=12%)	-68,000	317,186	252,589	218,693	201,362	179,788	1,101,619
IRR	(68,000.00)						447%
BCR							17

Grow-out Phase

Crabs can be grown in earthen ponds, pens, or cages depending on the size of crabs at initial stocking and duration of culture.

Pond

Crabs may be cultured singly or in combination with one or two other species, usually with milkfish, tilapia, or 'siganid' in ponds. Pond may be installed with net fence to prevent the crabs from escaping (Fig. 28). Cannibalism is reduced by lowering the stocking density of crabs and maximizing space utilization by stocking herbivore or omnivore fish. Crabs are grown for 4–6 months depending on the initial size at stocking and desired market size. Culture period becomes shorter if bigger-sized crabs and fish are stocked or low density is used. Two growing cycles may be done in 1 year.

Fig. 28. Brackishwater earthen pond with net fence for the culture of mangrove crab.

Stocking

1. For monoculture of crabs, grow natural food as food and shading. For polyculture with milkfish, grow natural food such as lablab and other filamentous plants prior in stocking. Fill the pond gradually with additional water until 80-cm depth is attained, when natural food is sufficient. Sunlight penetrating directly to the bottom of the pond will increase the exposure of crabs abnd fish to high water temperature resulting to stress. Hence, the growth of natural food should be sufficient to protect them from direct sunlight.
2. For polyculture, stock ≥3.0 cm crablets 1,500–2,000/ha and milkfish fingerlings at 1,500–2,500 ind/ha after acclimation.
3. Determine the initial body weight and size (CW) of the crabs (about 20 crabs from each sample size). Compute for the average weight of crabs sampled.

Feeding Management

The cost of crabs, milkfish, labor, and feeds affect the economic viability of culture. Low-value fish, mollusks (e.g., snails, small bivalves), boiled corn, animal entrails, and other cheap protein sources available in the site can be used as natural food stuff for crabs.

Feeding management is as follows:

1. Feed crabs daily with any of the above food stuff available in the site. Chop feeds to the size appropriate to the mouth size of crab. Milkfish feed on lablab present in the pond.
2. Compute the amount of feeds. Refer to Step 3 under the Stocking section for the determination of initial body weight. Table 13 shows the amount of food to be given for a particular size of crab based on the decreasing percentage of food needed as the crab grows. Total amount of food can be determined using the formula:

   Feeding rate = average body weight x total number of animals (% survival) x % body weight

Table 13. Estimated amount of feeds to be given to mangrove crabs based on percent of body weight.

Amount of feed per crab (g)	Body weight (g)	Percent of body weight
2	<20	10–12
2–4.5	21–50	9
4–8	51–100	8
7–14	101–200	7
12–18	201–300	6
15–20	301–400	5
16–20	401–500	4
15–18	501–600	3
18–21	601–700	3
21–24	701–800	3

3. Feed the crabs twice daily preferably between 6:00–8:00 am and 4:00–6:00 pm. Provide half of the daily food ration during each feeding.
4. Put 3–5% feed in each of four feeding trays situated around the pond equally distributed in a 5,000-m^2 pond to monitor food consumption (Fig. 29). Broadcast the rest of the feeds evenly.
5. Maintain growth of lablab and other natural food by fertilizing the pond water with dried chicken manure placed inside sacks set at equal distances within the pond.
6. Regulate feeding to prevent wastage and water deterioration in the pond. Adjust feeding regularly to avoid overfeeding or underfeeding.

Fig. 29. Feeding tray used to monitor food consumption of crabs.

Water Management

Pond water deteriorates due to uneaten feeds, accumulated feces, and other wastes. To maintain good water quality, the following steps should be followed:

1. Maintain water depth of at least 80 cm and monitor water parameters regularly. The optimum water quality to be maintained is shown in Table 14.

2. Change about 30% of water every spring tide (new moon and full moon) or whenever necessary during high tide. Volume of water to be changed may be increased as the culture period progresses.

Table 14. Optimum water and soil conditions for culture of crab and fish.

Parameters	Value
Temperature	27–31ºC
Salinity	20–30 ppt
Dissolved oxygen	≥5 ppm
pH water	7.5–8.5
soil	6.5–8.5
Hydrogen sulfide	0.004 ppm
Unionized ammonia	0.10 ppm
Nitrite	0.01 ppm
Organic matter	1–10%
Transparency	20–30 cm

Monitoring and Sampling

Mangrove crabs cultured in ponds are not easily visible and are difficult to count or collect. Therefore, the average weight of the stock can be determined based on the monthly monitoring of crab weight.

The condition of the crabs and water in the pond should be monitored regularly so that remedial measures can be done as soon as possible and when necessary. Monitoring can be performed using the following steps:

1. Sample 20–30 crabs 30 days after stocking and every 15 or 30 days thereafter.
2. Use lift nets to sample crabs (Fig. 30).
3. Weigh the crabs to determine growth and to adjust feeding rate.
4. Use feeding trays to monitor consumption.
5. Monitor water quality (Fig. 31).

Fig. 30. Sampling of crabs using lift net.

Fig. 31. Monitoring of pond water salinity using a refractometer.

Harvesting

Market size for crabs starts at ≥350 g for *S. serrata* and ≥250 g for *S. olivacea* and *S. tranquebarica.* However, desired weight for *S. serrata* is ≥500 g in international markets. Table 15 shows the ideal body weight and corresponding CW of market size *S. serrata*. Some crabs grow faster hence can be harvested sooner. Selective harvesting reduces the incidence of cannibalism and makes it possible for the remaining crabs to grow faster. In monoculture, some crabs are transferred to other pond compartments 2–3 months after stocking if survival rate is still high so that growth would be faster and cannibalism is reduced.

Table 15. Ideal body weight for corresponding CW of market size mangrove crab *(Scylla serrata).*

Approximate body weight (g)	Ranges of CW (cm)	
	Female	Male
400	13.0–13.8	11.8–12.4
500	14.0–14.4	12.6–13.0
600	14.5–15.2	13.4–13.9
700	15.5–16.0	13.6–14.4
800	15.8–16.3	14.7–15.0
900	16.5–17.0	15.2–15.8
1000	16.7–17.5	15.5–16.2

a) Selective harvest

1. Do not feed the crabs the afternoon prior to harvest. Distribute baited traps in the pond to attract crabs the following morning. Retrieve traps after 30 mins and collect market size crabs. Return small crabs in the pond. Repeat deployment of baited traps.
2. Drain 30–50% of water during low tide and introduce water immediately during high tide. Crabs swim against the current and towards the incoming water near the gate. Scoop out the big and fat crabs that aggregate near the gate.

b) Total harvest

1. Drain or pump all the water out from the pond at low tide.
2. Handpick crabs and wash in clean seawater or brackishwater (Fig. 32).
3. Tie crabs with plastic straw or other indigenous materials. Place crabs in shaded area and cover with wet mangrove or banana leaves, cotton cloth ('katsa'), or jute sack to keep crabs moist and hydrated.
4. Undersized or underweight crabs may be restocked in another pond or cages for further culture or fattening for another 2–3 weeks.

Fig. 32. Handpicking of crabs after total draining of pond.

Pens

Mangrove crabs can be grown in rectangular-, square-, or irregularly-shaped pens ranging from 500 m^2 to 1,000 m^2 installed in mangrove forest (Fig. 33). Water is not always available in sufficient quantity during low tide thus, the molting and feeding of crabs are affected. It is better to stock bigger crabs (≥150 g) so that the culture period becomes shorter. Fattening of crabs is more suitable in this set-up because culture period is short (2–3 weeks). Stocking density can also be increased since the frequency of molting in bigger crabs becomes less.

Construction of Pen

1. Enclose the area with bamboo slats or nets supported by wood or bamboo poles that are buried 50–60 cm in the soil. Consider an effective height of 2.0–2.5 m or higher than the highest tide in the area. Put about 30 cm overhang net on the top end of the fence (Fig. 33).
2. Install bamboo catwalk from the side to the middle of the pen for ease in feeding and sampling of crabs (Fig. 34).
3. Allot 20–30% of the total pen area for canals (0.5-m deep) to hold water during low tide. Position canals in the middle, away from the bamboo or net partitions to prevent crabs from escaping through deep burrows. The crabs look for refuge in the canals during low tide.

Fig. 33. Pen with overhang net on top to prevent crabs from escaping.

Fig. 34. Pen installed in mangroves. Catwalk (arrow) is provided for ease in monitoring and feeding of crabs.

Stocking

1. Determine the weight and measurement of crabs. Choose healthy crabs for stocking. Stocking can be done in 3–5 consecutive days if the required quantity is not sufficient at one time. However, the size difference of the crabs should not be big.
2. Acclimate crabs prior to stocking by slowly introducing the water from the pen to the container where the crabs are held.
3. Stock crabs when the water temperature range is 27–30°C.

Feeding and Water Management

1. Feed crabs with chopped fish and mollusk meat. Determine the amount of feeds to be given based on the weight and total number of crabs (Table 3).
2. Put feed stuff in feeding trays made of 5–10-mm mesh net installed inside the pen. Monitor the food in the trays an hour after feeding. Reduce the amount by about 20% in the next feeding if there is food left in the tray. Increase the amount of food by 10–20% if the food is totally consumed.
3. Maintain good water exchange by ensuring that water flows in and out of the pen. Remove accumulated debris around the pen that hinders the water flow.
4. Maintain canals to keep water to a depth of at least 0.5 m.

