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Full Length Research Paper

The status of mangrove mud crab fishery in Kenya, East Africa

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Mangrove mud crabs, *Scylla* sp. are among crustaceans of commercial value along the Kenyan coast and in many mangrove areas in the Western Indian Ocean region. In Kenya the crabs are landed by artisanal fishermen. Rising population in the coastal areas and high demand for the crabs has led to increased pressure on the crabs. The population structure and maturity stages of *Scylla serrata* from Ngomeni - Fundisa area of Malindi were investigated from July 2005 to July 2006. The size of crabs caught ranged from 50 to 125 mm carapace length, with crabs of 75 mm carapace length dominating. Male crabs dominated in the captured population. Linear relationships were obtained for both female and male crabs for the Carapace length - Carapace width. The size at first maturity was at 75 and 70 mm carapace length for male and female crabs respectively. There is an indication of exploitation pressure on the population and to ensure sustainable management, regulation on the minimum size of the crabs to be caught is recommended.

Key words: Malindi, mangroves, maturity stages, mud crab, population structure, *Scylla serrata.*

INTRODUCTION

Along the Kenyan coast, minimum commercial fishery is done in the deep sea. The bulk of marine fishery in Kenya is landed by artisanal fishermen who fish in the inshore areas. The mangrove areas along the Kenyan coast encourage crab fisheries. Mangrove mud crabs are among crustaceans of commercial value that utilize mangrove areas as a critical habitat during their life cycle and as adults, feed on benthic invertebrates living in the mangroves (Hill, 1975). The families of brachyuran crabs in Kenya include: Xanthidae, Cancaridae, Portunidae, Majidae, Ocypodidae, Grapsidae, Gecarcinidae and Potamonidae. The edible Portunid crabs found along the Kenyan coast are *S serrata, Thalamita crenata* and *Portunus pelagicus*. *S. serrata* is the only species from the genus *Scylla*, reported to occur in Kenya (Richmond, 1997). In Kenya, *S. serrata* because of its big size is the only crab fished for commercial purposes due to its big size while *P. pelagicus* is eaten locally. The areas with high crab landings along the Kenyan coast are Lamu, Kwale, Malindi and Kilifi districts and crabs are caught throughout the year. The total crab landings in Kenya between 1984 and 1997 ranged from 50 to 130 tonnes (Fisheries Department, 1997).

In Malindi district, mud crabs are caught by fishermen using traditional methods. The catch in this area supplies the tourist hotels and resorts in Malindi town (Fondo, 2007). Two main methods of crab fishing are commonly used by the local fishermen in Malindi area. The first method is using baited lines attached to sticks that are placed on the banks of the water channels. The bait is usually a fish cut in to pieces, tied to a stone, and is placed in the water. The crab on locating the bait will hold onto it using its chelae and in the process pull the line and cause the stick at the bank to shake. The fisherman then moves to catch the crab using a scoop net. The second method is using a 2 m long hooked pole. The fishermen identify crab burrows (which usually extend

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between the roots of mangrove trees) and prod the burrows with the pole. If there is a crab in the hole, it will snap the rod using its chelae producing a sound. It is then thoroughly disturbed and sometime comes out by itself or is pulled out using the pole. The disadvantages of this method are that it is laborious involving walking within the mud; and during the capture process the chela and walking legs may be broken. Care needs to be taken by the fishermen for fingers not to be cut off as the crabs are usually ferocious. In both cases the crabs are caught in the channels along the mangroves.

