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Biology and conservation of the genus *Scylla* in India subcontinent

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Abstract

Mud crabs usually inhabit brackish water bodies of South-East Asia including India. The biological significance of the species is its survibility in wide range of hydro-biological fluctuating environments including salinity. The life cycle of the species includes two important larval stages at which they are vulnerable to various predators. Pathophysiological status of the species is a challenge for its aquaculture. Inspite of a huge economical and high food values, informations on biochemical, molecular, physiological, ecological and taxonomical aspects of mud crabs (*Scylla* sp.) in comparison to other important aquaculture candidates are very limited. The present review is an attempt to string together various informations available on mud crabs (*S. serrata*) so that it will provide a platform to have all the basic informations regarding the species for interested workers. It is believed that understanding the pathology, ecophysiology, genetics and reproduction of the species in its natural environment will not only help in its conservation but also will help in its enhanced production.

Key words

Ecophysiology, Life cycle, Conservation, Aquaculture, *Scylla* sp.

Introduction

The mud crab *Scylla* sp. is an important commercial species which demands attention as a potential candidate for aquaculture (Kathirvel *et al*., 2004; Ruscoe *et al*., 2004; Mohanty *et al*., 2006) with an average annual landing of > 24,000 tones in Indo-Pacific zones (Anon, 2005). Mud crabs are cosmopolitan in distribution and have exploited every aquatic niche thereby considerably contribute to the food web in its habitat. The species also draws attention to researchers as an excellent animal model for the study of stress tolerance and attenuation of physiological homoeostasis with respect to environmental stress (Chen and Chia, 1996a; Hai *et al*., 1998; Hamasaki, 2003; Paital and Chainy, 2010). Despite its high importance, information on its taxonomy, biochemistry and ecophysiology in its natural environment are scantily studied hitherto, particularly in India. Therefore, in the present review, an attempt is made to string various basic informations available on mud crabs in one platform. The aggregated informations may help to make strategies for its conservation which in turn may contribute for its better culture and production.

Research on crabs was started in India since mid twentieth century and basically was related to the systematic of the species. All total 55 species of crabs were described in India under 30 genera. Overtone (1997) documented about the distribution of *Scylla* species in Indo-Pacific regions. Srinivasgam *et al*. (2000) and Kathirvel *et al*. (2004) reported the presence of only two species i.e. *S. serrata* and *S. tranquebarica* in Indian water bodies. Works on growth of the crab *Scylla* sp. related to eye stalk ablation, sexual maturity and hatchery management was initiated by Babu and Manjulatha (1993). The work was lead to the level of physiological study of the crabs for the proteolytic activity analysis of seminal plasma of *Scylla* sp. by Jayasankar and Subramoniam (1997). Bhavanishankar and Subramoniam (1998) developed the procedure for cryopreservation of the crab *S. serrata* spermatozoa. Rao *et al*. (2005) studied the physiological response of metallothonein in *S. serrata* to cadmium exposure. Mohapatra *et al*. (2005) investigated the food and feeding habit of *S. serrata* and *S. tranquebarica* at Chilika lagoon of Odisha. Vijayavel *et al*. (2004 and 2006) studied the physiological role of naphthalene on the oxidative metabolism of the mud crab *S. serrata* and *S. tranquebarica*