Monitoring and Sampling

1. Monitor the condition of crabs daily. Check for signs of disease and other abnormalities. Perform remedial measures when necessary.
2. Repair net or bamboo enclosures immediately if holes or damages are found.

Predators

The common predators of mangrove crabs are other species of crabs (*Thalamita* spp., *Varuna litterata*, etc.) and carnivorous fish (seabass, grouper, snapper, etc.). They prey on the newly molted crabs. Hence, it is better to stock bigger crabs so that molting frequency becomes less. Predators should be caught during low tide.

Harvesting

1. Follow the same procedure for the selective and total harvest of crabs used in pond operations. However, harvest in pens should coincide with low tide for ease in the collection of crabs.
2. Wash crabs with clean seawater.
3. Tie crabs with plastic straw or other available indigenous materials. Refer to Fig. 51 in the tying of crabs.

Cages

Cages are used for short-term culture of crabs such as fattening. Lean crabs (≥350 g for *S. serrata* and ≥200 g for *S. olivacea* and *S. tranquebarica*) can be fattened in cages made of bamboo or plastic for 2–3 weeks in communal or individual system. The cages (floating or fixed) are set up in ponds, estuaries, mangroves, sheltered coastal waters, shallow lagoons, or bays. Bamboo cages partitioned into compartments (Fig. 35) or plastic boxes are used for individual fattening of crabs.

Fig. 35. Compartmentalized bamboo cages set up in pond for crab fattening.

Construction of Cages

1. Construct cage measuring about 2 m length (l) x 0.5 m width (w) x 0.30 m height (h). Use bamboo for side walling, bottom flooring, and hinge covers. The hinged covers prevent the escape of crabs. The walls of the cage should have 1-cm gap between bamboo slats or splits to allow water movement within the cage. The bottom should have no gaps to avoid the limbs of the crab being trapped between bamboo slats.

2. Divide one cage into 10 compartments. Reinforce nails with nylon monofilament for better support. Several compartmentalized cages can be constructed depending on the requirement.
3. Look for a protected and sheltered area in estuaries, coastal waters, or shallow lagoons that retains water depth of more than 30 cm during the lowest tide.
4. Set up the cages and secure by tying to the branch of mangrove or bamboo poles staked into the soil. Cage should settle at the bottom during the lowest tide and may float at highest tide.

Stocking

1. Acclimate crabs prior to stocking when these are sourced from another area with a different salinity level.
2. Put one crab per compartment.

Feeding Management

1. Feed crabs daily with any of the food stuff mentioned in the Feeding Management Section under Grow-out Phase. Chop food stuff to the size appropriate to crab size.
2. Determine the amount of feeds (Table 3).
3. Feed crabs in the morning and afternoon. Give crabs half of the daily food ration for each feeding.
4. Remove excess food prior to the next feeding. Adjust the amount of feed stuff based on consumption.
5. Maintain good water flow in and out of the cage.

Monitoring and Maintenance

1. Monitor the condition of the crabs daily. Check for signs of disease and abnormalities in the crabs.
2. Avoid the growth of filamentous algae and other fouling organisms that may hinder the water flow in the cage.
3. Dry the cages after each harvest to kill any attached algae or fouling organisms. Scrub the cage for the next cycle.

Harvesting

It is easy to do selective and total harvest of crabs in cages as these are stocked individually in compartments.

1. Choose fattened crabs. Remove from the cage and wash with clean seawater or brackishwater.
2. Tie crabs with plastic straw or other tying materials available (Fig. 51).
3. Sort and transport to trading centers or other buyers.

Health Management

Mangrove crab is a hardy crustacean. It may harbor viruses, bacteria, and parasites, but the infection may not result in mortality unless environmental conditions are very poor. Abnormalities in appearance may also be observed due to exposure to contaminants such as antibiotics and heavy metals. Abnormalities do not usually result in mortality but may result in cheaper market price. Some of the diseases and abnormalities observed in crabs in grow-out culture, including their treatment, are presented in Table 16. Diseases are classified into viral, bacterial, and parasitic while abnormalities are categorized into shell fouling, external morphological deformities, discoloration of the exoskeleton, internal abnormalities, and others.

Successful crab health management begins with disease prevention rather than treatment. Disease prevention is accomplished through good management practices, which involve maintaining good water quality, preventing injury and stress during handling, and providing good nutrition and proper sanitation. Crabs live in the water that provides them oxygen and food. Likewise, crabs excrete their wastes in the water that affects water quality. Potential crab pathogens are also found in the water.

Proper management practices, especially on pond preparation (as described in the previous chapter), will prevent disease occurrences or mitigate the effect of infection. Transmission, gross signs, diagnosis, prevention, and control of each type of disease or abnormality are indicated herein for guidance.

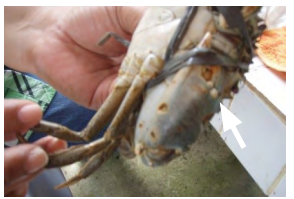
Table 16. Diseases and abnormalities affecting mangrove crabs.

Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control
			Viral Infection		
WSSV	• WSSV affects all stages. • Low temperature enhances infection.	Observed mortality in crab due to WSSV infection occurs after consuming large amounts of WSSV-infected shrimp present in the system.	Crabs may carry WSSV without showing any sign of disease.	PCR technique	• WSSV infection cannot be treated. • This may be prevented by: • filtering the water that enters the pond to prevent entry of infected shrimp and other carriers; • avoiding polyculture of crab with other crustaceans • using WSSV-negative crablets; and • avoiding culture during the cold months

Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control

Infectious hypodermal and hematopoetic necrosis virus (IHHNV)	IHHNV infects juvenile to adult stages.	It is transmitted by ingestion of infected organism.	IHHNV-infected crab may die when exposed to stressful environmental conditions with no apparent signs of the disease.	PCR technique	• IHHNV-infection cannot be treated.
					• It may be prevented by:
					  • filtering the water that enters the pond to prevent entry of infected shrimp and other carriers;
					  • avoiding polyculture of crabs with other crustaceans; and
					  • using IHHNV-negative crablets

Bacterial Infection					

Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	
Shell disease	• This is caused by digesting chitin, a gram-negative, rod-shaped bacteria belonging to the genus *Vibrio*, *Pseudomonas*, *Aeromonas*, and *Spirillium* following mechanical injury. • It affects larvae to adult stages, but rarely results in mortality.		• Infected crabs may exhibit black deposits on the ventral part of the crab or melanised (dark brown to black pigmentation) and perforations on the shell. • Numerous perforations may lead to molting difficulty that may stress the crab and result in mortality.	Based on gross signs	• Maintain good water quality. • Avoid mechanical damage by not overstocking or by providing individual housing.	 Crab with shell disease showing black spots on the ventral region.  Crab with bacterial shell disease. The presence of perforations could be portal of entries for secondary infections.
Parasitic Infestation						

Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	
Hematodinium	• Hematodinium is a dinoflagellate infecting crustaceans. • It invades the hemolymph and results in mortality.	• It may be transmitted by ingestion of dead infected organisms. • It rarely occurs in salinities below 11 ppt.	• The ventral surfaces of infected crab are chalk white to light pink in appearance. • The gills, hepatopancreas, and other organs are cream in color.	Microscopic observation of the smear of the hemolymph	• There is no reported treatment. • It may be prevented by preparing the pond properly including prolonged drying.	 Light pink exoskeleton of infected crab.

Table 16. Continued.

Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	
Stalked barnacle	• The crab is infested with stalked barnacles belonging to the genus *Octolasmi*. • It infests juvenile to adult crabs.		• Stalked barnacles may colonize the gill chambers in debilitating numbers, which may adversely affect oxygen and carbon dioxide exchange. • Stalked barnacles may compete with the crab for oxygen. The synergistic effect may result in crab mortality.	Based on gross signs	There are no known prevention and control methods.	 *Octolasmis* sp. on the gills of crab.

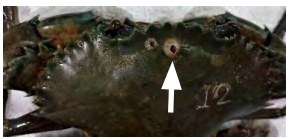
Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	
Barnacles	• Acorn barnacles belonging to the genus *Balanus* infest juveniles to adult crabs. • The intensity of infestation is usually correlated with the size of the crab due to long standing exposure to the same environmental condition and longer intermolt periods.		Barnacles are found attached to the carapace and chelipeds of crabs.	Based on gross signs	• Barnacles are removed with the molted exoskeleton. • They may be prevented by providing enough food and water change to enhance molting.	 *Balanus* sp. on the carapace of crab.

Table 16. Continued.

Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	

Fouling microorganisms on the exoskeleton	• This is a mixture of filamentous bacteria and algae, single or colonial protozoans, and debris.
	• Crabs preen to keep their shells clean. Crabs may fail to preen due to limited space, which may lead to the accumulation of fouling organisms.
			• Fouling micro-organisms are found on the shell of juvenile to adult crab.
			• Velvety green to brown organisms may be attached to the crab shell.
			• Light infestation does not affect the mangrove crab; heavy infestation may lead to slow movement due to the additional load and the inability or longer inter-molt period.
				Based on gross signs	• This may be prevented by providing:
					  • rearing conditions that allow normal behavioral patterns like burying in the sediment and exposure to air;
					  • adequate space for preening and movement to inhibit attachment of fouling organisms; and
					  • enough food and water change to enhance molting.
					• Fouling organisms are removed with the molted exoskeleton.
						
						'Lumot' covering the carapace of crab.

