Seychelles Mariculture Master Plan

Aquaculture Fact Sheet

Mud Crab

Scylla serrata

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By Advance Africa Management Services

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1. Background

Common Names

Mud crab; Giant mud crab	*English*
Crabe de palétuviers	*French*

Biology and ecology

The giant mud crab *Scylla serrata* is a crustacean of the Portunidae (swimming crabs) family. There are four mud crab species in the genus *Scylla*, of which *S. serrata* is the only species native to the western Indian Ocean (Keenan *et al*. 1998). It has a natural Indo-West Pacific distribution, from the south and east coast of Africa including South Africa and the Red Sea, to the central Pacific Ocean islands of Tahiti and French Polynesia, and latitudinally from Japan to the Sydney Australia (

Figure 1) (Heasman *et al*., 1985; Shelley and Lovatelli, 2011; Alberts-Hubatsch *et al*., 2016). It also occurs in Hawaii as an introduced species (Alberts-Hubatsch *et al*., 2016). The species generally occurs at depths of 0 to 50m, and inhabits sheltered coastal habitats, intertidal flats and estuaries, and has a strong mangrove-association (Hill *et al*., 1982; Overton *et al*., 1997; Ng, 1998; FAO, 2019a).

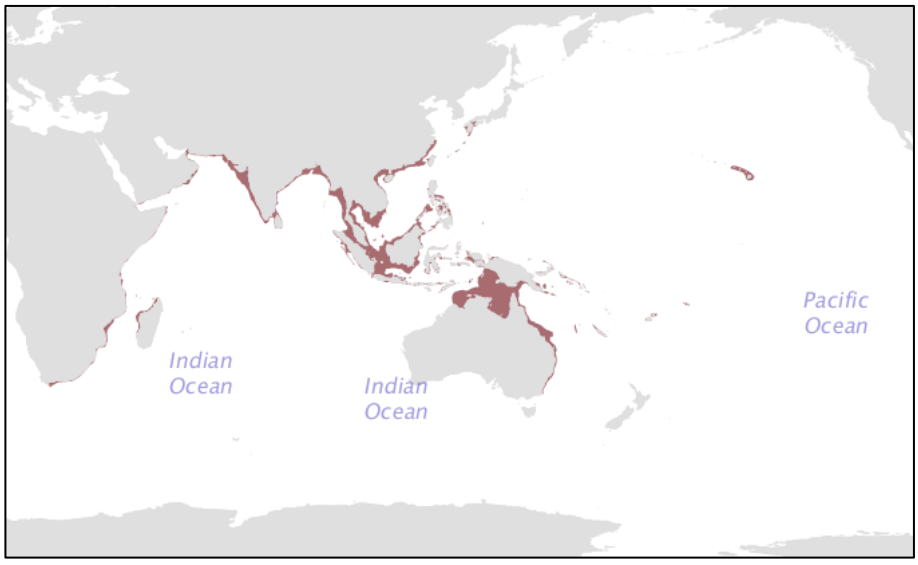

Figure 1: Natural distribution of mud crab *S. serrata* (Source: FAO, 2019b).

The body of *S. serrata* consists of a hard, smooth carapace, dark green or brown to black in colour with an H-shaped groove, a pair of front claws (chelae), and four pairs of walking legs, the pack pair of which is flattened for swimming (pleopods) (Figure 2) (Shelley and Lovatelli, 2011; FAO, 2019b). The two chelae differ in function and appearance; the right-hand claw is larger and is used for crushing the shells of prey such as crustaceans and molluscs, and the left-hand claw is for cutting through food (Figure 2) (Fielder and Heasman, 1978; Shelley and Lovatelli, 2011). The walking legs can be lost, e.g. through fighting with other mud crabs, but can be regenerated with moulting (Shelley and Lovatelli, 2011).

S. serrata reaches a maximum size of 280mm carapace width (CW), with a maximum recorded weight of 3kg (Ng, 1998). They reach sexual maturity at 90 to 110mm CW, at an age of 18 to 24 months (Shelley and Lovatelli, 2011). Sexes can be distinguished by the shape of the abdomen on the underside of the carapace; mature females' abdomens are rounded while those of males are V-shaped (Figure 3). Additionally, from 140 to 160mm CW, the crushing claw of males becomes larger and more developed than that of females (Shelley and Lovatelli, 2011). The crabs' hard outer

shell (exoskeleton) does not grow. Crabs grow in stanzas by moulting, which is triggered by hormones. Prior to moulting, the crabs secrete enzymes which separate the old shell from the skin, and a new cuticle is secreted under the shell. The crab draws in water under the new cuticle which expands it, and causes the old shell to split open along suture lines, and it leaves the hard exoskeleton. At this point the crab is soft-shelled, and the outer cuticle begins to harden. Crabs do not feed from up to 14 days prior to moulting, and begin feeding 2 to 4 days after moulting when the mouthparts have hardened (Du Plessis, 1971; Alberts-Hubatsch *et al*., 2016).

Figure 2: Mud crab *S. serrata* (Source: SEAFDEC).