Despite the ecological and economic importance of mud crabs, few studies on the population dynamics and sustainability of the crab fisheries have been done in the East African coast. In the Indian Ocean region, research work has been carried out on *S. serrata* with the general aim of culturing it (Marichamy and Rajapackiam, 1984; Mwaluma, 2002; Nurdiani and Zeng, 2007; Mirera and Mtila, 2009). Various aspects of life history of crabs have been studied including distribution, growth, feeding habits, and methods of capture, culture, reproduction and diseases (Kyomo, 1999; Davis et al., 2004; Ruscoe et al., 2004; Mann et al., 2007; Rodriguez et al., 2007; Quinitio et al., 2007; Barnes et al., 2007). *Scylla* is of great importance to the overall Indian Ocean fisheries and there is a need for research in its biology and reproduction for developing its aquaculture. Onyango (2002) determined the maturity stages and found a positive relationship between fecundity and carapace width and embryo mass weight; and that spawning occurred through out the year. Mutyagera (1981) reported that the crustacean fishery is the most profitable of the fishery activities off the East African coast. He observed that biological studies of the East Africa decapods of food value have been preliminary and require more attention. Muthiga (1986) also reported in preliminary investigations that crab resources are under - exploited; therefore research is needed to assess crab biology and ecology, relative abundance of stocks, methods and type of collecting gears, processing of crabs and marketing. With gradual increase in market demand of mud crab through the tourism industry and increasing coastal population, mud crab culture has the potential of developing as an alternative livelihood for people. In recent years, the demand for mud crab farming in Kenya has expanded (Mirera and Mtila, 2009). The aim of this study was to investigate the population structure and maturity stages of the mangrove mud crab *S. serrata* in Malindi district, northern coast of Kenya.

METHODOLOGY

Study site

The study was conducted in Ngomeni, Fundisa and Marereni areas of Malindi district north of Kenya coast (Figure 1). The study area, like many parts of the Kenyan coast experience tropical climate influenced by the monsoon winds in two distinct periods; the Northeast monsoon (NEM) from October to March and the Southeast monsoon (SEM) from April to September. Annual mean rainfall ranges from 508 to 1150 mm with long rains from March to July and short rains from October to December. Annual mean air temperatures range from 28 to 32ºC and the salinity ranges between 34 to 35.5 ppt.

The Ngomeni - Fundisa and Marereni areas where the crab fishing takes place, has fringe type mangroves, with known 8 species of mangroves., the dominant being Rhizophora mucronata and Avicennia marina (Ferguson, 1993). The average high tide is 2.96 m and the average low tide 0.71 m and the substrate is sandy – clay - loam to silty - clay loam (Yap and Landoy, 1986). Saltworks occupy the high ground, tidal swamps and flats areas of Ngomeni to Marereni, while in Ngomeni there is an old, non - operational shrimp farm. Crab fishing takes place in the channels and fringes of the mangrove areas.

Crab population structure

The population structure of the captured mud crab was determined by measuring the carapace length and width (mm) of individual crabs using Vernier caliper, from July 2005 to July 2006. The carapace length was measured from the centre point between the antennae and the bottom edge of the carapace. The carapace width was measured across the widest part of the carapace from the left to the right ninth lateral spines. The weights (grams) were taken using a top loading electronic weighing balance. This was done for crabs brought to the main market in Malindi, for five consecutive days in each month. The monthly size frequency distributions, carapace length and width relationship, length and weight relationship and sex ratios were analyzed using Excel. The length at first maturity that is the lengths at which 50% of the individuals are sexually mature was also determined.

Reproductive stages

The maturity stages of the crabs collected from the Malindi market were determined. The crabs were dissected and gonads examined. The four major stages of maturity were distinguished for female crabs based on the color of the ovary following Quin and Kojis (1987)

Stage 0 Immature/resting: Ovary is very thin and transparent.
Stage 1 Developing: Ovary is thin and creamy white
Stage 2 Well developed: Ovary is thick and yellow - orange
Stage 3 Ripe: Ovary is highly lobulated and orange to orange - red.

The maturity stages of male were determined following Kathirvel and Srinivasagam (1992).
Stage I Immature/resting: Testis is transparent to creamy; occupying <1/6th of body cavity.
Stage II Maturing: The testis is creamy white; occupying 1/4th of body cavity.
Stage III Mature: The testis is milky white with thick vas deferens; occupying full body cavity.