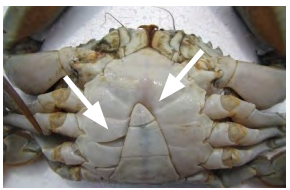
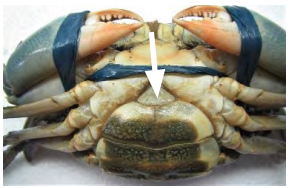
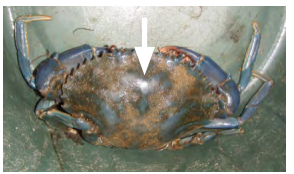
Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	
			External Abnormalities			
Black deposits on the abdominal region	• The black deposits observed on the abdominal region is due to the prolonged contact with the deteriorating pond bottom. • They affect juvenile to adult crabs		• The black deposits are due to the accumulation of sediments on the ventral part of the crab. • Thick deposits may slow down the crab movement.	Based on gross signs	• This may be prevented by proper pond preparation to improve pond bottom condition. • The deposits may be removed by scraping.	 Crab with black deposits on the abdominal region and chelipeds.
Morphological deformities	The deformities are due to exposure to high dose of antibiotics like oxytetracycline and furazolidone at the larval stages.		Morphological deformities such as fused frontal and lateral spines, asymmetrical and depressed tip of abdominal flap, and gap between sternites are observed in juvenile to adult crabs	Based on gross signs	This may be prevented by avoiding or reducing the use of chemotherapeutants at the hatchery phase.	 Crab with gap between sternites and asymmetrical abdominal flap.

Table 16. Continued.

Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	
			Discoloration of the Exoskeleton			
Albinism	• Albinism is a nutritional disease. • It affects juvenile to adult crabs.		There is light or whitish discoloration on exoskeleton or limbs.	Based on gross signs	• The discoloration may be reversed once diet is corrected. • Feeding with diets high in vitamin C and E may reverse or prevent albinism.	 Crab showing albinism. Arrow indicates the discolored part of the flap.
Bluish shell discoloration	• The disease is due to high copper content. • It is observed in sub-adult to adult crabs.		There is a bluish discoloration of the exoskeleton.	Based on gross signs	It may be prevented or reversed by transferring crab in a clean environment.	 Crab with bluish discoloration on the carapace and appendages.

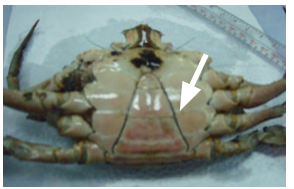
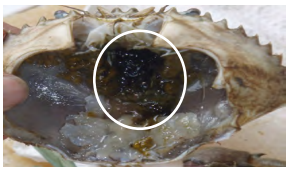
Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	
Red sternum	The disease is due to heavy metal contamination such as copper and zinc, with or without secondary bacterial infection.		There is pinkish or reddish discoloration of the abdominal region and appendages and pinkish muscles.	Based on gross signs	This may be prevented or reversed by transferring crab in a clean environment	 Crab with reddish discoloration on the abdominal region.
Rust spot discoloration	• This is due to exposure to copper in combination with other metals/ contaminants. • Affects juvenile to adult crabs.		There are irregularly-shaped, rust-colored lesions found on the carapace. The lesion may be eroded in severe cases.	Based on gross signs	This may be prevented by avoiding exposure of the cultured crab to heavy metals.	 Irregularly shaped rust colored lesions on the carapace of crab.

Table 16. Continued.

Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	
Rusty discoloration	• The discoloration is due to low soil and water pH. • It affects adult crabs.		• Rusty or orange to brown deposits are observed on the crab exoskeleton, which is more apparent on the abdominal region. • Although shell discoloration has no effect on the shell, acidic environment, which is the factor leading to discoloration, may adversely affect or impair other organs like the gills and the eyes and impair metabolism.	Based on gross signs	It may be prevented by preparing pond properly to avoid acid sulfate soil. Lime may be applied to correct soil pH.	 Crab with rusty discoloration of the abdominal region due to acidic environment.

Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	
			Internal Abnormalities			
Black or brown gills or gill fouling	• This is due to poor environmental conditions such as high organic load and heavy siltation. • This may also be due to stressful conditions such as overcrowding, extreme temperature or pH, low dissolved oxygen, high ammonia, etc. • This may be a manifestation of other disease syndromes such as precipitation of dissolved chemicals and vitamin C deficiency. • It affects juvenile to adult crabs.		• There is brown or gray to black discoloration of the gill arch or the entire gill structure. • The presence of fouling organisms may clog the gills, impairing water movement leading to respiratory stress or suffocation resulting in mortality.		This may be prevented by: • removing the sludge during pond preparation to avoid heavy siltation; • providing adequate Vitamin C diet, but avoid overfeeding; • maintaining good water quality free from suspended particles that may clog the gills; and • maintaining optimum dissolved oxygen content (> 5 ppm) by regular water change.	 Crab with black gill.

Table 16. Continued.

Disease/ abnormality	Description	Transmission	Gross signs and Effects on Crab	Diagnosis	Prevention and Control	
Black ovary	• Black ovary is associated with the deposition of the melanin pigment as a result of mechanical or microbial injury and vitamin C deficiency. • It affects adult crabs.	.	• Black ovary may affect fecundity among females and cause spawning failure or incomplete spawning. • The affected crab may be prone to diseases if the cause is Vitamin C deficiency.		This may be prevented by providing the crab with adequate diets rich in Vitamin C.	 Crab with black ovary.

Costs and Returns Analysis

The feasibility of growing the crablets in earthen brackishwater pond sourced either from nursery ponds or purchased from the wild is described in this section. Technical assumptions are shown in Table 17. The *Scylla serrata* crablets are stocked at a maximum density of 1,000/ha together with milkfish at 1,500/ha. The survival rates after 5–6 months are assumed to be 50% for crabs and 80% for milkfish. Selective harvesting for crabs is done after 4 months.

Table 17. Technical assumptions in the financial analysis of mangrove crab culture in grow-out brackishwater pond.

Pond area (ha)	3
Stocking density:	
Crabs (2–3 cm)/ha	1,000
Milkfish (2.5–3 cm)/ha	1,500
Number of runs/year	2
Survival rate (%):	
Crabs	50%
Milkfish	80%

It is assumed that the 3-ha pond to be used is rented and the only capital outlay is bamboo catwalk for each three compartments and a common bamboo shed for the laborers, which costs about P50,000 with an economic life of 3 years (P16,666.70 depreciation/year).

The costs and returns of mangrove crab culture in pond is shown in Table 18. The pond operator will have a revenue of P715,875/run and a net income of P539,264/year. However, the revenue also depends on the prevailing market price. The quality of harvest is normally varied, hence the price depends on the classification. There are about five classifications considered in the pricing of harvested crabs in the costs and returns.

Table 18. Costs and returns analysis of mangrove crab culture in grow-out pond after 5–6 months of culture.

Revenue:

Mangrove crabs		P607,875
Milkfish		P108,000
	Total:	P715,875

Item	Quantity	Unit Cost (P)	Total Cost (P)
Variable Cost			
Crabs (1,000 x 3 ha)	3,000	20	60,000
Milkfish (1500 x 3 ha)	4,500	2.5	11,250
Feeds: fish and agihis			134,460
Formulated feeds for milkfish (supplemental feed)			10,000
Pond preparation needs (lime, teased, chicken manure, etc.)			62,000
Crab traps (bintol) and seine (milkfish)			10,000
Straw for tying and polysterene boxes			5,000
Hired labor (during harvest)			1,800
Gasoline			2,000
Total			296,510
Fixed Cost			
Labor, 2 workers	144 days	300	86,400
Depreciation, for one run or 6 months			8,333
Pond repair			25,000
Pond rental, 6 months	3 years	20,000/year	30,000
Total			149,733
Total Cost			**446,243**
Income per run			269,632
Return on investment (%)			539.26
Payback period (years)			0.19

Financial analysis showed that grow-out culture of mangrove crabs with milkfish is a profitable business. The return on investment (ROI) of 539.26% can be obtained in 1 year. Payback period or the time needed to recover investments is 0.19 year.

Soft-Shell Crab Production

Soft-shell crab farming has become popular due to its profitability apart from the fact that consumers can eat all the parts of the crab when cooked. Crabs molt or shed their hard outer shell as part of a normal process in crustaceans in order for them to grow. A newly molted crab is soft and pliable. The shell starts to harden after a few hours hence they must be taken out of seawater or brackishwater immediately after molting for it to remain soft.

The production of soft-shell crabs, particularly mangrove crabs, is well-established in several Asian countries but its sustainability is challenged by the lack of wild seedstock in the natural habitat. In the Philippines, production of soft-shell crabs has been practiced only a decade ago due to lack of seedstock. Sourcing of crablets from the natural environment is not encouraged due to the dwindling population of mangrove crabs. Instead, it is recommended that crablets used for soft-shell crab production should come from hatcheries. Any species of mangrove crab or blue swimming crab can be used for the production of soft-shell crab. However, the focus of this section is the utilization of mangrove crabs.

Site

A brackishwater earthen pond can be utilized for the production of soft-shell crabs. The site should have adequate supply of clean brackishwater, freshwater, and electricity. It should also be accessible to market roads and sources of hatchery-produced seedstock. Please refer to Site Selection Section under the Culture of Crabs.

Setup

The pond should be prepared prior to the setting up of the facilities for soft-shell crab production (refer to Pond Culture Section on the detailed pond preparation). A 3,000–5,000-m^2 pond compartment can accommodate about 5,600 boxes with enough space for paddle wheels in case these will be installed.

