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Full Length Research Paper

A preliminary study on the response of mangrove mud crab (*Scylla serrata*) to different feed types under drive-in cage culture system

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The populations in coastal areas in east Africa have increased dramatically in the last decades, resulting in increased pressure on coastal resources. The examples are declining fish catches, deteriorating conditions of coral reefs and reduction of mangroves forests. The objective of the study was to asses the potential of grow-out Aquaculture of mud crabs *Scylla serrata*, as an alternative livelihood for resource-poor coastal communities. Growth rate and survival of mud crabs (*S. serrata*) cultured in individual drive-in cages (30 x 30 x 30 cm) located in the mangrove forests dominated by *Rhizophora mucronata* were evaluated. The effect of feed (*Terebralia pallustris* - gastropod meat, fish offal and mixture of the 2) was determined in a completely randomised design. Feeding was done at 10% body weight at incoming tide throughout the experimental period of 120 days. Monthly sampling was employed and total weight (g), cheliped length (cm), carapace length (cm) and width (cm) were measured. The study aimed at establishing the growth rate, moulting and mortality of crabs fed using locally available feeds. A total of 180 drive- in cages were used for the experiment giving 60 replicates for each treatment. Drive- in cages were built with "fitos" and grouped in sets of 10 for easy management. Crab seed stock of 50 - 380 g for the experiment were bought from artisanal fishermen. Application of ANOVA and post-hoc test revealed that crabs fed with mixed feed had significantly higher % growth (47.9%) compared to fish offal (33.4%) but were similar to gastropod meat (43.2%) $p < 0.05$. Growth rate was significantly affected by feed type, where higher values were recorded in mixed feed diets (gastropod meat and fish offal, 1.29 g/day) compared to the individual feeds (0.96 and 0.97 g/day for fish offal and gastropods meat respectively. There was no significant difference in growth of monosex crabs female (0.996 - 1.55 g/day) and males (0.893 -1.01 g/day) $p = 0.373$.

Key words: Mangrove, mud crab, feed, drive-in cage, growth.

INTRODUCTION

Traditionally, mud crabs are collected from the wild and used as food at home or sold to local tourist hotels in Kenya. In recent years, the demand for mud crab farming in Kenya has expanded rapidly (Mirera, 2008). With gradual increase in market demand through the tourism industry and increasing coastal population, mud crab culture has the potential of developing significantly as an alternative livelihood alternative for the people (UNEP, 1998; Omodei Zarini et al., 2004). However, mud crab culture in Kenya lacks history and consequently, no suitable culture technologies are easily available to the farmers. As a popular seafood, the mud crab (*Scylla serrata)*, calls for an understanding on the nutrients required for its growth (Catacutan, 2002). Knowledge of the nutritional requirements of *S. serrata* is necessary for the development of cost-effective diets that can be formulated with some flexibility using ingredients that can be locally available and affordable (Sheen and Wu, 1999). However, limited information is available concerning nutritional requirements of this crustacean species. Though it has been observed from studies that the juvenile *S. serrata* show a preference for detritus, while much larger crabs have more crustacean and fish in their diet (Prasad and Neelakantan, 1988) but no information exists on the nutritional requirements for bigger crabs cul-

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tured under drive-in cages.

S. serrata has a successful culture history in south east Asian and fetches a high price in local and international markets (Cowan, 1984) . Mud crab culture in mangroves or tidal flats has been practiced in Indonesia, Vietnam and China and is considered to be ecologically friendly (SEAFDEC Asian Aquac, 1997). In Bangladesh and Indonesia, it is the most important crab species for food and trade and is cultured extensively in ponds together with shrimp (Giasuddin and Alam, 1991) and in mangrove tidal flats (Kador, 1991; Fitzgerald, 1997). In the Philip-pines, mud crab culture was introduced to provide alter-native livelihood for fishers in the villages (Triño and Rodriquez, 1999). Initially, culture methods were deve-loped using ponds (Catanaoan, 1972) and more recently pens (Baliao et al., 1999). Most farms in south east Asia have used trash fish, clam meat or animal by-products as feeds (Baliao et al., 1998; Dau, 1998; Marichamy and Rajapckkiam, 1998; William and Fitz Gerald, 2002) which are not readily available for use in east Africa. The attempts to culture mud crabs in Kenya using trash fish under pen culture, was not viable for the local farmers (Mwaluma, 2002). Attempts have been made in the western Indian ocean region to give maize floor feeds to crabs by the desperate crab farmers who lack alternatives (Rashid and Kassim pers com). However, over the last 5 years attempts have been made to culture mud crabs under different culture methods in Kenya with some success (Mwaluma, 2002, 2003; Mirera, 2008). The latest mud crab research in Kenya has shown that mud crab culture can be a break though if a farmer is able to manage 100 drive-in cages and above (Mirera, 2008) but not without some teething problems.