RESULTS

Crab fishery

Crabs are fished throughout the year in Malindi district. The crab landings from 2003 to 2005 are shown in Table 1. In general, the catch in Malindi Dictrict increased from 11,990 kg in 2003 to 14,476 kg in 2005.

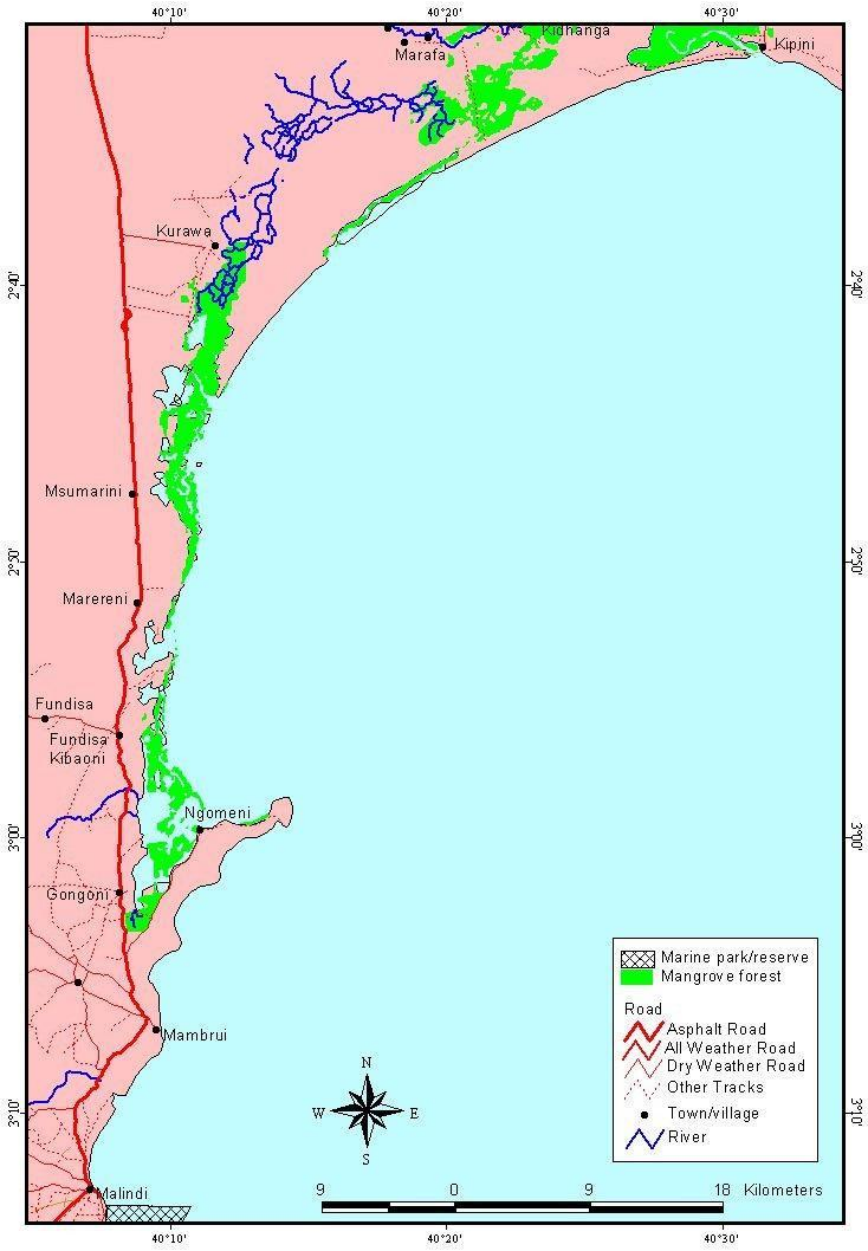

Figure 1. Map showing the study area.