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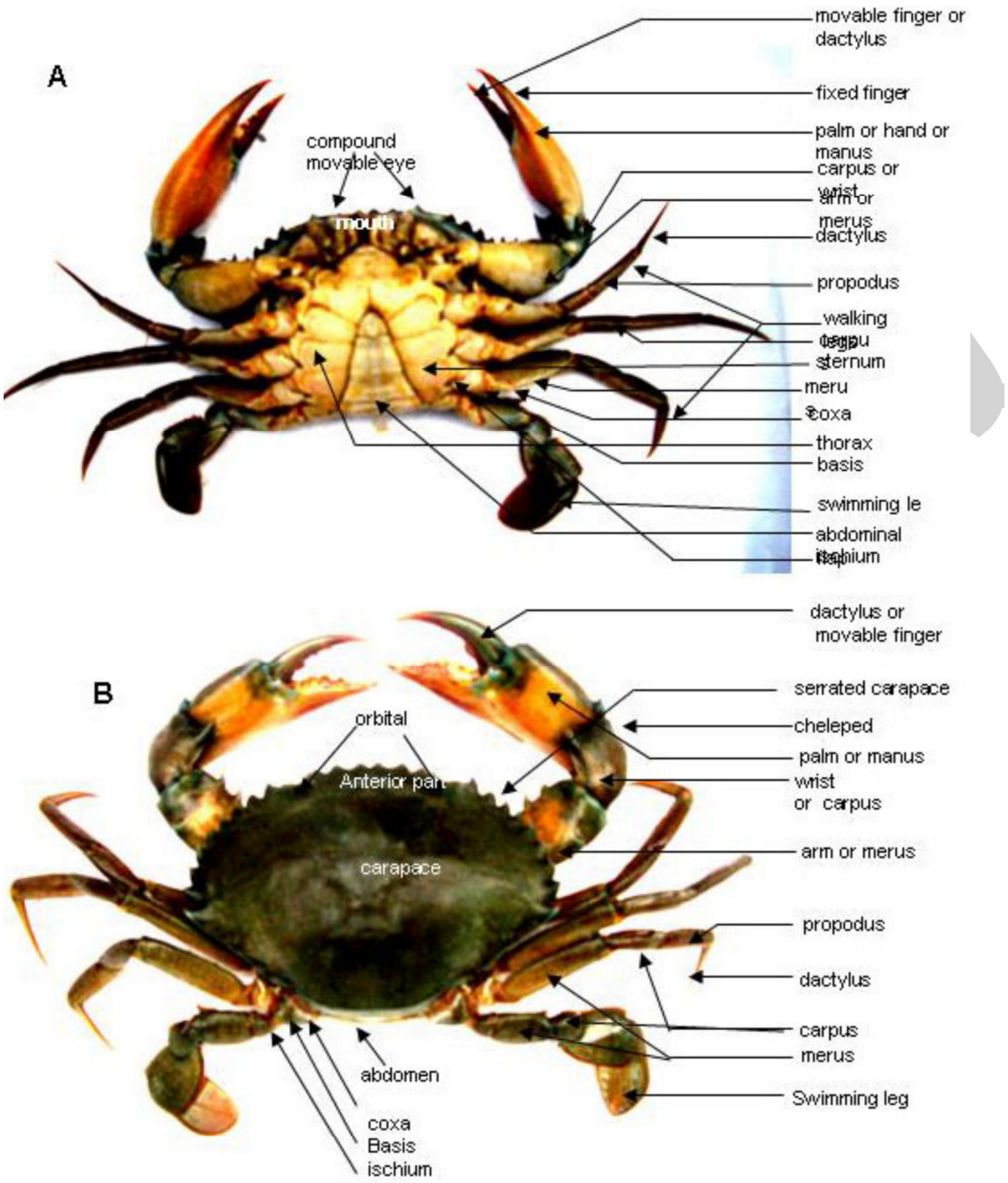

Fig. 1: *Scylla serrata* (A) Ventral view showing abdominal flap and different body parts, (B) Dorsal view showing carapace and legs

in Tamilnadu. Mohanty *et al*. (2006) described the occurrence of the above two species of *Scylla* in Chilika lagoon of Odisha. Recently, we have reported on the ecophysiology of the crab *S. serrata* related to oxidative damage and antioxidant defences with respect to altered salinity conditions (Paital and Chainy, 2010). The Central Institute of Brackish Water Aquaculture (CIBA), Chennai has made an attempt on the culture and breeding of the mud crabs *S. serrata* and *S. tranquebarica* at laboratory conditions and its application in field culture. Mohapatra *et al.* (2010) established a relationship among the carapace width, body weight and gonado-somatic index for the mud crab *S. serrata.* All the above literatures described basically on the characterization, distribution, taxonomy and a little on physiology of mud crabs. So, it seems that very poor attention has been paid on the crabs in general and mud crabs in particular in India.

General informations: Mud crabs are commonly called as mangrove crabs, Indo-west pacific salmon crabs, serrated swimming crabs, edible mud crabs etc. The genus *Scylla* has four species namely *serrata, tranquebarica, oceanica* and *paramamosain*. Although genus *Scylla* has four identified species (Keenan *et al*., 1998; Imai *et al*., 2004), their proper identification is still unclear. In