Another system for the production of soft-shell crabs is the recirculating aquaculture system (RAS), which is set up in a covered structure. (Fig. 36). This is composed of layers of polypropylene crab boxes. Each layer has 10 boxes. Each group is usually composed of 100 boxes and equipped with a water treatment system using recycling filtering disinfectant fluid. One crab is stocked in each box. The cost of RAS is expensive but monitoring of crabs is easier than in the pond system. When pond is available, however, the succeeding system described in this section is more appropriate.

Fig. 36. Recirculating aquaculture system (RAS) inside a covered structure for the production of soft-shell crabs.

Crab Boxes in Pond

1. Purchase crab boxes measuring 20 cm (l) x 14 cm (w) x 5.5 cm (h) top part (cover) and 20.5 cm (l) x 14.5 cm (w) x 9 cm (h) bottom part (base) (Fig. 37) or bigger-sized crab boxes measuring 28 cm (l) x 18 cm (w) x 3cm (h) top part and 28 cm (l) x 18 cm (w) x 12.5 cm (h) bottom part; flap not included in the measurement.

Fig. 37. Crab box with matching cover.

2. Plastic perforated trays can also be used, but they should be thick or sturdy enough to withstand crab bites (Fig. 38). Provide each crab box with perforated cover. Use mesh net to cover and fasten the net on all sides of the box using nylon twine if the tray has no matching cover. Put a slit on top for the insertion of crabs and feeds.

Fig. 38. Plastic trays with improvised net cover.

Roofed Bridge and Floating Platforms

1. Construct a roofed bridge (120–150 cm wide) in the middle part of the pond to access the floating platforms and provide a small covered working area (Fig. 39). The length of the roofed bridge depends on the size of the pond.

Fig. 39. Roofed bridge installed in the middle of the pond.

2. Raise the floor of the roofed bridge and working area to 15–20 cm above the water surface (Fig. 40).

Fig. 40. Floor of bridge elevated 15-20 cm above the water surface.

3. Install necessary light bulbs and plugs in the roofed bridge and working area for monitoring during the night.
4. Prepare floating platforms made of 2-cm diameter polyvinylchloride (PVC) pipes. The floating frame is composed of three 10-feet long parallel pipes (Fig. 41). Adjust the space between the pipes according to the width and length of the trays or boxes. Connect these frames with PVC elbows and tees.

Fig. 41. Floating platforms made of polyvinylchloride pipes.

5. Prepare the crab boxes. Each frame can hold at least 24 boxes.
6. Tie a polyethylene rope to a wooden or bamboo pole (Fig. 42). Insert the rope in the rings installed in the mid-section of the floating frame. Tie the other end of the rope to the opposite pole. Install a pulley to each floating frame to facilitate dragging of platforms with the boxes.

Fig. 42. Wooden poles where ropes are tied to support the floating frames.

Culture of Mangrove Crabs

Source

Any species of mangrove crab with 60–100 g body weight can be used. If not available, crablets with 1-cm CW (0.24–0.4 g) from the hatchery are grown in net cages installed in brackishwater earthen pond for about 6–7 weeks. Crablets are fed mussel meat or fish at 30% and formulated diet at 70% of the total body weight (refer to the Nursery Phase Section). The water is changed every spring tide or whenever necessary at about 30% of the pond water. Crabs are harvested when they attain 3–4 cm CW (2–5 g) (Fig. 43).

The crabs are further reared in grow-out ponds at 1–1.5 ind/m^2. The crabs are fed with low value fish and mollusks meat at 10–12% of the biomass. The water is changed every spring tide at 30–50% of total volume. Harvesting is done when majority of the crabs attain 60–100 g (6.5–8.5 cm CW), which is usually within 1.5–2 months after stocking (Fig. 43).

Sourcing of hatchery-reared crab instars (0.24–0.4 g; 0.8–1.0 cm CW) for stocking in net cages

Stocking of crab instars in net cages in nursery pond

Harvest of 3.0–4.0 cm CW (2.0–5.0 g) crabs after 6–7 weeks in the nursery pond

Culture of havested crabs in grow-out pond for 1.5–2 months

Harvest of crab juveniles (60–100 g; 6.5–8.5 cm CW) in grow-out pond

Stocking of juveniles in crab boxes for soft-shell crab production

Fig. 43. Production of crab instars to 60-100 g crablets or juveniles for stocking in boxes.

Stocking of Crabs

1. Select crabs weighing 60-100 g and put in baskets. Acclimate by gradually introducing pond water (Fig. 44).

Fig. 44. Acclimation of crabs prior to stocking in boxes

2. Stock crabs individually in perforated boxes. Provide each box with perforated cover for easy monitoring and feeding (Fig. 45).

Fig. 45. Stocking of crabs individually in boxes.

3. Position the boxes on floating platforms (Fig. 46).

Fig. 46. Putting the crab boxes in floating frames.

Feeding and Water Management

1. Wash the feeds (low-value fish, mollusk meat, chicken or fish entrails) and chop.
2. Feed the crabs at 6 - 8% of the total body weight by inserting the feed through the holes of each box or slit of the net cover in the early morning or late afternoon every other day.
3. Replace 30-50% of the pond water every spring tide or whenever necessary.
4. Inspect the crabs every 4 hours by pulling the frames towards the roofed bridge. Inspect each container through the holes for molted and dead crabs. A crab has molted if an empty shell is seen inside the box (Fig. 47).

Fig. 47. Newly molted crab (arrow) with the old shell.

5. Retrieve the boxes containing dead and molted crabs.
6. Discard dead crabs. Put newly molted crabs in basin with freshwater and aerate for 30-60 minutes (Fig. 48).

Fig. 48. Newly molted crabs held in basins with aerated freshwater prior to packing and freezing.

7. Sort and pack in plastic food containers or wrap individually using plastic food wrap (Fig. 49). Store in freezer.
8. Sell to restaurants or to other consumers.

Soft-shell crabs can be eaten whole when cooked since the guts are clean and the shell and legs need not be removed.

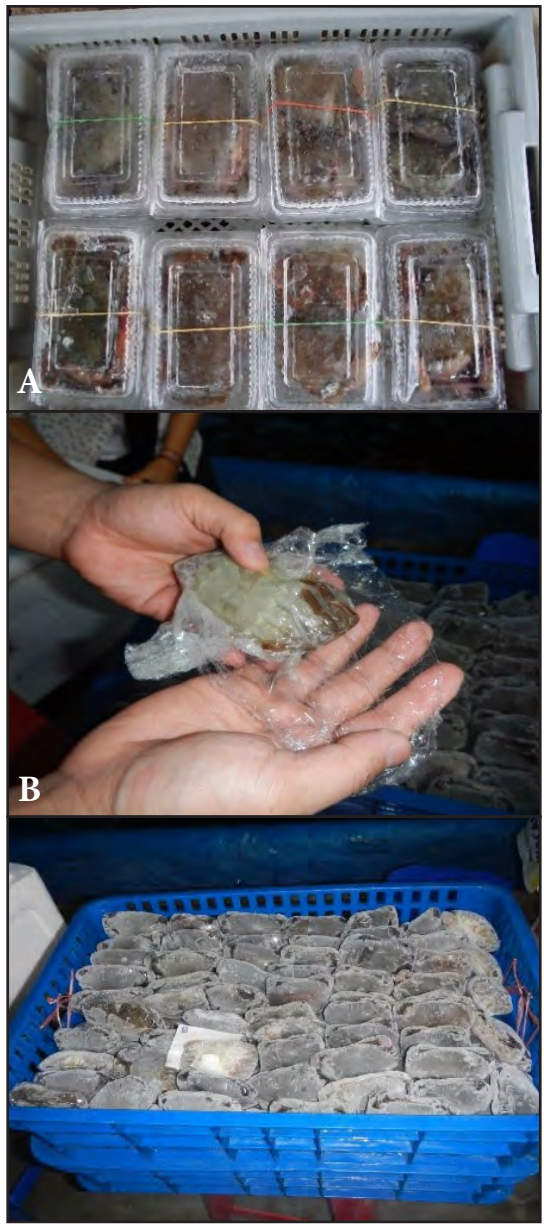


Fig. 49. Soft-shell crabs packed in plastic food containers (A) or individually wrapped using plastic food wrap (B) prior to freezing.

Cost and Return Analysis

The technical information is shown in Table 18. Soft-shell crab farming is labor intensive. It requires frequent monitoring to check for molting. Laborers must observe each compartment regularly to monitor presence of newly-molted crabs. This culture phase also includes growing crablets from the hatchery in the nursery for 6–7 weeks, and for another 1.5–2 months in grow out ponds until crabs attain 60–100g weight. Soft-shell crab farming enables operators to have at least four crops per year. Since the crabs are stocked and monitored individually in compartments, soft-shell crabs have high survival rate relative to other types of mangrove crab culture. With an average of 85% survival rate, an operator can produce 4,760 soft-shell crabs per crop out of the 5,600 crabs stocked (Table 19).

Table 19. Technical information for soft-shell crab production.

	Nursery	Grow-out	Soft-shell crab
Days of culture (mo)	1	1.5-2.0	2
Total area of facilities (ha)	0.5	1	0.3-0.5
Number of Crops per year	4	4	4
Total number of stock per crop (pcs)	10,000	8,000	5,600
Survival rate (%)	80	70	85
Total recovery at harvest per crop (pcs/m^2 per crop)	8,000	5,600	4,760
Average weight per piece at harvest (g/pc)	5	60	100
Cost of crablets from hatchery (pc)	6		
Farm gate selling price (pc)			70
Gross value of harvest per crop (crop)			333,200

Modified from Quinitio et al. (2015).