Population structure

Figure 2 shows the size frequency distribution of the male and female crabs measured from Malindi market during the study period. The carapace length ranged from 50 to 125 mm, with a peak at 75 mm for male and 70 mm carapace length for female crabs. The trend shows that landed female crabs were smaller in size than the male crabs. The mean carapace length of female (81 mm) and male crabs (85 mm) were not significantly different (t - test, p = 0.021< 0.05). Crabs less than 50 mm carapace length were not in the catches. Male crabs dominated the catch by 60%.

Sex ratio in relation to size

Males dominated in number in all the size classes except from the 65 to 69 mm and 70 - 74 mm size classes (Table 2). There were no significant differences in the three size classes (50 - 54, 55 - 59 and 125 - 130 mm). The pooled chi -square showed a significant difference from the normal ratio of 1:1 (χ^2 = 70.6; p = < 0.05).

Morphometric relationships

The carapace length and width relationships for the male

Table 1. Crab landings from Malindi district (2003 - 2005). (Source: Fisheries Department, 2006).

	Crab landings (kg)		
Month/year	**2003**	**2004**	**2005**
January	1 710	960	1 102
February	830	1 900	1 770
March	530	1 260	1 522
April	700	700	1 750
May	750	540	1 720
June	850	350	1 497
July	1 610	1 310	1 368
August	1 170	1 520	-
September	760	1 656	667
October	700	1 036	1 850
November	1 350	1 345	320
December	1 030	-	910
Total	11 990	12 577	14 476

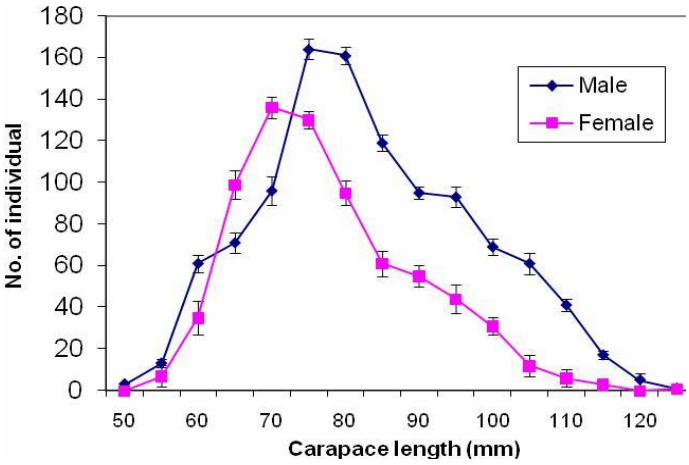

Figure 2. Size frequency distribution of male (n = 1070) and female (n = 715) Scylla serrata in Malindi district.

and female crabs obtained linear relationships with the following equations: W = 1.4637L + 1.0392 for female crabs and W = 1.4486L + 2.1106 for male, which both show significant relationship (r^2 = 0.9596 for females and r^2 = 0.9667 for males). The equations for carapace length - weight relationships for female and male crabs obtained were: W = 0.0029L 2.5863 and W = 0.0001L 3.3827 respectively.

Maturity stages

The maturity stages of the male crabs examined from October 2005 to July 2006 showed more immature or resting males (Stage I) than the later stages (Figure 3). For Stage I male crabs, there was a peak in October, gradually decreasing till January and then another peak followed in February to March 2006 (75%), which gradually decreased towards July. This stage was absent in April. The percentage of maturing (Stage II) male crabs was high in December 2005 to January 2006 (60 - 70 %) and in April to May 2006 (50 - 30 %). More mature (Stage III) male crabs were observed in November 2005 and April to July 2006, making up 50% of the catch. Stage II crabs were absent in November 2005 while Stage III crabs were absent in December 2005 and February 2006.

Mature female crabs were absent from December 2005 to February 2006, while earlier stages (Stages 0 and 1) were absent in August to September 2005 (Figure 4). Stage 0 crabs had highest percentage (85 - 70 %) in December 2005, January 2006 and May 2006 while the frequency of stage 1 was highest in February 2006 and April 2006 (70 - 50 %). The frequency of Stage 2 crabs was high in August to November 2005 (> 60%), while that of Stage 3 crabs were high in July 2006 (60%). Mature stages (Stages 3 and 2) dominated between July to November while earlier stages (Stages 0 and 1) dominated from December to May.