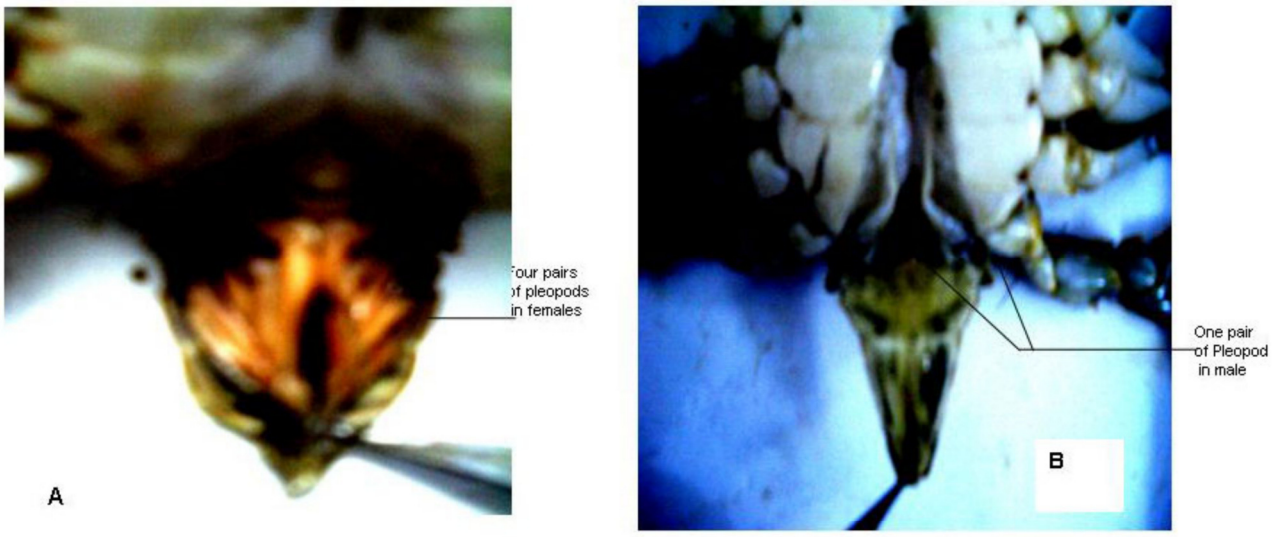

Fig. 2: Differences in pleopod numbers in abdominal flap of male and female. (A) four pairs of pleopods in female, (B) one pair of pleopods in male

India, only two species namely, *S. serrata* and *S. tranquebarica* deserve attention with ambiguity in their identification. Gopikrishna and Shekhar (2003) had shown differences between two Indian *Scylla* species collected from Pulicat lake of Chennai by analyzing restriction digestion product of 16s and 12s rRNA. However, the fact has to be confirmed from other locations. Mohanty *et al*. (2006) distinguished the above two species of *Scylla* collected from Chilika lagoon of Odisha basing on morphological parameters. Several attempts were made to solve the above problem using various morphological criteria (Overtone, 1997; Keenan *et al*., 1998; Fushimi and Watanabe, 1999; Srinivasagam *et al*., 2000; Kathirvel, *et al*., 2004). A few attempts were also made using molecular (Fuseya and Watenabe, 1996; Imai *et al*., 2002; Imai and Numachi, 2002; Imai *et al*., 2004) and biochemical techniques (Keenan *et al*., 1998) to identify the crabs. However, Imai *et al*. (2004) classified *Scylla* sp. collected from various parts of the globe by using molecular markers like ITS-1 and 16S rDNA. Such molecular attempts may be more useful in identifying the four species.

The body of *Scylla* sp. is broad, transverse and some what convex at its carapace with even surface. The carapace is formed with fused tergites and serrated anteriorly with six teeth and anterolaterally with nine teeth in each side. The species bears each one pair of antennae, antennules and stalked eyes in the anterior side. The body is divisible into three parts namely cephalic, thoracic and abdominal region. Mouth is positioned at mid anterocephalic region with well distinct mouth parts like mandible and maxillae etc. The podal appendages constitute of a pair of strong chelipeds anteroventrally with movable fingers called dactylus, three pairs of walking legs mid ventrally and posteroventrally a pair of appendages with pedal like modification. The chelipeds in mud crabs along with the middle three pairs of legs are used for walking as well as for burrowing. The last pair of pedal like legs are used for swimming (Fig. 1). Thorax of the mud crabs is divided into six segments. The abdominal flap covers the thorax ventrally. The mature males have the triangular abdominal flap where as it is more flattened at the base as well as at the middle in case of females. Abdominal flap in both the sexes has soft and flattened structures called pleopods, which have fine cilial divisions through out the edges. The male mud crab contains only two pairs of abdominal pleopods instead of four pairs in female (Fig. 2). Biologically, the broad abdominal flap with more numbers of pleopod in females is an advantage to bear the eggs till their hatching (Fig. 2, 3).

Several workers (Srinivasagam *et al*., 2000; Mohanty *et al*., 2006) are of the opinion that *S. tranquebarica* is comparatively larger than *S. serrata*. *S. oceanica* with 2.5 kg body weight and 20 cm carapace width and *S. serrata* with 0.9 kg body weight and 18 cm carapace width were reported from Taiwan (Oshiro, 1991). In India, *S. tranquebarica* with 2.8 kg body weight and 24 cm carapace width and *S. serrata* with 0.83 kg body weight and 18.1 cm carapace width were recorded (Mohanty *et al*., 2006).

Mud crabs are distributed in Indo-pacific regions, South Africa, Indonesia, Philippines, Taiwan, Japan, China, east and west cost of Australia, Western Samoa, Salmon Island, Fiji, New Caledonia, Malaysia and Singapore (Roy and Das, 2000; Roy and Bhadra, 2005).