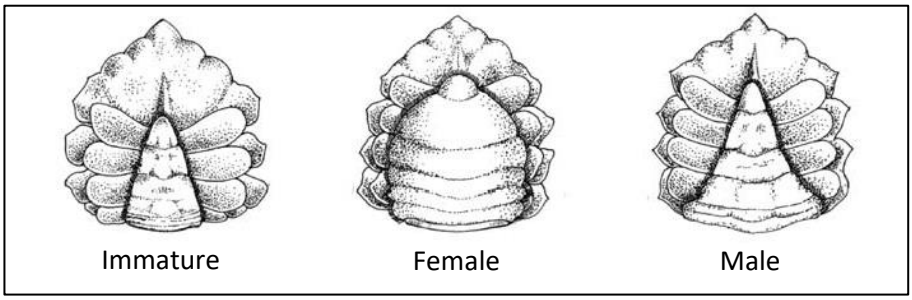

Figure 3: Abdomen structure of immature, female and male mud crabs (Source: SEAFDEC).

S. serrata is nocturnal, with feeding and mating activities occurring at night (FAO, 2019b). During the day, larger adults (from 110mm CW) burrow into the soft muddy sediment of mangrove and estuarine habitats (Hill *et al*., 1982; FAO, 2019b). Subadults and juveniles (60 to 110mm CW) seek shelter under structure such as rocks, seagrass and mangrove roots, and also move into subtidal areas at low tide (Shelley and Lovatelli, 2011; Mirera, 2017; FAO, 2019b). *S. serrata* is omnivorous and opportunistic; smaller juveniles consume mainly detritus, while the diet of larger juveniles and adults (>80mm CW) includes invertebrates, fish and plant materials (Alberts-Hubatsch *et al*., 2016; FAO, 2019b). Feeding occurs within estuarine systems, in the intertidal zone, on reef flats and in seagrass beds (Demopoulos *et al*., 2008; Shelley and Lovatelli, 2011).

Mud crabs form mating pairs up to four days prior to females moulting. The male crab carries the female until she moults, at which point he releases her. After she has become soft-shelled, mating occurs and lasts 7 to 18 hours. The male remains with the female to protect her until her shell has hardened (Heasman *et al*., 1985; Shelley and Lovatelli, 2011). Females retain sperm and eggs become fertilised when they are mature. The female is able to fertilise eggs at least once more at subsequent egg maturations without mating (Brick, 1974; Raviv *et al*., 2008; Alberts-Hubatsch *et al*., 2016). Following fertilisation, females undertake a spawning migration. They can travel as far as 95km offshore to waters of up to 60m depth, and spawn eggs on a sandy substrate (Hill, 1994; Alberts-Hubatsch *et al*., 2016). Following spawning, the female collects the eggs into an egg mass (‘sponge’) attached to her abdomen. After the planktonic

larval stages, the offspring settle as crablets, and about one month after spawning, juveniles recruit back to brackish water habitats such as estuaries (Shelley and Lovatelli, 2011). Spawning in *S. serrata* can occur year-round in tropical and subtropical areas, and occurs seasonally in warmer months at higher latitudes, with peak spawning differing among regions (Du Plessis 1971; Hill 1975; Heasman, 1985; Alberts-Hubatsch *et al*., 2016).

Fisheries

Mud crab has high-quality meat and reaches large sizes, and is a highly regarded food product. Mud crab species are thus subject to heavy fishing pressure throughout their distributions (Ewel, 2008; Allan and Fielder, 2004; FAO, 2019a, b). Global catches of *S. serrata* have increased since the 1990s. The total reported 2016 catch of this species was 45 390 tonnes (Figure 4) (FAO, 2018, 2019b). The largest mud crab catches, including *S. serrata*, are taken by Indonesia and Thailand, together accounting for approximately 85% of recorded catches in 1999 (FAO, 2018).

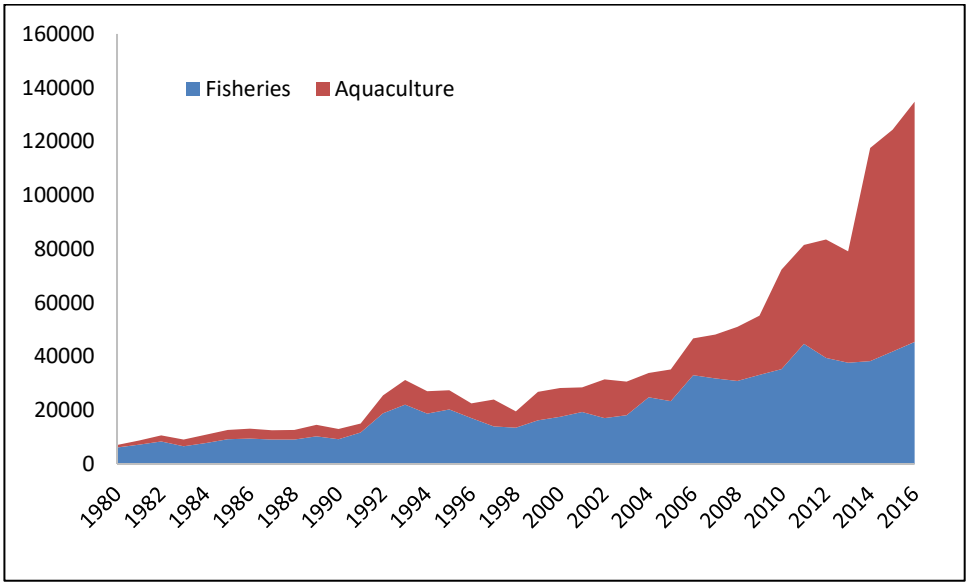

Figure 4: Global production of *S. serrata*, 1980 to 2016 (Source: FAO, 2018).