Soft-shell crabs cost P70/piece (farm gate price) yielding a gross revenue of P333,200/crop (Table 20). With four crops per year, this results in an annual revenue of P1,332,800. Considering the costs, a profit of P562,560 can be generated per year. Labor cost is more than half of the total fixed costs (67%). This type of investment requires a capital of P566,189 (Table 21).

Table 20. Costs and returns for soft-shell crab farming.

Item	Quantity	Unit price (P)	Cost/crop (P) x4	Cost (P)/year
VARIABLE COSTS				
Nursery phase				
Crablets (pcs)	10,000	6	60,000	240,000
Feeds (kg)	19	25	475	1,900
Lime, fertilizer, and other inputs			1,500	6,000
Grow-out phase (until 60g)				
Feeds (kg)	168	25	4,200	16,800
Pond preparation expenses			1,500	6,000
Electricity			4,000	16,000
Soft-shell crab production				
Feeds (kg)	348	25	8,700	34,800
Chemicals and manure for pond prep			1,500	6,000
Electricity			10,000	40,000
Other supplies			2,000	8,000
Total Variable Cost			93,875	375,500
FIXED COST				
Lease			6,250	25,000

Table 20. Continued.

Item	Quantity	Unit price (P)	Cost/crop (P) x4	Cost (P)/year
Maintenance and repairs (5% of fixed asset)			7,023	28,092
Labor (soft-shell crab production)			51,200	204,800
Labor (nursery and growout)			11,000	44,000
Depreciation costs			23,212	92,848
Total Fixed Cost			98,685	394,740
TOTAL COST			192,560	770,240
Gross revenue (P)			333,200	1,332,800
Net Income			140,640	562,560
Return on investment (%)			25	100
Break-even production (pc)			2,751	11,003
Payback period (years)			1.00	
Break-even price (P/pc)			40.45	

Table 21. Investment items, cost, and schedule of depreciation of capital assets for soft-shell crab farming.

Items	Price/ unit (P)	Quantity	Total cost (P)	Lifespan (years)	Depreciation/year (P)	Re-investments on year 3
Floating frames	861	209	179,949	10	18,000	
Tray/Box	50	5,800	290,000	5	58,000	
Freezer, 10 cubic ft.	15,000	1	15,000	10	1,500	
Generator set 15kVA	30,000	1	30,000	5	6,000	
Air compressor	1,800	1	1,800	5	360	
Weighing scale (50 kg)	2000	2	4,000	5	800	5000
Weighing scale (500 g)	500	2	1,000	3	333	
Refractometer	15,000	1	15,000	5	3,000	
Working area	15,000	1	15,000	8	1,875	
Electrical system	5,000	1	5,000	10	500	
Impulse sealer	5,000	1	5,000	5	1,000	4440
Other supplies	4,440		4,440	3	1,480	
Total Investment Cost			566,189		92,848	9,440
Annual Depreciation Cost					92,848	9,440

Market Outlet

Soft-shell crabs are sorted and processed (eyes and gills removed) based on the requirement of the buyer prior to packing. Small-scale farmers/producers sell their crabs to brokers or directly to seafood processors (Fig. 50). Then the crabs are delivered to local markets such as restaurants, supermarkets, and local consumers. However, large-scale producers set up their own freezing equipment and directly sell their products either to seafood processors or to local end users. The diagram below shows the marketing channel of soft-shell crabs.

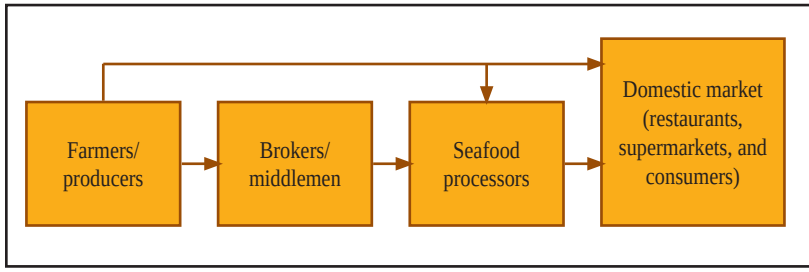


Fig. 50. Market channel for soft-shell crabs.

Philippine National Standards

PNS/BAFS 235:2017 ICS 67.120.30 describes the Philippine National Standards for cultured frozen soft shell mangrove crabs and blue swimming crabs grown for human consumption or for further processing.

Postharvest and Transport

Suitable conditions and procedures for handling, processing, and transport of mangrove crabs should be maintained after harvest to ensure high survival and quality until they reach their final destination. After harvesting, follow the process below:

Postharvest

Handling and cleaning of crabs

1. Avoid unnecessary handling as some parts of the crabs especially the claws can snap off easily. Crabs have the tendency to voluntarily detach the claws and legs if mishandled.
2. Clean crabs by brushing off the mud and other adhering dirt while washing them in seawater or brackishwater.

Tying

The claws of the crabs are tied close to the abdomen to prevent them from struggling and fighting with each other. Tying the crabs also protects the handlers from any harm. Tying materials commonly used include plastic straw, rattan strips, nipa leaves, coconut leaves, and cotton strings.

There are several ways to tie the crabs. Below is one way:

1. Hold the crabs between the swimming and walking legs using the thumb and pointer finger (Fig. 51A).
2. Put the string underneath the animal, between the claws and the first walking legs (Fig. 51B).
3. Put the string around the folded claw (Fig. 51C). Do the same with the other claw (Fig. 51D).
4. Tuck the string under the swimming legs on both sides and tie the strings (Fig. 51E).

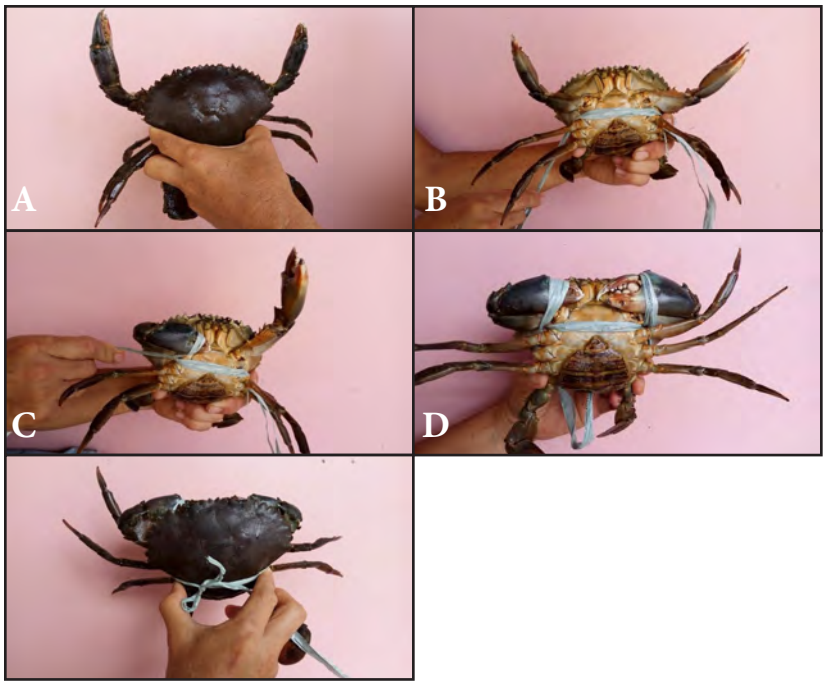


Fig. 51. Steps in tying the crabs.

Sorting

Sort or grade the crabs based on the following:

- Species
- Sex
- Body size/weight
- Maturity
- Completeness of limbs and presence of deformities

One of the most common methods of determining the ovarian maturity of a female crab aside from checking the external features is to press the first abdominal segment adjacent to the carapace (Fig. 52). A mature female crab has an orange ovary and can easily be seen because it fills up the cavity under the carapace as seen in Figure 52. An immature female crab has a thin and transparent to yellow ovary.

Fig. 52. Determining the maturity of ovary of crabs by pressing the first abdominal segment adjacent to the carapace. Photo credits: Arnulfo M. Mascariñas.

Transport to primary market and traders

1. Put the sorted crabs in perforated plastic crates or any suitable containers (Fig. 53). The mode and duration of transport should be considered in selecting the type of containers to be used.

Fig. 53. Perforated plastic crates (A) and baskets (B) commonly used for holding crabs prior to packing and transport to local destination.

2. Transport crabs to wholesalers (brokers and middlemen) and traders or 'consignacions' if not purchased within the day after harvest. Extending the holding period of crabs causes stress and reduces the weight of the crab.

Storage of crabs

If crabs are not transported immediately to the final destination, they should be treated as follows:

1. Store crabs in perforated plastic crates or trays (refer to Fig. 53) in a cool and well-ventilated room. Cover the plastic crates or containers with moist material.
2. Sprinkle the crabs with seawater or brackishwater regularly to keep them cool.
3. Sort and separate crabs that are weak and deformed (Fig. 54). Different labels and prices are assigned to each crab class.

Fig. 54. Sorting of crabs in the trading center.

Postharvest Quality of Crabs

Quality Grading

Quality of live crabs is assessed for its fullness by pressing the abdomen and carapace and other physiological conditions.

1. Press the abdomen adjacent to the second walking legs (Fig. 55). Apply pressure using the thumb. The crab is full of meat if the abdomen is firm.

Fig. 55. Examining the meat fullness of crab by pressing the abdominal area near the first and second walking legs.