Ecology: Since, mud crabs prefer brackish water habitat, they migrate from high salinity to estuarine or brackish water bodies during their post larval or juvenile stages (Srinivasagam *et al*., 2000). Tagging, telemetric and ultrasonic transmitter studies and laboratory experiments have clearly demonstrated the anadromous behavior of mud crabs in relation to habitat selection (Webley *et al.,* 2009). Muddy bottoms of mangrove forest with fluctuating salinity are preferred by *S. serrata* (Vay, 2001). Oshiro (1991) reported that *S. serrata* prefers marshy mangroves at Okinawa where as *S. oceanica* prefers high salinity in addition to sandy muddy bottoms of seaward water at Taiwan and Philippines. However, the habitat preference of *S. tranquebarica* is intermediate of the two habitats

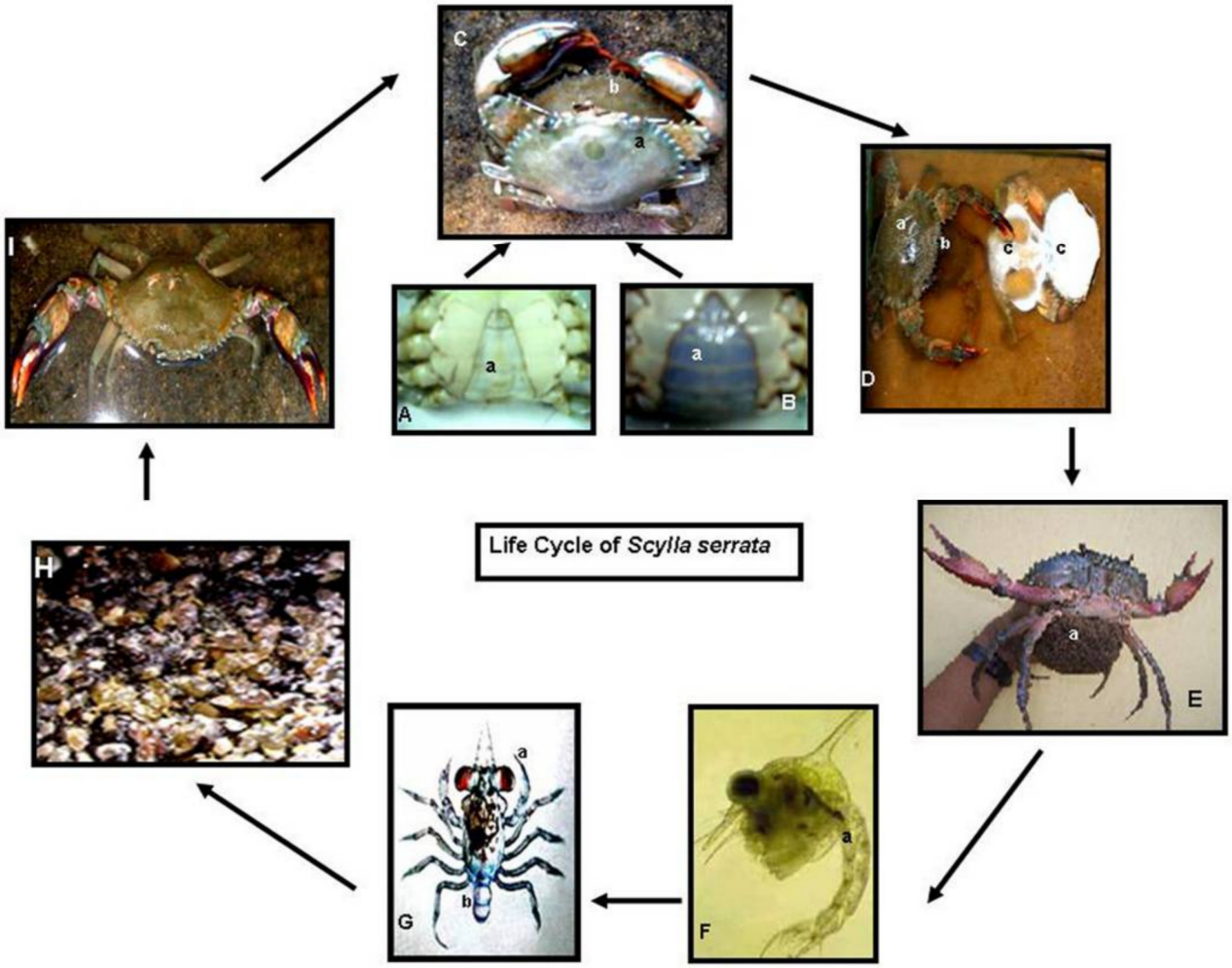

Fig. 3: Reproduction in the crab *Scylla serrata*. (A) male mud crab (a- triangular abdominal flap), (B) female mud crab (a- flattened abdominal flap), (C) Coupling in mud crab (a- male mud crab climbs over female, b- female mud crab), (D) After false coupling, female crab molts after which true coupling takes place (a-male helps in removing the shell of molted females and protect the soft female crab from predation and autobalism, b- molted female crab, c- old exoskeleton of molted female), (E) Ovigerous female (a-millions of eggs in the abdomen of female), (F) hatching of eggs into first larval form *i.e*. zoea (a-tail of zoea which helps in movement), (G) megalopa, the second larval stage of mud crab (a- pre-developed cheleped, b- rudimentary tail which develops into abdominal flap), (H) first instar crab (crablets), (I) adult crab