S. serrata is fished by industrial and artisanal fisheries in southeast Asia, Australia and east and southern Africa. Methods for harvesting this species include seine and trawl netting, baited and unbaited traps, baited mesh pots, hooking, and catching by hand (Bonine *et al*., 2005; FAO, 2019b). In east Africa, *S. serrata* is harvested mainly by artisanal fishers using traditional capture methods such as hooks, sticks, traps, seine nets and digging (Muthiga, 1986; Mirera, 2011; Mirera and Moksnes, 2013; Moksnes *et al*., 2015).

Harvesting of mud crab is largely unregulated, with the exception of the Australian fisheries (Overton *et al*. 1997). Heavy and increasing fishing throughout the distribution of *S. serrata* has led to population declines and reduced catches throughout the tropical Indo-Pacific Ocean (Marichamy and Rajapackiam, 2001; Bonine *et al*. 2005; Mirera 2011), in east Africa, (Francis and Bryceson, 2001; Mahika *et al*., 2005; Mirera and Moksnes, 2013; Moksnes *et al*., 2015) and southeast Asia (Le Vay *et al*., 2007; Richmond *et al.* 2006; Walton *et al.* 2006; Ewel, 2008; Meynecke *et al*., 2013).

Aquaculture

Mud crab species have been farmed in southeast Asia and southern China since the 1970s, however recent increases in demand for mud crab products has led to expansion of the industry. In 2014, the global mud crab aquaculture production was 185 000 tonnes, with a value of USD 565 million. Since 2010, aquaculture production of *S. serrata* has exceeded that of fisheries production. In 2016, 89 390 tonnes of *S. serrata* were produced by aquaculture, 66% of total production (Figure 4) (FAO, 2018). Vietnam is the largest aquaculture producer of *S. serrata*; in 2016, Vietnam produced 59 633 tonnes (67% of total aquaculture production of the species) (Figure 5). Vietnam is followed by

Philippines and Indonesia, and smaller quantities are produced annually by countries including Sri Lanka, Cambodia, Singapore and Tanzania (FAO, 2018).

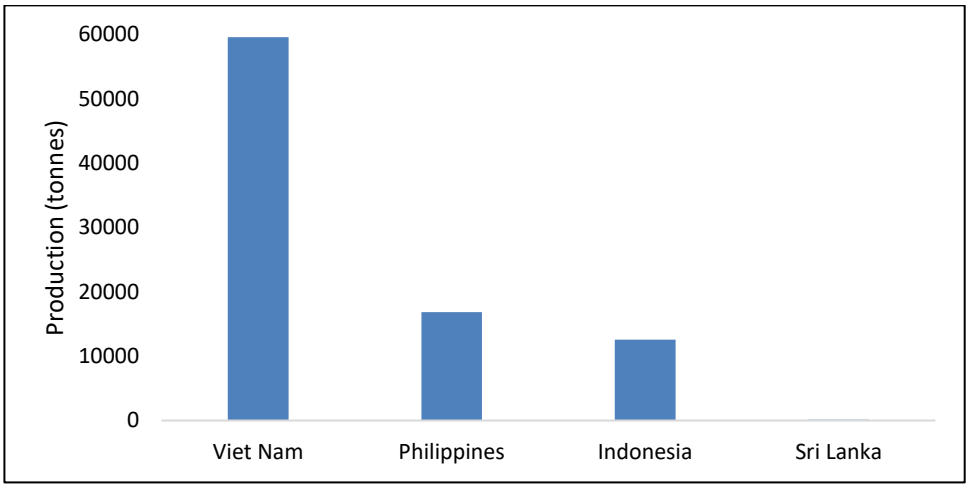

Figure 5: *S. serrata* 2016 aquaculture production per country (FAO, 2018).

Mud crab farming includes both fattening and grow-out practices. Fattening involves holding and feeding recently moulted crabs with low meat content for one to two months, to increase their meat content and achieve a higher market value. In grow-out systems, crabs are grown from juveniles, through a series of moults until they reach market size as either soft-shell or hard-shell crabs (Lindner, 2005). Traditionally, mud crab farming and fattening has been based largely on wild-caught juveniles or moulted (lean) adults (Shelley, 2008).

The growing demand for mud crab and the declining supply of wild caught crabs for grow-out led to hatchery development in China in the 1990s to produce juveniles for grow-out and fattening (Wang *et al*., 1994, 1998; Gui-Zhong *et al.*, 2005). Mud crab hatcheries operate in China, Vietnam, the Philippines and Australia, producing *S. serrata* and *S. paramamosain* for grow-out (Allan and Fielder, 2004; Lindner, 2005; Shelley, 2008; Shelley and Lovatelli, 2011; Moksnes *et al*., 2015). In 2016, there were 614 operational mud crab hatcheries in Vietnam producing juvenile crabs for farming. Hatchery-reared juveniles contribute significantly to the overall aquaculture production in China, Vietnam and Australia, however other countries such as the Philippines still rely mostly on wild-caught crabs (Shelley, 2008).