In general, problems hindering crab culture in different parts of the world have been associated with lack and high cost of seed, inadequate transfer and application of new technology, unstable production and price fluctuation (Cowan, 1984). In the work of Cholik and Hanafi (1991), it was established that the main problems associated with low survival of cultured crabs in ponds were shortage of seed supply and feed. Hence the aim of the research was to access the potential for sustainable grow-out Aquaculture of mud crabs. This could be achieved by, accessing the growth rate of mud crabs under drive-in cage culture system, comparing mud crab growth rate using locally available and affordable feed types, comparing male and female growth rates.

MATERIALS AND METHODS

Study site

The study site was located at the Kwetu training centre in Mtwapa creek (4° 00'S and 39°45'E), 20 km north of Mombasa city (Figure 1). The site forms a section of the 525 ha of mangrove forest in Mtwapa creek. The site is intertidal and covered by a multi-species mangrove stand including the species *Rhizophora mucronata*, *Avicennia marina*, *Sonneratia alba, Xylocarpus granatum, Xylocarpus molluscensis, Lumnitzera racemosa, Heritiera littoralis*, and *Ceriops tagal.*

Cages were grouped into 3 sets within the same mangrove forest under the same forest canopy of *R. mucronata* with small differences in location characteristics that could have limited impact on crab growth/survival (Pers. com, Arriesgado). However, no studies exist on the influence of micro- habitats on mud crab growth. The substrate was categorised as silty clay soils using grain size composition under the Shephard, (1984) triangle and depth of mud in the area was 50 cm. A pseudo- natural channel passed through the cages. There was extensive root network of especially *R. mucronata* where the cages were constructed under. All cages were flooded by seawater on a daily basis at high tide with the height of water increasing as tide height increased.

Experimental design

Drive-in cages were constructed using closely spaced sticks “fitos” (collected from local shrubs) driven vertically into the mud to a depth of 30 cm and tied together with a fishing line. They were covered with a lid made of similar sticks but longer in size that were tied together to form a mat shape. Drive-in cages allow crabs to dig and hide in the mud as in the wild, while the 30 cm depth makes it impossible for them to dig out and escape. An individual cage measured 30 by 30 cm on each side and about 30 - 40 cm high. Cages were built in racks of 10 (2 by 5 adjacent individual cages) and each group assigned to one treatment based on feed type, which is fish offal, gastropod meat (*Terebralia pallustris*) and a mixture of the 2 feeds. Fish offal was chosen for the study due to its availability at no cost locally (only transport costs from 1 village to another) as opposed to trash fish used by Mwaluma (2002). Gastropods are abundant too in the mangrove forests where crabs are cultured, though in some communities they are used as food, however it’s speculated that over exploitation may cause ecological problems. Each treatment had a total of 6 replicates in this experiment giving a total of 180 crabs used in the study. Temperature within the cages was measured twice a week, at high tide and low tide for both mud and water.

Crabs for the experiment were bought from local fishermen who searched for them from the wild in Mtwapa creek mangroves. During cage stocking, male and female crabs were assigned randomly to the cages. The stocked crabs were measured for weight, carapace length and width. Initial weight of crabs ranged between 50 and 380 g (Figure 2). Stocking was conducted between June to July 2006 and final harvest was conducted on September 20, 2006 giving an experimental run of 120 days. Measurements of wet weight, carapace length and carapace width were conducted approximately 2 - 4 weeks giving 4 growth intervals for analysis (Figure 2).