preferred by *S. serrata* and *S. tranquebarica*. A recent study showed that habitat selection differs with respect to life cycle stages in mud crabs. Megalopa larvae of *Scylla* sp. prefer a structurally complex habitat rich with refuge and food. But crablets of *S. serrata* strongly prefer seagrass habitats (Webley *et al*., 2009). The nature of substratum for benthic life in estuaries in Indian coast for *Scylla* sp. varies from sandy to sandy muddy or totally muddy with wide fluctuating hydro-biological factors. The environmental factors for *Scylla* in India may vary with a wide range of temperature (18- 31 ^{o}C), salinity (1 - 33 ppt), alkalinity (70 to 119 mg l^{-1}) and from a highly reduced environment to over saturated dissolved oxygen (4-10 mg l^{-1}) content (Mohapatra *et al*., 2007b; Panigrahi *et al*., 2007).

Analysis of the undigested gut content of mud crabs in India reveals the presence of remaining of molluscs, crustaceans, fishes and plant materials (Kathirvel *et al*., 2004; Mohapatra *et al*., 2005). Mud crabs are fond of molluscan diets like *Perna viridis* and also choose fish and crustaceans as their potential food source. Rotifers and *Nauplii* are identified as the preferable feeds for *Scylla* larvae. Supply of immobilized states of the above two types of feeds enhances the larval growth in *S. serrata* (Davis *et al*., 2005). The survival of mud crab larvae is also affected by essential fatty acid contents of their diet (Suprayudi *et al*., 2004). However, Holme *et al*. (2007) experimented on crab feed management and indicated that corn oil may be replaced partially (1:1 ratio) at the level of 6% of the total dry weight of diet to get maximal development, growth and survival of the crab *S. serrata*. Mud crabs are mostly nocturnal feeder (Ghosh *et al*., 2003). It is reported that the capture of crabs during day time is only about one tenth of the total crab landing using fish bet (Mohapatra *et al*., 2004-05). Therefore, nocturnal feeding is suggested for the culture of mud crabs.

Hiding behavior of mud crab juveniles under aquatic plants and plant remaining in the daytime in lower depth water bodies are well known. Mud crabs are also known for their burrowing behavior. Habitat selection behavior of crablets of *Scylla* sp. in structurally complex habitation than simple and transparent niche is reported (Webley *et al*., 2009). However, these crabs are not zone specific in their habitat because they can change habitats with a walking speed of 219 to 910 m in one night. During copulation, the copulating male helps the female to molt and cast the shell and also protects the molted female (Fig. 3). Autobalism during food scarcity and during molting is observed in this species.

Salinity plays a vital role in regulating the physiology of marine organisms (Lesser, 2006). High salinity (35 ppt) induces oxidative damage to proteins and lipids in the crab *S. serrata* with an alternation of antioxidant molecules. Nevertheless, it was not genotoxic in *S. serrata* as no change in DNA unwinding was observed (Paital and Chainy, 2010, 2012a, b). The excretion in *S. serrata* shifts from ammonotelism to ureotelism with increased salinity (Chen and Chia, 1996a, b). On the other hand, an elevation of ammonia excretion and decrease in oxygen up take and carbon dioxide release was noticed with increased salinity from 10 to 35 ppt (Paital and Chainy, 2010).

Temperature along with salinity are found to have more influence on the metabolism of *Scylla* sp. Ruscoe *et al*. (2004) proposed that limiting the rotifer supply as staple food to *Scylla* zoea larvae at salinity 10 to 35 ppt and temperature 30°C produces a maximal survibility and production. Such experimental confirmation in megalopa and early crablets of *S. serrata* are required for the aquaculture of the crabs. The crab *S. serrata* experiences oxidative stress (Kong *et al*., 2005, 2007) and different tissue mitochondrial count (Wang *et al*., 2007) in response to cold stress. Kong *et al*. (2008) reported that the seasonal factors like high temperature with a prevalent low salinity in tropical climate can damage both proteins and lipids in gill tissues of mud crabs in summer season.

Pollutant like naphthalene, a fumigant, induces oxidative stress in *S. tranquebarica* in its natural environment (Vijayavel *et al*., 2006). It also causes reproductive dysfunction by altering vetellogenesis in *S. serrata* (Vijayavel and Balasubramanian, 2008). It has been reported that retention time and a slow rate of elimination of the pharmacological compounds like enrofloxacin and ciprofloxacin are high in hepatopancreas of *S. serrata* (Fang *et al*., 2007). *S. serrata* has been shown to protect it self from cadmium toxicity by enhancing the level of stress resistance metal protein such as metallothionein (Rao *et al*., 2005). Recently Oosterom *et al.* (2010) reported that GST enzyme of *S. serrata* can be used as biomarkers for pollution impact assessment. Although crustaceans are much prone to physiological disorder on their exposure to radiations (Mukherjee *et al.,* 2010), the fact is still to be confirmed in mud crabs.