In Asia, mud crab are farmed in small- and large-scale operations, mostly in boxes in land-based ponds, and in bamboo enclosures (pens) in the intertidal zone (Figure 6) (Triño and Rodriguez, 2002; Keenan, 2003; Shelley, 2008; Shelley and Lovatelli, 2011; Moksnes *et al*., 2015). In east Africa, research into farming of *S. serrata* began in Kenya beginning in the late 1990s. Mud crab farming is practiced and developing in Kenya and Tanzania, and is based on fattening of wild-caught crabs in mangrove forest systems (Mirera, 2007; Shipton and Hecht, 2007; Moksnes *et al*., 2015). These operations mainly use small wooden boxes (30x30cm) intertidal zone of mangroves, holding one subadult (150-300g) mud crab per box, which are fed through a number of moults and fattened before harvesting at 500 to 1000g (Moksnes *et al*., 2015). The development of crab aquaculture has been initiated in Mauritius, Madagascar and Mozambique (Mirera, 2007, 2009, 2011; Shipton and Hecht, 2007). There are currently no mud crab hatcheries in east Africa and all farming relies on wild-caught juveniles or lean adults.

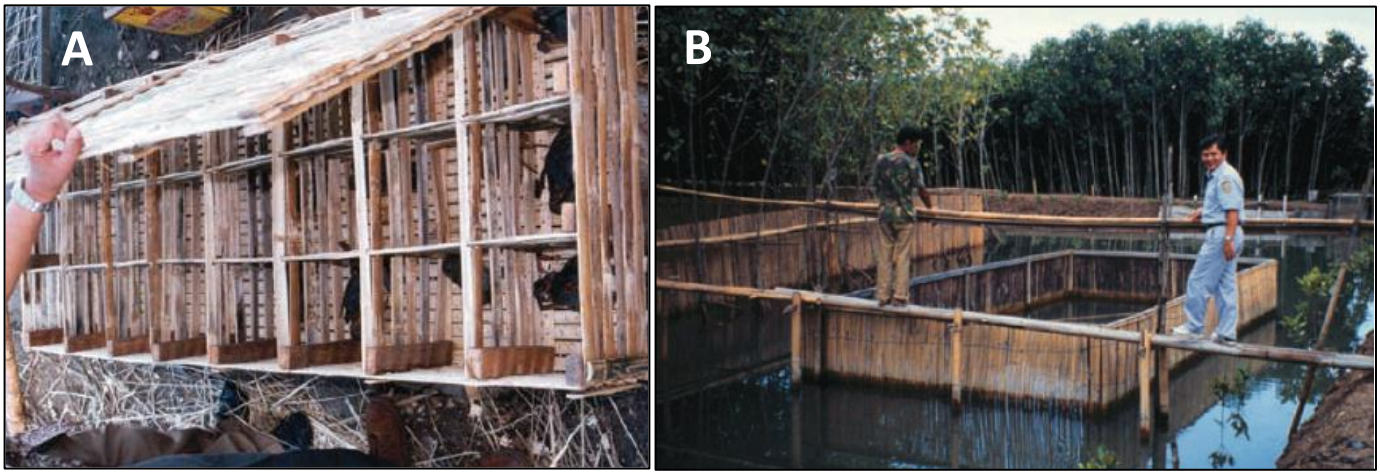

Figure 6: Mud crab fattening in A) Individual bamboo boxes in the Philippines; and B) Bamboo pens in Indonesia (Source: Shelley, 2008).

2. Technical approach to aquaculture production

Production cycle

Mud crab can be farmed entirely on land, in a combination of tank- and earthen pond-based systems (Figure 7). Adult mud crabs (broodstock) are captured from the wild and held in land-based tanks, where they spawn and produce eggs. After hatching, mud crab larvae are reared in tanks. Their nursery phase can be completed either in tanks, or in nets within ponds. Following the nursery phase, juvenile mud crabs are held in ponds until they reach grow-out size, and are transferred to cellular tank systems or larger ponds (Figure 7).

The land-based tank systems are typically a combination of pump-ashore Recirculating Aquaculture Systems (RAS) and flow through systems. The water that is pumped ashore is filtered before entering the tanks to remove pathogens and to provide optimal water quality for the crabs. Similarly, effluent water leaving the tanks is cleaned in accordance with the relevant Seychelles Aquaculture Standard and global best practice.