Size at first maturity

The smallest mature female and male crabs recorded during the study period had both a carapace length of 65 mm. The crab size plotted against the percentage frequency of maturity for male and female crabs (Figure 5) show that the size at first maturity was at 75 and 70 mm carapace length for male and female crabs respectively.

DISCUSSION

Over the years crab landings in the Malindi area has increased. The methods of capture of crabs vary along the Kenyan coast, and for Malindi district, there are two common methods used as described earlier. This is different to the case in south coast of Kenya where the most common method of crab capture used is the basket trap (lema or dema in Kiswahili) (Onyango, 1995). The crab sizes examined ranged from 50 to 120 mm carapace length, with the 75 mm carapace length as the dominant size indicating small size crabs are being exploited in the population. Hill et al. (1982) found that the distribution and abundance of *S. serrata* depend on the development stage: juveniles up to 8 cm carapace width were most abundant on intertidal flats, while sub – adult and adult crabs were more subtidal. In Tanzania, mud crab density estimates using burrow density and burrow occupancy in three mangrove habitats were less than 1 per 25 m^2 in open channel, 3 per 25 m^2 in man-grove mangrove fringe and 1 per 25m^2 in the inner forest (Barnes et al., 2002). Chandrasekaran and Natarajan

Table 2. The sex ratio and chi - square tests for the different size classes of *S. serrata* in Malindi district.

Size class (CL mm)	Males	Females	Ratio M:F	Chi-square	p
50-54	3	0	1:0	3.006	0.0832
55-59	13	7	1:0.538	1.800	0.1797
60-64	61	35	1:0.574	7.041	0.0076*
65-69	71	99	1:1.394	4.612	0.0317*
70-74	96	136	1:1.417	6.897	0.0086*
75-79	164	130	1:0.793	3.932	0.0474*
80-84	161	95	1:0.590	17.016	0*
85-89	119	61	1:0.513	18.689	0*
90-94	95	55	1:0.579	10.667	0.0011*
95-99	93	44	1:0.473	17.526	0*
100-104	69	31	1:0.449	14.440	0.0001*
105-109	61	12	1:0.197	32.890	0*
110-114	41	6	1:0.146	26.064	0*
115-119	17	3	1:0.176	9.800	0.0017*
120-124	5	0	0	5.000	0.0254*
125-130	1	1	1	0	1
Pooled	1 070	715	1:0.668	70.602	0*

* Significant at p = 0.05.

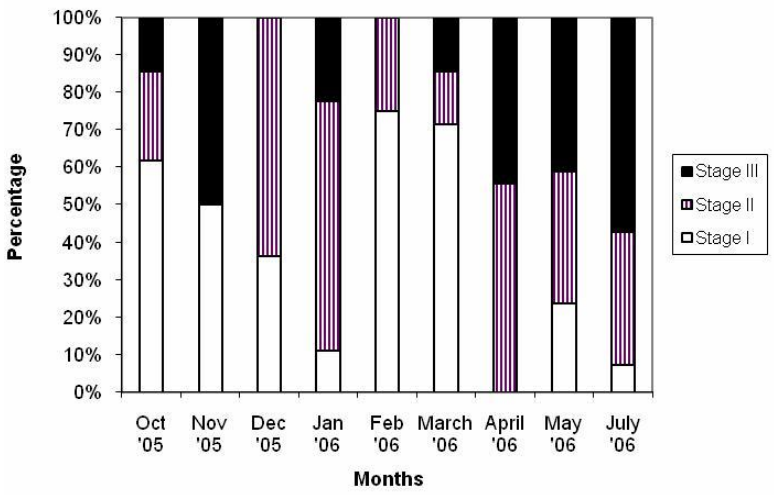

Figure 3. Percentage of maturity stages I, II and III in male (n = 108) *S. serrata* from October 2005 to July 2006 in Malindi district.