Crustaceans like crabs may become susceptible to various stresses when they passed over the threshold value of above environmental factors (Manduzio *et al*., 2005; Lesser, 2006). Therefore, *S. serrata* are rightly known for its wide range of environment stress tolerance and attenuation of physiological homoeostasis particularly with respect to changing salinity (Hai *et al*., 1998) and temperature (Hill, 1974; Chen and Chia, 1996a,b; Hamasaki, 2003).

Reproduction and life cycle: It is reported that though mud crabs are marine in origin, they are euryhyaline and migrate in post larval or juvenile stages to brackish water bodies where they grow and attain adult hood (Srinivasagam *et al*., 2000; Webley *et al*., 2009). It indicates existence of certain correlation between the marine and estuarine environmental osmotic, thermal and other hydrobilogical factors and life cycle particularly on the larval and early adulthood stages of mud crabs. Because the ecobiological along with pathophysiological status of mud crabs may influence the life cycle and growth of *Scylla* sp. in both natural as well as in cultured conditions (Babu and Manjulatha, 1993; Mwaluma, 2002; Manjulatha, 2003; Davis *et al*., 2005; Weng *et al*., 2007; Webley *et al*., 2009).

The breeding in *Scylla* sp. is strictly species specific. Copulation in mud crabs takes around 2-3 days. In the first step, the male climbs dorsally over the female and clasps and carry her with his cheliped for a period of 3 to 4 days until the female under goes molting (Fig. 3C). The male then helps the female to shed her shell and then again climbs her ventrally for true mating. The copulation continues for 7 to 12 hr or even for days after which the transfer of non-motile spermatozoa passed into the female seminal receptacle. The act of sperm transfer longs for 5 to 7 hr (Bhavanishankar and Subramoniam, 1998). The male can show polygamy with one to two days interval. Similarly, one female also can copulate with two males and receives the sperm from the both. However, in such case, the spermatozoa deposited by the second crab are only utilized by the female for fertilization (Srinivasagam *et al*., 2000). The sperm in female seminal receptacle can survive up to 9 to 12 months with repetitive extrusion of eggs in 2 to 3 batches at laboratory condition (Chen, 1976; Srinivasagam *et al*., 2000). Fertilization is internal in *Scylla* and females bearing about 1 to 5 millions of eggs (Fig. 3E) migrate to shoreline in order to hatch (Srinivasagam *et al*., 2000; Hill, 1996). The spawning in *S. serrata* is highly influenced by environmental factors (Hill, 1996). The eggs are hatched after fertilization and undergo development through only two larval stages *i.e.* zoea and megalopa (Fig. 3 F, G). It is very difficult to distinguish the two larval stages in naked eye and the species and sex specific larvae of mud crabs though microscopic study. Nevertheless, Srinivasagam *et al.* (2000) documented very nicely the microscopic distinction between the larval stages of *Scylla* sp. (Table 1).

Reports about the growth of the mud crabs in nature are very poor. However, it is species specific (Vay, 2001). The growth of adult mud crabs is reported to be enhanced by supplementing essential fatty acids in their diets (Suprayudi *et al.,* 2004). Age is also an important factor to contribute to the growth of mud crabs in nature. The growth of S. *tranquebarica* from 8 to 12 cm and 14 to 15 cm in first and second years, respectively, is reported. *S. oceanica*

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Table - 1: Identification of larval stages of *Scylla* species (Srinivasagam *et al*., 2000)

Larval stage	Identifying porphological characters
Zoea I	Sessile eyes with 5 abdominal segments, telson spine (3+3)
Zoea II	Stalked eye with telson spine (4+4)
Zoea III	Six abdominal segments
Zoea IV	Rudiments of thoracic appendages with beards of pleopods in abdominal segments
Zoea V	Conspicuous thoracic appendages, pleopods in abdominal segments with setae, telson spine (5+5)
Megalopa	Carapace longer than width, five pairs of pleopods in abdomen, a pair of cheleped and four pairs of legs
First instar crab	Carapace with 9-anterolateral tooth on side, three pairs of walking legs, modifications of last pair of legs, like a paddle for swimming

can grow about 2 to 9 cm in carapace width in first year. But all *Scylla* sp. almost attains the maximum growth within one to two years of their hatching in their natural habitats.

Attainability of maturation for reproduction in case of mud crabs is species and sex specific. In general, carapace width is used as an index of maturity in mud crabs. The size at which the *Scylla* species get matured is well depicted in Table 2. However, the attainability of maturity may vary as a function of geographic location (Vay, 2001). In Australia, mud crabs attain physiological maturity at carapace width from 9 to 11 cm (Knunkey, 1996). Similarly, in South Africa, the maturity is reported to be at an average of 9.2 cm carapace width (Robertson and Krugar, 1994). In Chilika lagoon of India, the first maturity in female *S. tranquebarica* and *S. serrata* were observed to be 12.1 and 7.9 cm of carapace width, respectively (Mohanty *et al*., 2006). The carapace width as an index of maturity also corresponds to the anatomical maturation of the reproductive organs of mud crabs (Table 3).