Experimental crabs were fed at 10% of body weight per day using fish offal, gastropod meat and a mixture of the 2. Fish offal was collected everyday from local fishmongers and comprised principally of uncooked discarded organs, bones and meat scraps. Gastropods, *T. pallustris*, were collected from the adjacent mangrove forest where they are abundant. The gastropods were boiled whole for easy removal of meat. Each feeding treatment was assigned to a whole rack of cages for each replicate (gastropod meat, fish offal and mixed feed).

Statistical analyses of mean growth rate and % moulting frequency per feed type were performed using ANOVA and Duncan’s multiple range test (DMRT). If the variances were not normally distributed, data were subjected to square root transformations before ANOVA and DMRT was carried out. Differences between means were considered significant at $P < 0.05$.

RESULTS

ANOVA analyses showed significantly high growth rate

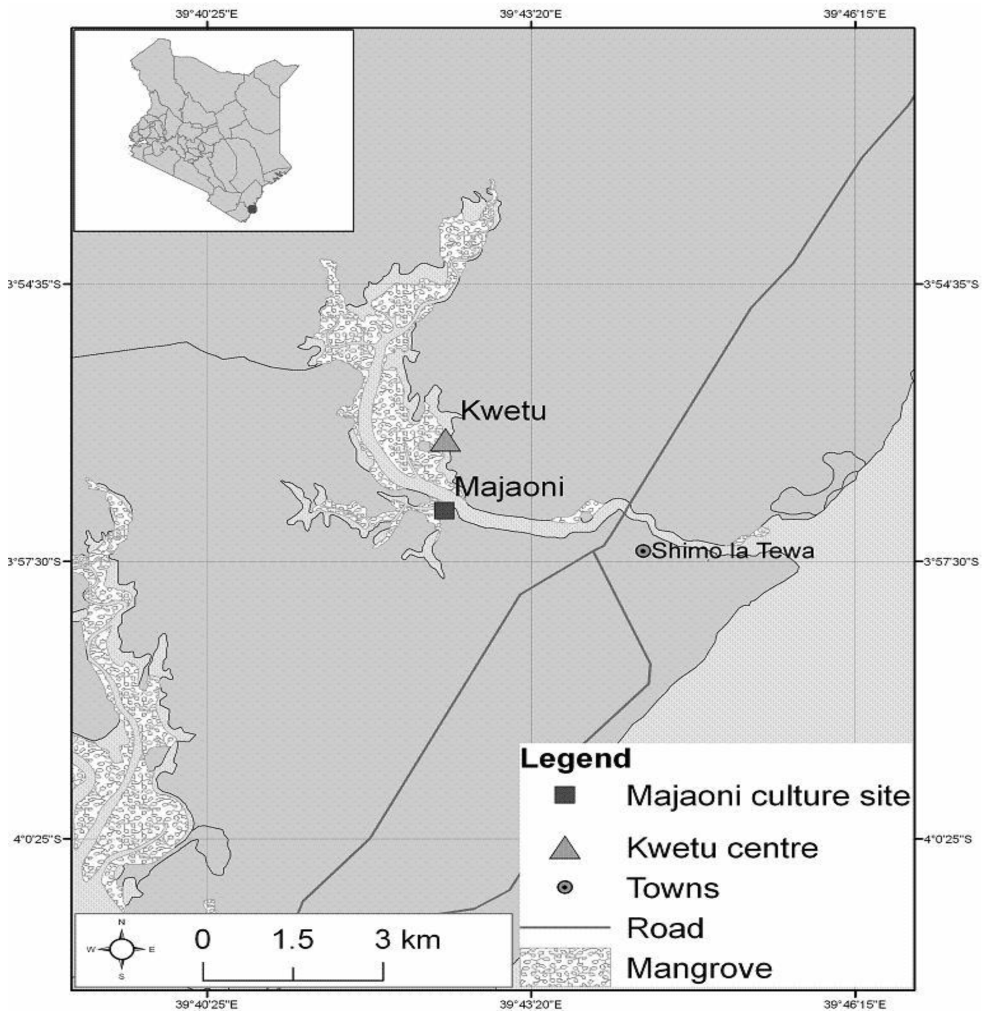

Figure 1. Map showing Mtwapa creek and the Kwetu mud crab experimental site where the study was conducted.