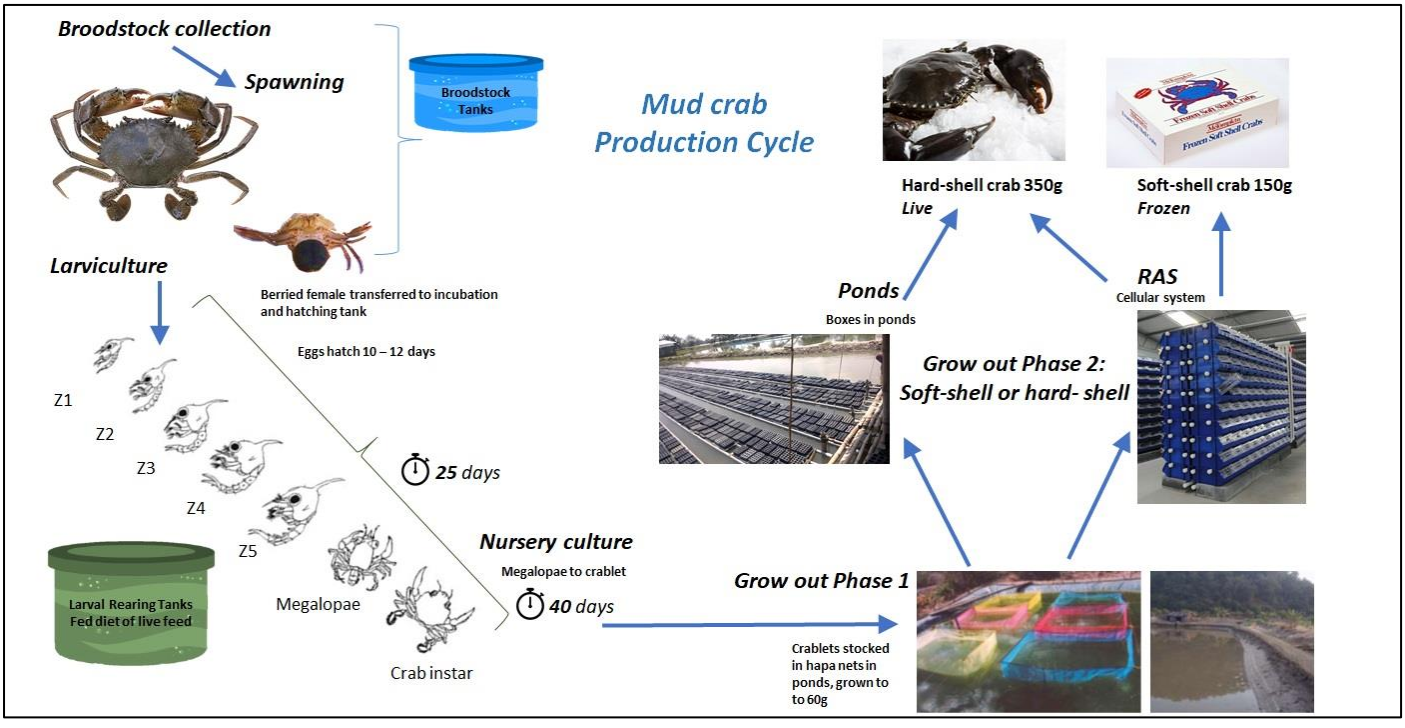

Figure 7: Production cycle of mud crabs.

Broodstock and spawning

Adult mud crab (broodstock) of 300 to 700g are collected from the wild and transferred to land-based facilities (Shelley and Lovatelli, 2011). They are inspected for parasites and injuries, and those that are healthy are used as broodstock. Broodstock crabs are first placed in quarantine tanks for two to three days, during which they receive regular baths in disinfectant, such as formalin or potassium permanganate (Lin *et al*., 1994; Gui-Zhong *et al*., 2005; Shelley and Lovatelli, 2011). They are then moved to holding tanks at densities of 1 to 5 crabs per m^2. Broodstock are fed up to three times per day with a diet high in protein and lipids, which can include bivalves, fish, squid, and pellet feed (Shelley and Lovatelli, 2011).

Mating takes place naturally in holding tanks. Mature females are likely to have already mated and may not need to mate in the tank to spawn fertilised eggs. Immature females mate in the tank when they moult to maturity (Shelley and Lovatelli, 2011). Females' ovaries are regularly assessed and those carrying fertilised eggs are moved to spawning tanks with a sandy bottom or sand tray for spawning of eggs (Figure 8A). The female mud crab digs a shallow depression in the sand, and extrudes the eggs which she attaches to her abdomen in an egg mass using her pleopods. The egg mass is originally orange and becomes black when it is close to hatching (Figure 8B) (Shelley and Lovatelli, 2011). Berried females carrying fertilised egg masses are transferred to small individual incubation tanks of 100 to 500L, and then to larger (400 to 1000L) individual hatching tanks. Females do not feed during incubation (Shelley and Lovatelli, 2011).

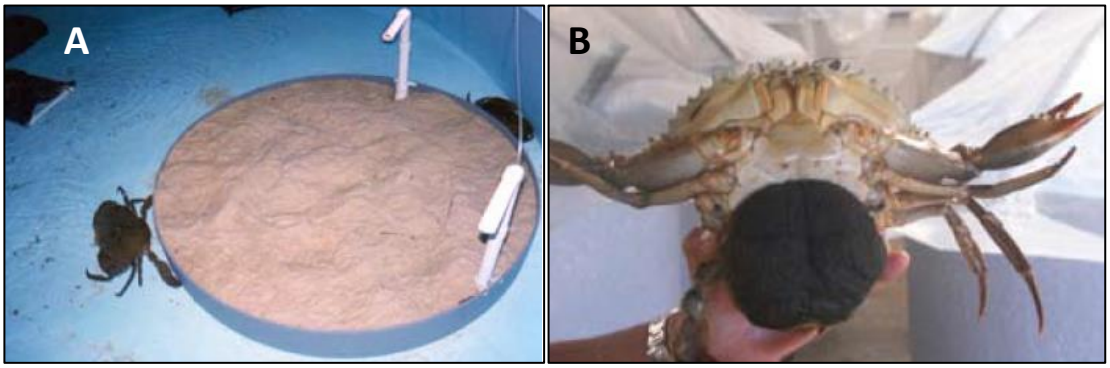

Figure 8: A) Spawning tank; and B) *S. serrata* black egg mass close to hatching (Source: Shelley and Lovatelli, 2011).