Table - 2: Carapace width as an index of maturation stage in *Scylla* sp. (Srinivasagam *et al*., 2000)

Species	Sex	Carapace width at first maturation (cm)
S. tranquebarica	Male	12.50 - 13.30
	Female	12.90 - 13.50
S. serrata	Male	8.00 - 8.90
	Female	8.50 - 9.60

Several reports support to the perennial breeding activity of mud crabs. In Rasimi river of Kenya, spawning in *S. serrata* is reported to be through out the year with a possible peak after June (Dorcus, 2002). In South Africa, a similar report was obtained by Davis *et al.* (2004) in the same species *S. serrata* with a peak at late winter or at early spring. In Kabira bay of Ishigaki island, the high and low peak of spawning in *S. serrata* was observed in May to June and October to November, respectively. In Chilika lagoon of India, *S. serrata* juveniles were observed through out the year and in case of *S. tranquebarica,* the juveniles were observed with a peak in May to September. However, the breeding in *S. serrata* was reported to occur from August to November and in *S. tranquebarica* it was from March to June in the lagoon (Mohanty *et al*., 2006).

Induced breeding in these crabs has given a new status to crab fisheries in the world. In India, Central Institute of Brackish water Aquaculture (CIBA), Chennai has taken the primary step to breed the crabs in laboratory condition in order to avail the crab seeds on commercial basis. In CIBA, it has been performed by unilateral eye stalk ablation (ESA) method. Unilateral or bilateral ESA in mud crabs stops the source of hyperglycemic hormone (HGH) responsible for metabolic regulation. ESA also stops the secretion of molt inhibiting hormone (MIH) in the female crab which leads to easier molting followed by copulation and subsequent breeding. ESA in mud crabs increases food intake, faster growth of ovary in female irrespective of their developmental stage or season. As a result, this does not help only in significant gain in weight in the female but also helps in increase in oocyte and advancement of extrusion of eggs. At a time a single female can produce millions of eggs in laboratory (~ 4 millions in *S. tranquebarica,* ~ 1.3 millions in *S. serrata*), thereby increasing a new stratum in fisheries seed markets.

Literature regarding survivability of *Scylla* sp. after their hatching in nature is very scanty. However, Hill (1975) described about 41-60% of natural mortality of *S. serrata* in their natural environment. In laboratory conditions, Srinivasagam *et al*. (2000) reported hatching of about 90% of the berried crabs constitutes

Table - 3: Identification of matured gonads in mud crabs (Srinivasagam *et al*., 2000)

Reproductive organ	Status	Identifying characters
Testis	Immature	Transparent or creamy color, occupies 1/6th of body cavity without prominent vas difference.
	Maturing	Creamy white in color and occupies 1/4th of body cavity.
	Matured	Milky white with thick vas difference occupying full body cavity
Ovary	Immature	Transparent or yellowish color, occupies 1/6th of body cavity without prominent seminal receptacle
	Maturing	Pink color occupies 1/3rd of body cavity.
	Matured	Orange red with prominent seminal receptacle occupying full body cavity

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pre-zoeal stages. In such cases, the susceptibility to mortality increases. The zoea larvae are positive photo tactic in nature. Therefore, most of the times they are predated by surface feeders. However, once achieved the adult hood, they can defends predators by their strong chelepeds.

It is noteworthy to mention that the fishery and aquaculture of mud crabs gained an outstanding fishery resource in India (Roy and Das, 2000; Ghosh *et al*., 2003; Kathirvel *et al*., 2004; Roy and Bhadra, 2005; Mohanty *et al*., 2006). Both *S. serrata* and *S. tranquebarica* have both nutritional as well as medicinal values (Gangal and Magar, 1967; Srinivasagam *et al*., 2000). Investigations have revealed that crab meat is rich source of protein with low fats (Table 4). Presence of essential elements and free amino acids has also been identified in crab meat (Chiou and Huang, 2003; Mohapatra *et al.,* 2007a and 2009). But primarily the international market value of mud crabs is due to their delicious meat. Due to the above reasons, mud crabs have a high export value, which

Table - 4: Biochemical compositions of crab meat (% wet wt.)