Table 1. Summary of the means ± sd for growth and survival performance of mud crabs in the 3 treatment diets and post hoc test results (DMRT).

Treatment	Fish offal	Gastropod meat	Mixed diet
Parameter			
Final weight (g)	235.9± 158.6	272.0 ± 74.3	295.0 ± 99.2
Growth rate g d^{-1}	0.96 ± 0.79^{b}	0.97 ± 0.64^{b}	1.29 ± 0.72^{a}
Final carapace length (cm)	6.8 ± 1.4	7.8 ± 0.7	8.3 ±1.03
Final carapace width (cm)	9.8± 2.3	11.3 ± 1.1	11.9 ±1.7
Survival rate (%)	35^{b}	61.5^{a}	47.1^{b}
Percent moults (%)	45^{b}	93^{a}	47^{b}

i.) $^{a,\ b}$: similar superscript numbers indicate no significant difference at $p < 0.05$ between treatments when similar parameters are being tested.
ii.) DMRT: Implies Duncan's multiple range test (post hoc test carried out after ANOVA).

for crabs fed on mixed diet (Table 1, Figure 2). The growth was approximately 25% higher than in fish and gastropod meat treatments. However, survival and moulting frequency were significantly high in the gastropod meat treatment (61.5 and 92.3%, respectively). Temperature varied during the experimental period between 24