2. Press the top of the carapace (Fig. 56). The crab is full of meat if the carapace is firm.

Fig. 56. Checking the meat fullness of crab by pressing the sides of the carapace.

3. Exclude crabs in the final packing and transport if found with the following conditions:

    - Bleeding - hemolymph oozing from any body parts of the crab due to mechanical injury (Fig. 57).

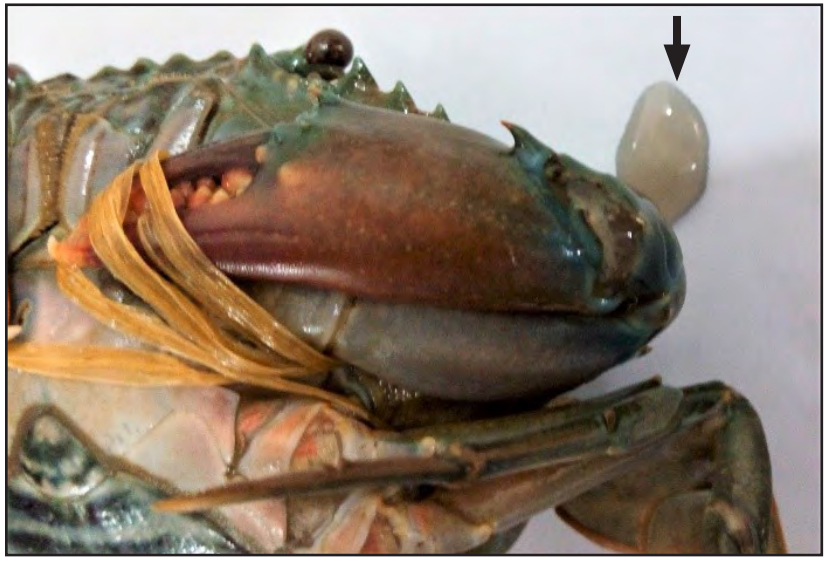


Fig. 57. Hemolymph oozing from the claw of crab.

- Frothing/Bubbling - bubbles coming out from the mouth may indicate that the crab is under stress and is dying (Fig. 58).

Fig. 58. Bubbles coming from the mouth of the crab.

- Weak - crab appears to be sluggish and does not show any resistance when the claws are touched. An active crab displays strong resistance even when tied and their eyes and legs react to any movement.

The quality of the crabs may also be adversely affected by long storage or holding. The practice of first-in, first-out in trading or consolidation centers should be observed.

Ammoniacal odor

When crabs are no longer washed after the initial cleaning during harvest, they may accumulate nitrogenous wastes until the ammoniacal odor ('panghi') becomes apparent. Crabs eat high-protein diets and convert these protein into ammoniacal excreta, through the gills. However, when the crabs are out of the water, the ammoniacal excreta eventually accumulates. Accumulation of unwashed ammoniacal excreta in the gills can cause the off-odor which becomes evident after 3 days of immersion, without washing and purging. Likewise, crabs develop obnoxious smell after they die and decay.

Wash and clean the crabs occasionally to rid of body wastes and prevent off-odor. After a long transport, the crabs should be allowed to recover from stress and purged with water upon arrival.

Muscle emaciation

The crabs are no longer fed to minimize waste excretion during holding and transport. During this period, crabs may experience nutritional starvation resulting in muscle emaciation. For long periods of storage without feeding, the crab's glycogen reserves become depleted and the primary physiological energy sources (e.g., lipids, carbohydrates, and proteins) are used up. Once the proteins are utilized, muscle atrophy and loss of weight become evident. Muscle emaciation normally occurs when the crabs are stored ≥3 days after harvest. Furthermore, muscle emaciation can result in limb loss.

'Hagas' is the term used for very lean or almost empty meat crabs. Crabs in this condition are believed to have a disease and may not be able to recover.

Packing

Various containers are used for packing depending on the destination and mode of transport. Some of the containers used are the following:

- Polystyrene boxes with ventilation holes for transport. This packing is required by airline companies (Fig. 59).
- Corrugated carton boxes (preferably wax-lined cardboard) with ventilation holes for transport of small quantities of crabs over short distance (Fig. 60).

Fig. 59. Polysterene boxes with ventilation holes used for crab transport.

Fig. 60. Carton boxes with ventilation holes for crab transport.

Pack crabs as follows:

1. Maintain the crabs in a cool (24–28°C) and moist condition by using moist banana or mangrove leaves, or wet jute sack or cotton cloth or 'katsa' as lining regardless of the type of container used. Do not use newspapers as these contain chemicals. If carton box is used, line the bottom with plastic sheet to avoid wetting the box.
2. Pack crabs as close as possible. Space allows movement and causes stress or damage to the crabs (Fig. 61).
3. Add a small chunk of ice (12–14 cm long x 4–5 cm diameter) in plastic that is wrapped in paper for each 550 cm (l) x 400 cm (w) x 430 cm (h) polysterene box to keep the crabs cool.

Fig. 61. Crabs are packed vertically and as close as possible to add another layer of crabs on top.

Transport to Exporters or Consolidators

The crabs are transported to exporters via van, truck, bus, inter-island vessel, or plane. Place the boxes in the coolest part of the vessel or vehicle. Land travel is longer and may take more than 10 hours to reach its final destination. Transport the crabs in the early morning or late afternoon or when the ambient temperature is cool.

Holding Facilities

The Bureau of Fisheries and Aquatic Resources (BFAR) is mandated to inspect, monitor, and register holding facilities. These tasks are performed by its Fish Health Officers (FHO). BFAR-FHOs are assigned in each of the 17 regions of the country to cater to the needs of its clients. The requirements for registration of holding facilities are as follows:

a. Submission of an accomplished application form for registration;
b. Securities and Exchange Commission (SEC)/Department of Trade and Industry (DTI)/Cooperative Development Authority (CDA) registration;
c. Mayor's permit/business permit;
d. Sanitation Standard Operating Procedures (SSOP) for live crab holding facilities;
e. Manpower profile;
f. Facility layout;
g. Location map; and
h. Photo of the holding facility.

Upon compliance of the requirements, the applicant will be informed officially of an inspection of the holding facility to be conducted by the BFAR-FHO, who also collects crab samples for analysis, when necessary. If the applicant has no previous record of conviction of any prohibited acts and based on the inspection and laboratory tests conducted, BFAR will issue the Certificate of Registration (COR). If the applicant is found to be non-compliant with the requirements, he will be asked to submit a Corrective Action Plan (CAP) with the similar time frame. The applicant will be subjected to a follow-up inspection to verify the progress of the CAP until compliance is attained.

The registered holding facilities of live mangrove crabs under BFAR - National Capital Region (NCR) is shown in Annex A.

Hygiene and Sanitation Practices

It is important that holding facilities for live crabs maintain sanitation standard operating procedures applicable for the handling, storage, packing, and transport of live crabs to ensure that these are free from any source of physical, chemical, or biological contaminations. These facilities should:

- Maintain hand-washing, sanitizing, and toilet facilities for the handlers;
- Protect the packaging materials from adulteration;
- Keep the toxic compounds used in cleaning the facilities in separate designated areas;
- Keep the holding facility free from any insect infestation and pets; and
- Make sure that handlers are fit to work and no one is a carrier of any contagious diseases.

Marketing

Market Forms

The market forms or products from crabs are the following:

1. Live crabs - Most of the exported crabs are live and classified as: (a) crabs with all body parts intact; and (b) crabs with lacking limbs. The latter are sold at a lower price per kilo compared to crabs with intact legs.
2. Crab claws - claws taken from live crabs or voluntarily removed by crabs. Due to its meaty and chunky nature, crab claws command a higher price over the live crabs that lack appendages (Fig. 62).
3. Soft-shell crabs - newly molted crabs that are frozen. The size range from 80–150 g each.

Fig. 62. Crab claws as another product form.

Market Outlet and Supply Chain

Marketable-size mangrove crabs are sold to wholesalers (brokers/middlemen), local consumers, or exporters (Fig. 63). The wholesalers airship the crabs to the final destination for export or for local consumption (e.g., restaurants, hotels). Crabs that do not go through middlemen are sold directly to local markets, restaurants, exporters, and sometimes to consumers. Large-scale crab farmers have shorter trading course than small-scale crab farmers since they have the means and capability to transport their products. Likewise, they have the capability to directly transact with traders and exporters. The small-scale crab farmers have longer trading routes since their products go through brokers and middlemen to reach buying stations or consolidators. Some brokers or middlemen can directly sell crabs in local public markets. Likewise, many small-scale farmers sell the crabs directly to consumers within their area. Whatever is not absorbed by the export market, including rejects such as undersized, lean crabs with missing claws and limbs, and those with unequal size of claws, go to the local market.

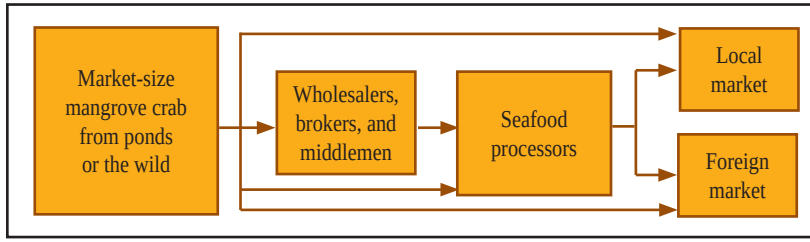


Fig. 63. Postharvest supply chain.