(1994) found that newly recruited juveniles prefer sheltered and shallow water habitats amongst seagrasses, algae and mangrove roots. In this study, no juvenile crabs were found in the catch. The catches came mainly from channels in the mangroves, where crabs are abundant.

From the results it was shown that males dominated in the catches and the pooled chi - squared showed a significant difference from the normal ratio of 1:1($\chi 2$ = 70.6; p = < 0.05). In the study on *S. serrata* from the South coast of Kenya (Onyango, 2002); males were more numerous in the catch in the small sizes while females dominated the catch in the larger sizes. For this case, the overall sex ratio was not significant from the 1:1 ratio (χ^2 = 0.776; p = 0.25 > 0.05) (Onyango, 2002). However, in a study conducted on *S. serrata* of Bangladesh, the overall sex ratio of male to female was found to be 1: 0.94. The sex ratio was uneven in most size groups with the highest sex ratio 1: 2.63 recorded for crabs with carapace width71 - 80 mm and the lowest was 1 :0.35 for crabs of carapace width 91 -100 mm (Ali, et al. 2004). Different maturity stages for male and female crabs were encountered in the study and immature crabs dominated the catch. Both mature female and male crabs were

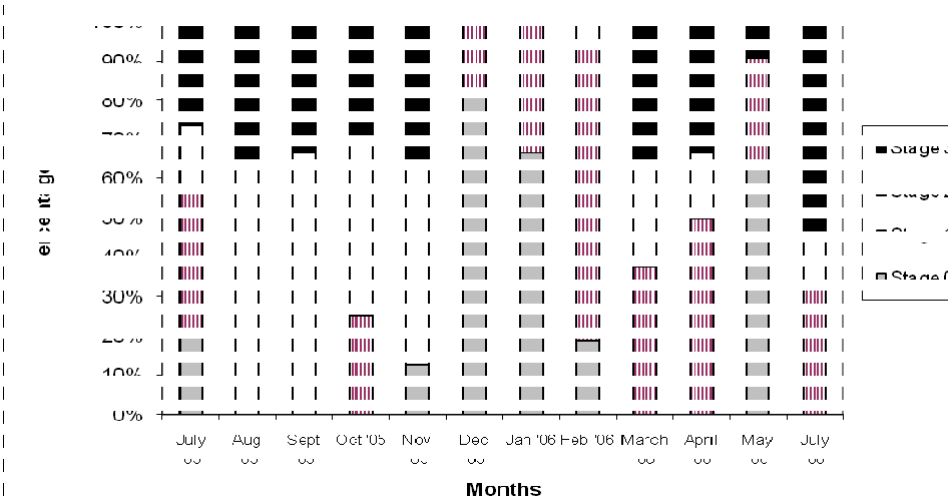

Figure 4. Percentage of maturity stages 0, 1, 2 and 3 in female (n = 141). *S. serrata* from July 2005 to July 2006 in Malindi district.

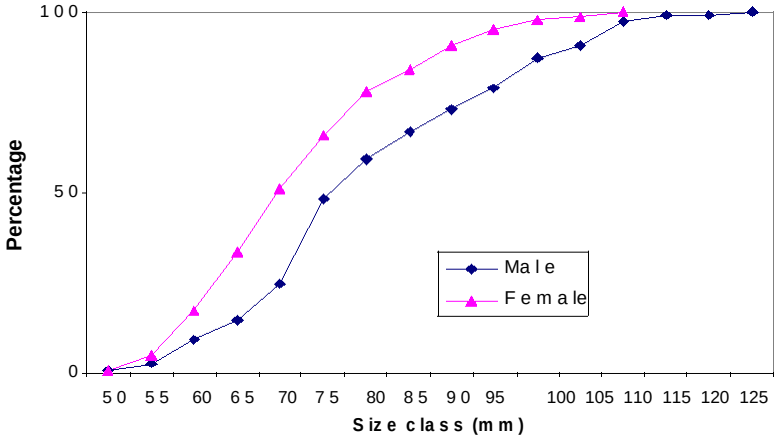

Figure 5. Percentage maturity stages of male and female *S. serrata* in Malindi district.