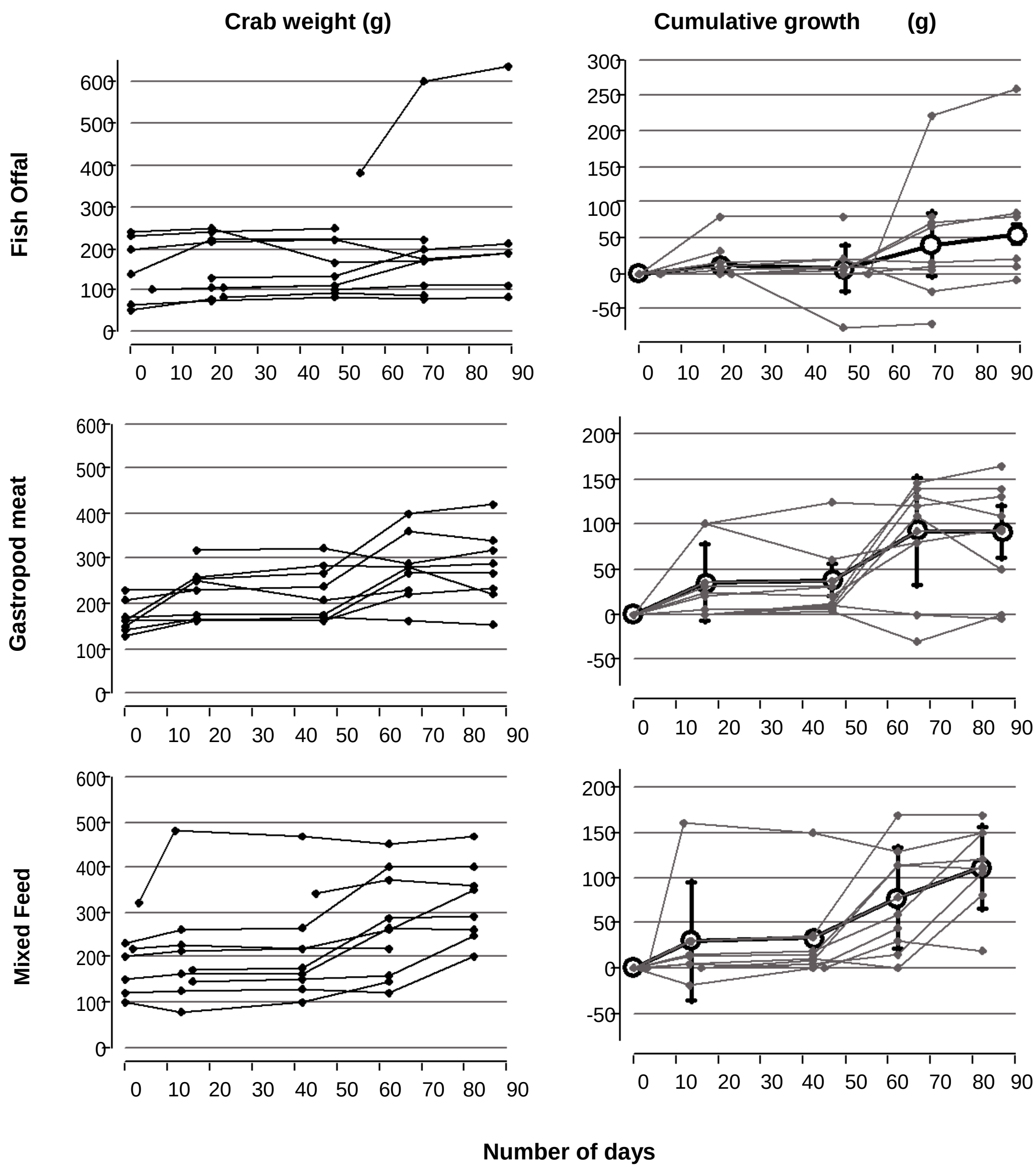

Figure 2. Growth trajectories of individual crabs in the three feeding trials; fish only, gastropod only and mixed, from top to bottom. The left panel shows individual crab weights (g), the right panel shows cumulative growth with each crab's initial weight set to zero (g). The mean (and standard deviation) of growth at each sampling interval are shown by the black line with open circles in the right panel.

and 29 °C due to changing weather conditions that affectted insulation, though similar in all treatments.

Growth

The initial weight of experimental crabs varied broadly between 50 and 380 g, giving mean weights of 150 -180 g (Figure 2). Over the 120 experimental days, maximum growth of individual crabs varied between 130 and 260 g. Cheliped loss contributed to a decrease in weight of between 50 and 70 g where males lost higher values compared to females. The Loss of cheliped was associated to, poor handling at sampling, moulting failure and cannibalistic fighting within crabs in separate chambers. The mixed feed treatment yielded a higher growth rate of 1.29 ± 0.72 g/crab/day with a % growth of 47.9%, 0.96 ± 0.79 g/day for fish offal (33.4% increase) and 0.97 ± 0.64 g/day for gastropod meat (43.2% increase) . ANOVA test indicated a significant difference in growth rate between treatments ($p < 0.05$) while maximum and minimum individual growth rates were similar in all treatments (< 2.5 g/day and > 0.3 g/day).