Price depends on the species, season, size, sex, maturity, completeness of claws and limbs, and overall quality of the crabs.

Major crab exporters are based in Manila and Cebu. The crabs that pass export quality grades are sent to or picked-up by processors or exporters. Upon arrival at the exporters' area, the crabs are purged and cleaned. Sorting, weighing, and classifying are again done. The crabs are packed in layered polysterene boxes with ventilation holes depending on the ambient temperature at the destination.

Live crabs are exported to mainland China, Hong Kong, Taiwan, Singapore, and Malaysia. The list of exporters of mangrove crabs is shown in Annex B.

Export Market Access Requirements

- Registration of holding facilities for live crabs – Holding facilities for live crabs intended for export must comply with the requirements prescribed by BFAR.
- Traceability – Exporters of crabs must be able to demonstrate the traceability of the crabs for export. This requires an effective documentation system of the crab or the farm where they were raised including the packing dates and the buyers' or importers' names and addresses. This is to ensure that in any event that something goes wrong with the product, only the affected lot is recalled.
- Local transport permit (LTP)/auxillary invoice – This document is secured from the local government unit (LGU) having jurisdiction over the harvest area or crab source.

- Export permit – Exports of live crabs are always accompanied by an export permit issued by BFAR on a per shipment basis to establish the legality of the shipment.
- Sanitary/health certificate – This document is issued by BFAR to show that the live crabs were handled, stored, and transported in accordance with existing rules and regulations on good handling and sanitary practices and that the products are fit for human consumption and free from any infection or disease.

Philippine National Standards

There is an existing PNS for live mangrove crabs, which aims to provide a common understanding on the scope of the standard; product description; process description; essential composition and quality factors; food additives; contaminants; hygiene and handling; packaging and labeling; methods of sampling; examination and analysis; definition of defectives and lot acceptance. Please refer to PNS/BAFS 178:2016 for the details on the PNS for live mangrove crabs.

Genetics

Genetic Marker Associated Technologies for Improved Mangrove Crab Breeding and Farming

Genetics is simply defined as the study of genes, genetic variation, and heredity. In any living organism, including farmed aquatic organisms, it is important to understand the mechanisms behind how and why aquatic animals respond to environmental cues based on their genetic background. In general, like in agriculture, aquaculture has benefitted from genetic techniques that have been applied in areas such as stock management, that is, from species and strain identification to population assessment as well as stock improvement. The various genetics applications described here can be adopted to help improve mangrove crab production and crab fishery management.

Morphometric and Genetic Approaches in Mangrove Crab Species/Stock Identification

As mentioned earlier, Estampador (1949) reported three species of mangrove crabs in the Philippines, *Scylla oceanica* (Dana 1852), *S. tranquebarica* (Fabricius 1798), and *S. serrata* (Forskål 1775), in which also the variety *S. serrata* var. *paramamosain* (Estampador 1949) was recognized.

Keenan et al. (1998) revised this to consist of four distinct species, with the features of Keenan et al.'s (1998) *S. serrata*, the king or black mangrove crab, and *S. olivacea* (Herbst 1796), the brown or orange mangrove crab, matching Estampador's (1949) *S. oceanica* and *S. serrata*, respectively. The classification of *S. tranquebarica*, the purple mangrove crab, was retained, and *S. paramamosain*, the green mangrove crab, was elevated to its own species.

The primary feature or trait used for identifying the species of an individual mangrove crab is the presence or absence of the inner carpus spine on the first pair of pereiopods, the shape of the frontal lobe spines, the distinctness and location of geometric patterns in the walking and swimming legs, and the shape of the dactyl prominences of the cheliped. Despite these established morphological features of the species, difficulty in species identification for the genus have

been reported especially in the early juvenile (crablet) stage. The effectiveness of the existing dichotomous key on Philippine mangrove crabs was tested against physical characters, key body measurements, and molecular methods of species identification. Gene sequences (16s region in the mitochondria, nuclear ITS-1 amplicons cut with Hha I restriction enzyme) were used to derive a more reliable hierarchy in the existing diagnostic characters that reduce uncertainties in species identification.

Accurate species identification is important. In the Philippines, any batch of wild-caught crablets for use in grow-out culture may be a mix of any of the three species commonly found, depending on the location. *S. serrata, S. tranquebarica,* and *S. olivacea* have overlapping ranges. Fishermen compensate for projected loss in yield caused by farming mixed species by increasing the number of captured crablets.

There have been no known morphological diagnostic markers for *Scylla* species at early developmental stages. The species diagnostic markers for this group, including the inner carpus spines, the frontal lobe spine shape, and the polygonal shapes on the swimming and walking legs only become evident during late crablet stages when the carapace width is at least 80 mm. Molecular markers or DNA-based markers are available for species identification of mangrove crabs but they cannot be applied outside of the laboratory.

For species identification in the field, image analysis and mobile computing have helped in the search for morphological diagnostic markers for the mangrove crab juveniles. Graphical analysis programs, such as SHAPE, convert geometric images into mathematical values, called Fourier components. These values are then analyzed to find similarities not easily detected using visual comparisons. With the combination of molecular, imaging, and mobile computing techniques, it became possible to detect morphological similarities that may not be detectable through simple visual inspection.

The species identification tool developed by the De La Salle University using both genetic and imaging methods, known as Crabifier, (https://sites.google.com/view/crabifier/home), is now available for use by the mangrove crab industry. This crab identifier can be used by crablet consolidators in sorting them according to species as well as by crab farmers who want to ensure that what they are procuring from collectors are their species prefererence.

Genetic Considerations in the Development and Management of Mangrove Crab Broodstock

Mangrove crab broodstock are initially sourced from the wild, such as estuaries or brackishwater ponds, either as immature adults that are further domesticated in a breeding facility or as mature females with orange ovaries ('aligue') immediately set aside for spawning. If a hatchery facility is operational, broodstocks are subsequently developed from offsprings of founder stocks. Current technologies have allowed the determination of the genetic background of potential broodstock through DNA marker analysis. With these tools, the ability to identify mangrove crab stocks/populations with high genetic variability is possible.

High genetic diversity in aquaculture stocks means that they are presumed to be more fit and possess better production traits. If information on the quality and genetic variation of stocks for use as potential breeders on farm is available, the farmer can develop his own stocks for propagation and be assured of a steady supply of good quality crablets for on-growing.

Aside from knowing the genetic background or make-up of mangrove crab broodstock, maintaining their genetic quality through generations entails knowledge and adoption of mating schemes that can help minimize inbreeding. It is important to prevent mating related individuals as this leads to producing crabs that possess similar genes, some of which may be deleterious or express less desirable traits/phenotypes such as slow growth, poor survival, or worse, morphological abnormalities. In general, methods to minimize inbreeding in aquaculture stocks include the use of a high number of male and female breeders that would comprise as effective population size. Effective population size is defined as the number of male and female breeders that participate in mating and/or contribute to the next generation of the farmed crab stocks. Effective population size differs from actual population size for not all animals that comprise a breeding population participate in mating regardless of their maturity to breed. Another method is to use breeders from different sources for seedstock production. By having at least two stocks, one can use females from stock A to be mated or paired off with males from stock B and vice-versa. This can ensure that no two related individuals are utilized for mating, thus avoiding inbreeding.

Mapping Ideal Sites and Identifying Heat-stress Resilient Stocks

Aquaculture is currently under threat because of the effects of rising temperatures and wide temperature fluctuations. Invertebrates such as mangrove crabs in coastal areas of the tropics are at the edge of their temperature tolerance. To address the need to determine geographical areas where temperatures stress is less, maps that mark out the combination of temperature range and variability were drawn. The categories are as follows:

- The average temperature ranges are low and there is low temperature variability;
- The average temperature ranges are low and there is high temperature variability;
- The average temperature ranges are high and there is low temperature variability; and
- The average temperature ranges are high and there is high temperature variability.

Maps (or CRABMAP) have been drawn for mangrove crab culture areas, namely the islands of Panay, Palawan, and Mindoro, and mangrove areas at the northern part of Cagayan and southern Sorsogon. These were drawn using 30-year average temperature data at 1-m^2 resolution that was downloaded from Bioclim (http://www.worldclim.org/bioclim) and PhilGIS (https://www.philgis.org/). The data were processed and visualized using open source software QGIS to obtain the maps of temperature vulnerability.

With such maps, fish farmers can be guided as to which sites are ideal for crab farming or where to find and collect mangrove crabs that are more adaptive/more suited for culture (in terms of temperature adaptability) in their own farm site.

Meanwhile, differentially expressed genes in crabs exposed to stressful environments (e.g., varying temperature profiles) have been noted and such information is also important in defining local crab populations that are more adapted to temperature stress.

Mangrove crabs from areas with different temperature profiles were collected and brought to the laboratory to be tested for response to temperature stress. Responses were noted as differences in the expression of mRNA, based on a functional genomics technique called RNASeq. The mRNA expressed are compared in case vs control experiments to determine the difference in response of individuals to heating from different sites.

If all crabs were responding in the same manner and were highly stressed to the same extent in the case and control experiment, then it can be concluded that mangrove crab farming will be extremely affected by rising temperatures. Mangrove crabs may not be the species to raise during periods of expected temperature rise. On the other hand, if all populations are both minimally stressed, then mangrove crabs should be a species of choice when temperatures are expected to rise. If the populations most exposed to higher temperature ranges and/or greater temperature variability are indeed better able to handle heating, then hatcheries should be using crabs from these areas as broodstock for breeding. Juveniles from areas with lower temperature ranges and variability will be more sensitive, then it would be better stocked in areas close to their origin. This study may be the first to test the temperature adaptation issue for an aquaculture species in the Philippines, and that is made possible by the application of RNASeq.