absent from December 2005 to February 2006 and this may be due to the migratory behaviour of the crabs. Hyland et al. (1984) have explained two categories of movement of mud crabs, a free ranging movement and on offshore migration by females. Mud crabs have been shown to move locally up to 4 km. Females migrate as much as 45 km offshore to spawn (Lee, 1992). These movements could explain the absence of mature crabs from December to February and may be the peak season for spawning. Relatively high numbers of female *S. serrata* with stage two ovaries have been reported in south coast of Kenya indicating that spawning occurred throughout the year, with peaks in August to September and November to December (Onyango, 2002). It has been postulated that the reproduction in tropical populations is more protracted and less seasonal. Reproductive activity has been shown to occur all year round at low latitudes and seasonally at higher latitudes (Quinn and Kojis, 1987). In the life cycle of many portunid crabs, the females move offshore to extrude eggs (Hyland et al., 1984). Studies have shown that female crabs migrate to the sea to spawn and this migration results in larvae being released in the sea (Hill, 1975). Spawning migration by female crabs *S. serrata* has been reported in Philippines, Malaysia, Thailand, South Africa, Australia and Vietnam (Arriola, 1940; Ong, 1966; Brick, 1974; Hill, 1975; Le Vay, 2001). Various species of mud crabs require different salinity for spawning. *S. serrata,* is dominant in oceans with salinity above 34 ppt and in mangroves that are inundated with high salinity water for most of the year and can survive in lower salinities (le Vay, 2001). Knowledge of spawning and hatching of eggs under natural conditions is lacking in the study area, but in captive conditions, salinity ranges used for spawning

are between 32 and 36 ppt (Mann et al. 1992) while larvae are reared in salinity range of between 30 to 35 ppt and in some cases can be as low as 26 ppt (Baylon and Failaman, 1992).

Sexual maturity in *S. serrata* is believed to occur at a smaller size in many tropical populations compared to subtropical populations. Higher water temperatures in the tropics are suspected to increase the crab's growth rate and decrease time to maturity (Quinn and Kojis, 1987). In tropical populations, a higher incidence of maturation in females appears to be associated with seasonal high rainfall, which may be related to periods of high productivity in coastal waters (Heasman et al., 1985). The size at which crabs reach their sexual maturity is important in conservation of a minimum legal size that may be needed to secure a spawning part of the population. The sizes at first maturity (that is the length at which 50 % of the individuals are sexually mature) obtained from this study were 70 mm for females and 75 mm for males. Some reported minimum sizes at first maturity for females of *S.serrata* within the Indian Ocean are: 57.36 mm (Kathirvel, 1981), 56 mm (Joel and Sanjeevaraj, 1982), 39 mm (Lalithadevi, 1985) and 94.77 mm (Onyango, 2002). It is noted that generally crabs from the Kenyan coast attain the size at first maturity at bigger sizes (Onyango (2002) and present study) than those in the Indian region, where the size at first maturity is attained in smaller crabs (first three listed above). Given that the crab catches were dominated by crabs of size 75 mm carapace length, means that the crabs are caught when they were just attaining maturity. This may be an indication of exploitation pressure on the crabs, such that younger crabs are caught and the crab population has no chance to grow and reach maturity. Therefore few young crabs are able to recruit into the spawning population. For the purposes of ensuring sustainable management of the resources, it would be important for the minimum size of crabs caught be regulated, so that crabs have time to mature and recruit into the population. With the increased demand, it is likely that mud crab populations will experience increased fishing pressure, targeting all size classes, from juveniles for culturing, to mature females for premium markets. Due to the migrations exhibited by the crabs, management should not only be concentrated in the intertidal areas but should also include offshore areas.

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