Composition	Male	Female
Protein	17.69	19.39
Fat	0.59	0.61
Moister	85	79
Ash	2.2	2.5

contribute to the economy of the country not only in India but also in most of the countries like Taiwan, Philippines, China, Bangladesh, etc. Apart from the above economic values, biologically crabs in general, also influence the ecosystem in many ways. Mud crabs in particular act as burrower as a result it helps in aeration, mixing and nutrient flow in soil. This in turn increases the soil fertility which facilitates the survival of other plants and soil dwelling animals. Moreover, bioturbation structure created by the crabs significantly helps in trapping sediments and mangrove seeds (Chaudhury and Choudhury, 1994) in the ecosystems, thereby, contributing significantly in mangrove plant conservation. One of the important role of crabs particularly in mangrove environments is production of millions of meroplanktonic larvae, which serve as potential food source for a large number of planktophagus organisms including rich number of edible fishes. On the other hand, it stabilizes the complex food web in the mangrove ecosystem. Inspite of their multiple significance for environment, fisheries and human consumption, a very poor attention has been paid on crabs particularly on the *Scylla* sp. in India.

In Australia, a dinoflagellet, *Himatodinium* sp. found to infect the hemolymph and tissues of the crabs causing the hymolymph to clot leading to death of the crabs. The bitter crab disease also common in Alaska, which is caused by the above dinoflagellates. White spot syndrome is a viral threat to mud crabs in which white patches appears on its shell. However, the crabs can survive up to one month after the injection or oral administration of the isolated above viral strain (Rajendran *et al*., 1999). Therefore, the *Scylla* sp. can resist the white spot syndrome viruses up to certain extent and can act as a carrier of this strain to its own type and other crustaceans (Supamattaya *et al*., 1998). The major preliminary indicators of the infected crabs are inactiveness, migration to shore or lotic regions and quivering movements. Similarly the rust spots, a bacterial disease occurs in carapace of the mud crabs reduces their economic value (Andersen *et al*., 2000). This is an important disease in mud crabs because it contributes to the mechanical damage of the carapace. The damage may cause due to the oclastic activities of chitin by bacteria and fungi. In this case, environmental factors like high nutrient load and low dissolved oxygen which is more prevalent in high salinity condition increases the susceptibility of the bacterial infection in mud crabs. It indicates that high salinity (>25 ppt) is not suitable for crab culture which increases vulnerability to infection. In contrast, Li *et al*. (2008) reported that infection of mud crabs by *Himatodium* sp. can occur at < 9 ppt salinity in China. However, prolonged infection gradually causes complete cuticular ulceration in the crabs. Lesions on the carapace, rust sport of the endocuticle below the cavity, remains of muscle attachment are the histological indicators of rust spot diseases. Frequently reduced survival occurs due to shell-potted, milk crab, black-gill, shell-fouled by algae and leg-quivered etc. in crab culture. Similarly, a reovirus (mud crab reovirus) has also been reported to be associated with the large scale loss of economic productivity of *Scylla* sp. in Southern China (Weng *et al*., 2007). From the above discussion it is clear that both the two viral infection to the crabs *Scylla* are epidemic and must be taken care immediately after their first occurrence in culture conditions.

It is noteworthy to mention that the mud crabs have a great commercial value in international market due to their delicacy. The female with mature ovaries are quite expensive having $ 6.30 to $ 7.8 per kg in Malaysia (Aldon and Dagoon, 1997). *Scylla* sp. accounts for an annual landing of > 24,000 tones (Sivasubramaniam and Angell, 1992; Anon, 2005). In addition, mud crabs serve as scavengers by consuming dead and decaying plant and animal bodies, act as intermediate hosts in the life cycle of some organisms, perform the role to increase soil aeration and fertility and forms a stable trophic level in marine as well as brackish water food web. Besides, studies on their ecophysiology and pathology, their race maintenance or live stock increment in the form of conservations are seem to be highly necessary in the developing countries like India. Steps for their conservation strategies may add to their better lively stock enhancement in their natural habitat.

Biotechnological approaches of *Scylla*: Boey *et al*. (2009a, b) demonstrated that the waste carapace of *S. serrata* can be used as catalyst in palm olein transesterification and biodiesel production. Similarly, structural changes in sperm acrosome of *S. serrata* are proposed to be used as biomarkers against heavy metal toxicity (Zhang *et al.,* 2010). Alkaline phosphatase enzyme can also be used as biomarker for arsenic toxicity as opined by Saha *et al.* (2009) in Sunderbans of India. The application of the mud crabs in relation to human consumption and environmental studies alarms

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about their conservation. Various appreciable steps like culture of mud crabs and crab fattening were undertaken by several organizations through out the world. At Chilika lagoon of India, Chilika Development Authority in collaboration with UNDP has also taken valuable steps for stock enhancement of mud crabs. Crab fattening and subside to farmers for mud crab cultures are few substantial examples. In this regard, certain other points may be taken into consideration for the conservation of the mud crabs such as establishment of both national and local research centers to study their pathophysiology, ecophysiology, predation of juveniles and moulted crabs, protection of gravid females, induced breeding etc. Steps such as subsides for crab culture and awareness programs for farmers about crab fattening, restriction of over fishing and fishing of immature crabs, proper handling of the infectious crabs etc. may be taken at Government level to conserve this economic species.

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