Determining Optimal Temperature-salinity Conditions for Mangrove Crab Farming

Controlled laboratory experiments have been conducted where crab juveniles were reared in conditions where set temperature and salinity combinations were made. The percentage of molting crabs and hormone (molt inhibiting hormone [MIH] and the extracellular signal-regulated kinase [ERK]) expressions were noted. Molting in crabs indicates growth since their carapace has to be shed and replaced in order to grow. It has been noted that at conditions where the rearing temperature is steady at either 26°C or 30°C and salinity is 30 ppt, crab molting percentage and frequency are high. In conditions where temperature fluctuates between 26–33°C, their molting percentage at different salinities do not differ significantly. Moreover, the mechanism behind molting (via hormone expressions) has been elucidated and information as such will be useful in "controlling" molting for purposes of synchronizing molting in the production of soft-shelled crabs.

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Annex A

No.	Company Name	Address
1	Bonnathan Seafoods Trading	9566 Jaime St. Airport Village, Vitalez, Paranaque City
2	Fong Bros. International Corp.	9474 A. Alejandro St., Airport Village, Paranaque City
3	GE Asia International Corporation	1321 Mactan Street, Baclaran, Parañaque City
4	Golden Harvest Seafood	371 Quirino Ave., Don Galo, Parañaque City
5	Golden Ocean Marine Products	9557 - B Mango St., Brgy. Vitalez, Airport Rd., Paranaque City
6	Inter Marine Center	9420 Urma Drive Airport Village, Parañaque City
7	Isla Aquamarine Resources	3406 Factor Compound, Don Galo, Parañaque City
8	Jamesrie Aquamarine Products	3255 Riverview Compound, Tambo, Parañaque City
9	Kenkaitwin Enterprises	0234 A. C. Santos St., Tambo, Parañaque City
10	Kohav Marine Products Trading	564 Quirino Ave., Tambo Parañaque
11	Millenium Ocean Star Corporation	780 LOPEZ Compound, TamboParanaque City, Philippines
12	Ocean Treasures Marine Trading	3261 Riverview Compound, Quirino Ave., Brgy. Tambo, Paranaque City
13	Purple Ocean Trading	9434 Cecil St., Airport Village.,Brgy. Vitalez, Paranaque City
14	Sea Sheperd International Export Import Inc.	2769 B.M. Delos Santos St., Tambo, Paranaque City
15	Sealamp Marine Products Trading	9487 Elizabeth Street, Vitalez, Paranaque City
16	Seaworld Commercial Trading Corp.	6091 Dimatimbangan St., Don Galo, Parañaque City
17	The Quality Prime Ocean Products Inc.	8 Los Tamaraos Drive, Tambo, Parañaque City
18	Unifresh Marine Products	231B Riverview Compound, Quirino Ave., Parañaque City
19	Wang-Wang Marine Products Trading, Inc.	9419 Urma Drive Airport Village, Vitalez, Parañaque City
20	White Gold Marine Products, Inc.	7 Mcdonough St. Tambo, Parañaque City
21	X3 Marine Products	1354 Lt. Garag Street, Barangay Baclaran, Paranaque City

No.	Company Name	Address
22	Xinhe Seafood Enterprises	9551 Gena St., Vitalez Village, Baltao, Parañaque City
23	Yeung Marine Products	4450 D. Campos Street, Don Galo, Paranaque City
24	Yeung Marine Products	Tayud, Consolacion, Cebu City
25	Harbour View Corporation	Lot 5 Veronica de Leon Street, Brgy. Sto. Niño, Ibayo, Parañaque
26	Orient Fresh Enterprises	3941 B Dahlia St., Sto. Niño Parañaque City
27	Unifresh Marine Products	231 Riverview Compound, Quirino Ave., Parañaque City

Annex B

Philippine Exporters of Mangrove Crabs; BFAR, July 2018.

No.	Company Name	Address	Country	Consignee
1	Bonnathan Seafoods Trading	Parañaque City, Metro Manila	China	Bonnatyhan Seafoods Trading
				Guangzhou Top Shipping Company Ltd
				Shanghai Rong Zhu Import & Export Co., Ltd
				Shanghai Xiongxing Import & Export Co., Ltd
				Xiamen CL Pilot Import & Export Co., Ltd
				Xiamen Runze Trading Co., Ltd

No.	Company Name	Address	Country	Consignee
2	Fong Bros. International Corp.	Parañaque City, Metro Manila	China	Fujian Hanyun Trade Co., Ltd
				Fujian Xixiong Import & Export Co., Ltd
				Guangzhou Top Shipping Company Ltd
				Shanghai Exchange Trade Co., Ltd
				Shanghai Haoji International Trade Co., Ltd
				Shanghai Jingwei International Trade Co., Ltd
				Shanghai Liu Yang Trade Co., Ltd
				Shanghai Xiongxing Import and Export Co., Ltd
				Shanghai YueRun Import & Export Co., Ltd
				Xiamen CL Pilot Import & Export Co., Ltd
				Xiamen Hengsheng Import and Export Co., Ltd
				Xiamen Chonglun New Energy Co., Ltd
				Xiamen Runze Trading Co., Ltd
				Xiamen Suntown Trade Co., Ltd
				Xiamen Xinghu Import and Export Co., Ltd
				Xiamen Yongbai Imp. & Exp. Co., Ltd
				Xiamen Yuanren Import and Export Co., Ltd
				Xiamen Yuhao Trading Company Limited

Annex B. Continued.

No.	Company Name	Address	Country	Consignee
3	Golden Harvest Seafood	Parañaque City, Metro Manila	China	Shanghai Haoji International Co., Ltd Shanghai Rong Zhu Import & Export Co., Ltd Shanghai Xiongxing Import and Export Co. Ltd Xiamen CL Pilot Import & Export Co., Ltd Xiamen Runze Trading Co., Ltd
4	Golden Ocean Marine Products	Parañaque City, Metro Manila	China	Fujian Richland Trading Co., Ltd Fujian Xixiong Import & Export Co., Ltd Guangzhou Rich Water Trading Co., Ltd Guangzhou Top Shipping Company Ltd
5	Inter Marine Center	Parañaque City, Metro Manila	China	Shanghai Xiongxing Import and Export Co., Ltd Xiamen CL Pilot Import & Export Co., Ltd Xiamen Runze Trading Co., Ltd Beijing Yi Cheng Xun Teng Trade Development Co. Ltd

No.	Company Name	Address	Country	Consignee
6	Isla Aquamarine Resources	Parañaque City, Metro Manila	China	Fuzhou Lin Dehui Import & Export Trade Co. Ltd Shanghai Xiongxing Import and Export Co., Ltd Xiamen CL Pilot Import & Export Co., Ltd Shanghai Rich Group International Trade Co., Ltd
7	Jamesrie Aquamarine Products	Parañaque City, Metro Manila	China	Shanghai Shengfu Int'l Trade Co., Ltd Shanghai Xiongxing Import and Export Co., Ltd Shanghai Xiongxing Import and Export Co. Ltd
8	Kohav Marine Products Trading	Parañaque City, Metro Manila	China	Xiamen CL Pilot Import & Export Co., Ltd Xiamen Changkun Great Cause Imp. & Exp. Co., Ltd Guangzhou Top Shipping Company Ltd Shanghai Haoji International Trade Co., Ltd
9	Ocean Treasures Marine Trading	Parañaque City, Metro Manila	China	Shanghai Jingwei International Trade Co., Ltd Shanghai Xiongxing Import and Export Co. Ltd Xiamen CL Pilot Import & Export Co., Ltd Beijing Yi Cheng Xun Teng Trade Development Co. Ltd Guangzhou Top Shipping Company Ltd

Annex B. Continued.

No.	Company Name	Address	Country	Consignee
10	Purple Ocean Trading	Parañaque City, Metro Manila	China	Shanghai Xiongxing Import and Export Co. Ltd Xiamen CL Pilot Import & Export Co., Ltd Xiamen Hengsheng Import and Export Co., Ltd
11	Sealamp Marine Products Trading	Parañaque City, Metro Manila	Palau	HP Myrsil General Merchandise Beijing Yi Cheng Xun Teng Trade Development Co. Ltd
12	The Quality Prime Ocean Products Trading Inc.	Parañaque City, Metro Manila	China	Guangzhou shun yuan zheng Network Technology Co., Ltd Guangzhou Top Shipping Company Ltd
13	Wang-Wang Marine Products Trading Inc.	Parañaque City, Metro Manila	China	Xiamen Runze Trading Co., Ltd
14	X3 Marine Products	Parañaque City, Metro Manila	China	Beijing Yi Cheng Xun Teng Trade Development Co. Ltd Beijing Yi Cheng Xun Teng Trade Development Co. Ltd
15	Xinhe Seafood Enterprises	Parañaque City, Metro Manila	China	Shanghai Xiongxing Import and Export Co. Ltd Xiamen Runze Trading Co., Ltd

No.	Company Name	Address	Country	Consignee
16	Yeung Marine Products	Parañaque City, Metro Manila	China	Beijing Yi Cheng Xun Teng Trade Development Co. Ltd Guangzhou shun yuan zheng Network Technology Co., Ltd Guangzhou Yun Yun Feng Trading Co., Ltd Xiamen Xinghu Imp. & Exp. Co., Ltd

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