Larviculture and nursery phase

Mud crab eggs hatch 10 to 12 days after spawning, and planktonic larvae of Zoea phase 1 are transferred from hatching tanks to larval rearing tanks at a density of 30 to 200 per litre (Gui-Zhong *et al*., 2005; Shelley and Lovatelli, 2011). They can be attracted to the water surface using a light as they are phototactic in their first phase (attracted to light), and collected from the surface by scooping or siphoning (Shelley and Lovatelli, 2011). The larval phase lasts 22 to 35 days. Zoeal larvae go through five zoeal phases of 3 to 5 days each, and grow by moulting (Figure 9). After the fifth moult larvae become megalopa (Figure 9).

Megalopae are transferred to nursery facilities, where they settle and metamorphose into crab instars of 3 to 4mm in 7 to 10 days (Figure 9). The nursey phase can take place either in tanks, or within hapa nets of a land-based pond with a mesh size of 1mm at a stocking density of 50 to 70 megalopae per m^2, or in nursery tanks at a stocking density of 1 to 50 per m^2 (Shelley and Lovatelli, 2011). Shelter habitats should be provided in tanks and cages to reduce cannibalism (Allan and Fielder, 2004). Crab instars moult and develop into crablets; after another 30 to 40 days crablets of around 250mm are transferred to grow-out facilities (Figure 10) (Blackshaw, 2001; Ganesh *et al*., 2015).

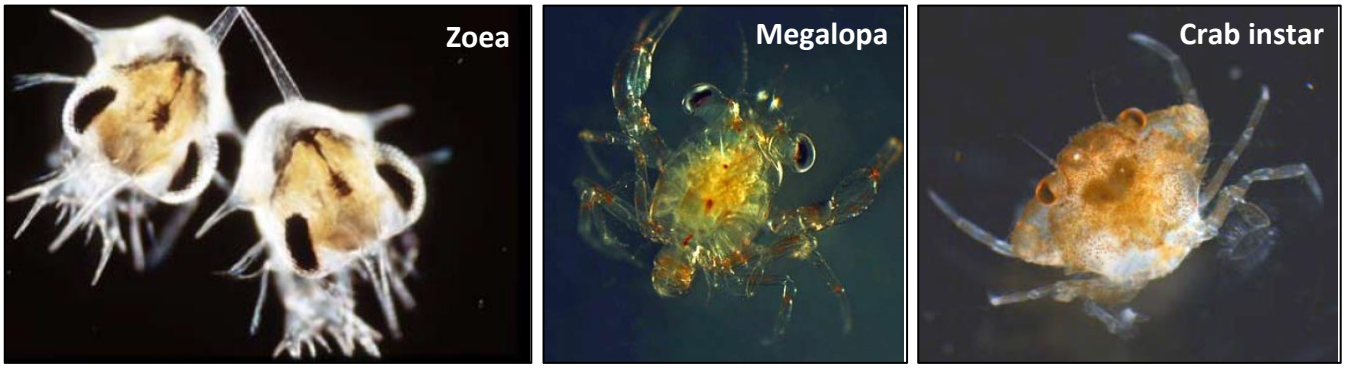

Figure 9: *S. serrata* zoea, megalopa and crab instar phases (Source: Shelley and Lovatelli, 2011).

During larval and nursery rearing of mud crabs, live feed, including rotifers, *Artemia* nauplii and microalgae are provided at overlapping intervals to meet the species' nutritional requirements (Gui-Zhong *et al*. 2005; Shelley *et al*., 2008). Artificial feed can also be used to feed mud crabs, which can be introduced during larval or crablet stage (Holme *et al*., 2009).

Figure 10: Hatchery-produced *S. serrata* crablets (Source: Shelley, 2008).

Grow-out

Crablets of around 25mm are transferred to land-based earthen ponds. Mud crabs can be grown in extensive earthen ponds to market size of >300mm, however this requires very low stocking densities (0.5 to 1.5 crabs per m^2) and thus large ponds, due to the high rates of cannibalism observed in this species (Lindner, 2005; Ganesh *et al*., 2015). They can therefore be grown initially in ponds to a size of 60 to 80g, following which they are harvested and transferred to more intensive systems for grow-out, with crabs stocked into individual boxes. This can be done either within earthen ponds (Figure 11), or in RAS or flow-through tanks systems (Figure 12) (Shelley and Lovatelli, 2011; Paterson and Mann, 2011; Ganesh *et al*., 2015).

Crabs in individual boxes are fed daily with fish, molluscs and/or artificial feed. Boxes are cleared daily of any uneaten feed, waste, debris and moulted shell (Shelley and Lovatelli, 2011). Crabs can be grown-out to market size either as soft- or hard-shell crabs. Soft-shell crabs are held for one to two months and harvested at a size if 150 to 250g within one hour of moulting, and immediately frozen before their shells begin to harden (Shelley and Lovatelli, 2011; Paterson and Mann, 2011; Ganesh *et al*., 2015). Tank systems are generally better suited to the harvesting of soft-shell crabs due to the relative ease of assessing cells. Hard-shell crabs are harvested after four to five months at a size of 300g or larger, and are generally fattened prior to harvesting; recently moulted crabs will not be harvested, but held and fed for one to two months to ensure they have a high meat content (Shelley and Lovatelli, 2011; Paterson and Mann, 2011; Ganesh *et al*., 2015; Moksnes *et al*., 2015). Hard-shell crabs are marketed live; they are removed from cages, claws are tied and they are kept moist and cool during transport to arrive fresh and live at markets (Shelley and Lovatelli, 2011).

Figure 11: Intensive grow-out within a pond system

Figure 12: Example of RAS or flow-through cellular system for intensive grow-out of mud crabs (Source: EWG-RAS; Shelley and Lovatelli, 2011).

Mud crabs in grow-out systems are fed largely on a diet of fish, generally obtained as offal from fisheries or low-value species from markets (Shelley and Lovatelli, 2011). Natural feeds can also be supplemented with formulated feed, consisting of both plant and meat material (Ali *et al.*, 2011; Genodepa and Failaman, 2016). In east African fattening operations, the mangrove snail (*Terebralia pallustris*) forms the main component of crabs' diet, together with low value fish (Moksnes *et al*., 2015).

Crab health

Mud crabs are relatively tolerant of culture conditions and are less prone to disease and infections than many other aquaculture species (Lindner, 2005). Infections such as 'milky disease' caused by a parasitic dinoflagellate, *Hematodinium*, have however been recorded in mud crabs in culture environments (Xu *et al*., 2007; Li *et al*., 2008; Xie *et al.*, 2009).

It is important to provide clean and hygienic hatchery and nursery environments, to prevent diseases, infections and parasites in hatchery-reared mud crabs. Maintaining optimal conditions, such as stocking densities, water quality and environmental parameters (e.g. water quality, salinity) in tanks and ponds can reduce stress and susceptibility to infections and disease (Shelley and Lovatelli, 2011). Disinfection of ponds prior to stocking, for example using quicklime, reduces the likelihood of infections in pond systems (Shelley and Lovatelli, 2011).

Prophylactic treatments can be used during the larval stage to reduce the risk of bacterial and fungal infections within the hatchery and later in grow-out facilities. Parasites and infections within the hatchery can also be largely treated using water treatments, such as formalin baths (Shelley and Lovatelli, 2011).

3. Market for mud crab products

Mud crabs are highly regarded for their meat taste and quality, and supply domestic and export markets throughout their distribution. *S. serrata* has the highest export price of the four mud crab species, due to its large size and meat quality (Quinitio *et al*., 2001; Triño and Rodriguez, 2002; Naylor *et al*., 2002; Lindner, 2005). The global market demand for mud crabs in Asia and elsewhere is increasing, which has led to increased production in southeast Asia and east Africa (Agbayani, 2001; ACDI/VOCA, 2005; Shipton and Hecht, 2007; Mirera, 2011; Moksnes et al., 2015; Mirera, 2017).

Mud crab are marketed in a number of different product forms. Soft-shell crabs (Figure 13), of 150 to 250g, have the highest value per kilogram of mud crab products. There is a global demand for soft-shell crab, with the largest markets in Asia (including Hong Kong, Signapore, Japan and China), Europe and the USA (Lwin, 2018; Norad, 2016). Hard-shell crabs are marketed mostly live (Figure 14), with the largest markets in China, the USA, Japan, South Korea and Thailand (Istiak, 2018). Crabs are graded after harvesting, and the highest quality crabs, those that are full of meat and have both chelae intact, have the highest value and supply export markets (Shelley and Lovatelli, 2011; Moksnes *et al*., 2015). Lower quality crabs (e.g. with missing chelae) can be used for other products such as frozen crabmeat (Shelley and Lovatelli, 2011). Different markets favour different sized whole crabs. In southeast Asia, mud crabs of 150 to 400g are most popular, in Europe, mud crabs of 300g are preferred, and in east Africa, mud crabs ranging from 250g to 1kg are sold in local markets in Tanzania, Kenya, and Mozambique (Richmond *et al*., 2006; Moksnes *et al*., 2015) and the preferred size of soft-shell crabs in Kenya is 250g.

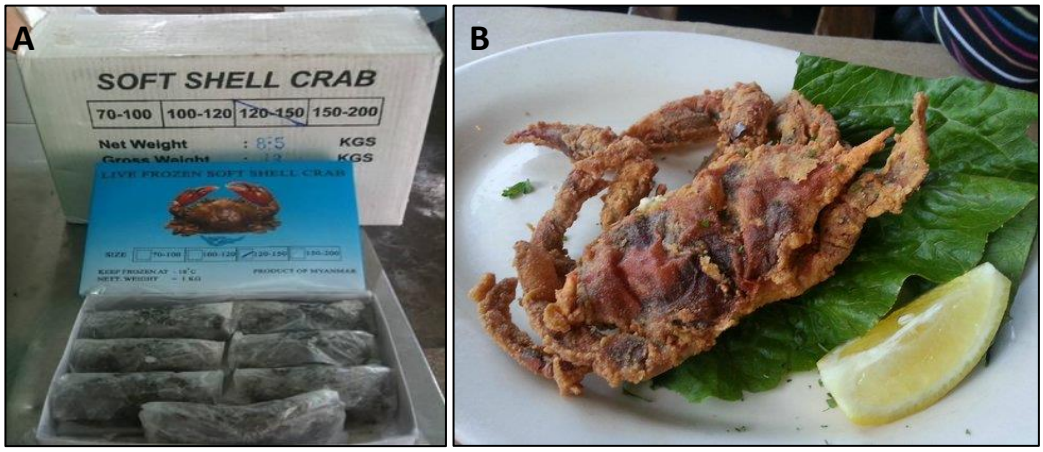

Figure 13: A) Frozen; and B) Prepared soft-shell mud crab (Source: Alibaba; Mud City Crab House).

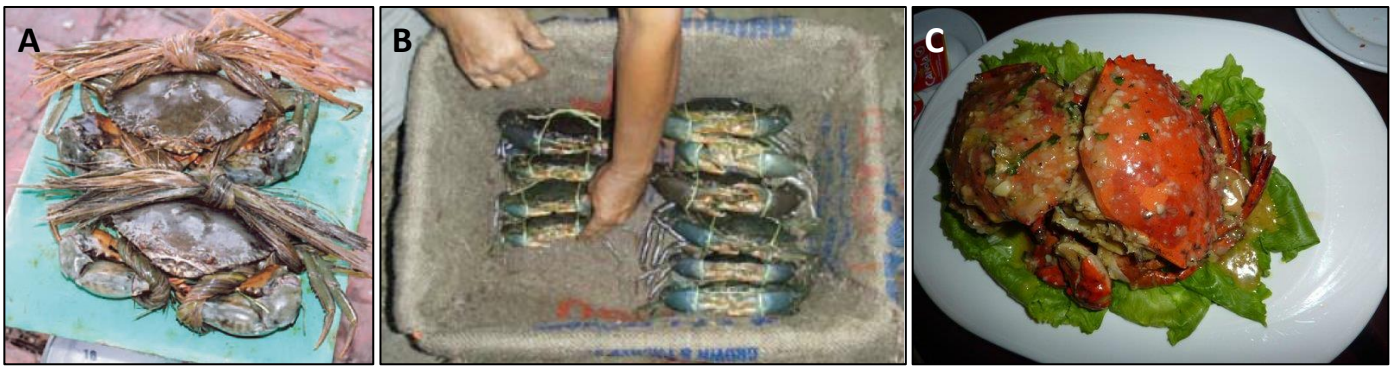

Figure 14: A) Live crabs for sale in Vietnam; B) Packing of live crabs for transport to markets; and C) Prepared hard-shell mud crab (Source: Shelley, 2008; Shelley and Lovatelli, 2011; Le Meridien Kota Kinabalu).

In Kenya and Tanzania, mud crab is economically important on the domestic, tourist and export markets (Mirera, 2011). The species has traditionally supported subsistence fisheries and local markets; however, its popularity among tourists to the region is growing and mud crab production is increasingly supplying tourism in hotels and restaurants (Overton *et al*., 1997; Barnes *et al*., 2002; Bonine *et al*., 2005; Mirera, 2011). There is also a small export market for mud crab produced in Kenya, Tanzania, Madagascar and Mauritius which is facilitated mostly through middlemen

(Moksnes *et al*., 2015). In 2017 and 2018, fresh live crab products (unspecified species) were imported by the USA from Mozambique and Kenya at a value of USD 12 to 30 per kg (NOAA, 2018).

The tourist demand for live hard-shelled crabs in east Africa is growing, and the global market for soft-shell crabs is increasing. This growing demand cannot be met by wild-caught fisheries, which provides an opportunity for aquaculture production of mud crabs to supply these markets (Lindner, 2005).

4. Suitability for aquaculture in Seychelles

The species

Mud crab is indigenous to Seychelles and broodstock can be obtained from local waters for use in aquaculture facilities. *S. serrata* has a high meat quality, and there is a growing global demand for soft- and hard-shell crabs for domestic and international markets.

Environmental and oceanographic conditions

The environmental conditions of Seychelles waters, such as temperature and salinity, are ideally suited to mud crab growth and survival. Hatchery, nursery and grow-out facilities in tank- and pond-based systems can thus be developed in Seychelles.

Access to markets

Seychelles' level of transport infrastructure and location in the middle of the western Indian Ocean makes it ideal for aquaculture production; It has access to markets in Europe, the USA, Africa and Asia, via air and sea transport, and is able to receive imports of supplies, such as feed and technical equipment, from high-quality suppliers around the world. It also has access to local markets as products can be transported within and between islands.

Soft-shell crabs can be frozen and transported to export markets. Live crabs can remain out of water for four to five days, as long as they are kept in suitable cool and moist condition (Keenan, 2003; Shelley and Lovatelli, 2011; Moksnes *et al*., 2015). This allows for ease of transport of live hard-shelled crabs to domestic and export markets.

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