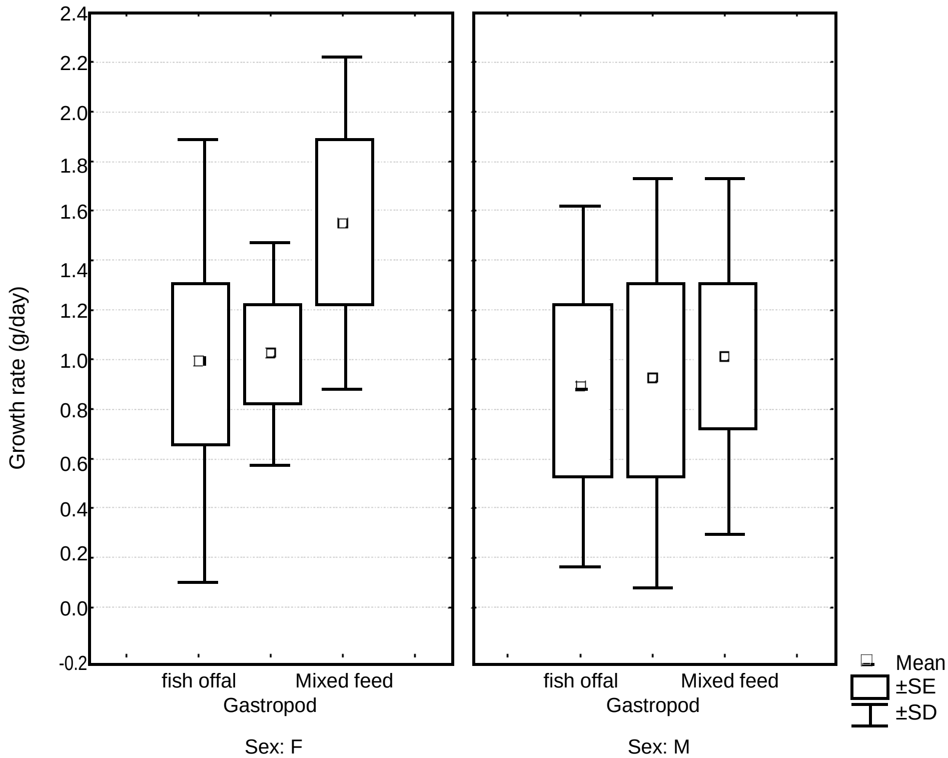

Figure 3. Comparison of male and female growth rate under different treatments (fish offal, gastropod meat and mixture of fish offal and gastropod meat)

Growth trajectories of individual crabs show trends of crab growth during the experimental period (Figure 2). A high variability of individual crab growth was observed in the different treatments. There were strong fluctuations in growth rate between neap and spring tide phases, where higher growth rates were observed during the latter. A general trend of decline in crab weight was observed as they approached moulting possibly due to reduced feeding at such time. This could have been the cause of the decline in growth observed in some crab as detailed in Figure 2. Growth rate values for females were (0.97 to 1.55 g/day) compared to males (0.89 to 1.01 g/day). ANOVA test indicated no significant difference in the growth rates, implying that both sexes had similar growth ($p = 0.373$). However, for both sexes higher growth rates were observed in the mixed feed treatment (Figure 3).

Mortality

High mortality of crab was observed within the first 3 days of stocking that was associated to stress during capture. A relatively lower mortality was continuously observed in the treatments that lead to periodical cage micro management (mud was scooped out of the cage compartments and replaced with a thick layer of fine sand). The cage micro-management was observed to reduce mortality rate. The mortality observed throughout the experimental period was categorised into different subdivisions:

i.) Failure to moult.
ii.) Dying during moulting process or shortly afterwards.
iii.) Predation with small crabs after moult due to soft shell.

The study recorded the highest mortality with the fish offal treatment, followed by mixed diet and minimal in the gastropod meat (Table 1).

Moulting dynamics

Crabs were observed to undergo different preparation stages prior to actual moulting that included: reduced/no feeding prior to moulting, development of v-shaped cracks on the inner part of the 2 chelipeds and general weight decrease. The study observed 62% moults during the whole experimental period whereby 59% occurred at neap tides and 3% at the earlier transition phase of spring tides (Table 2). During daily monitoring process, shade carapace was taken out at low tide to reduce chances of injuries on the soft moults crabs. All moults occurred at high tide when water could get its access to the cages. The study observed that 52% of the moults occurred during the night high tides and 10% day high tides respectively. It was established that new moult crabs increased in size between 15 and 25% based

Table 2. Moulting pattern of mud crab (*S. serrata*) for each feed treatment, by tidal cycle (neap vs. spring), tide phase (high vs. low) and time of day (day vs. night).

		Fish oval	Gastropod	mixed	Total
Tide cycle	neap	88.89	100	89.29	94.59
	spring	11.11	0	10.71	5.41
Tide phase	high	100	100	100	100
	low	0	0	0	0
Time of day	night	77.78	91.07	75	83.78
	day	22.22	8.93	25	16.22

I) a, b: different superscripts indicate significant differences at $p < 0.05$.

II) The values indicate the % of crabs that moulted for each season under the total moults per treatment (Total moult for each treatment equal to 100%).

on carapace width and weight increment. Significantly higher moulting % was observed in the gastropod meat fed treatments as opposed to the rest (Table 2). Drastic growth trends were observed in the cumulative mean growth curve for crabs fed with gastropod meat compared to the others which gave an indication of high moulting frequency that affected crab weights (Figure 2).

After moulting the exoskeleton of the crab was observed to be a thin membrane and the crab was delicate due to its soft muscle (sponge like). The exoskeleton hardened within 4 to 5 days. The moulted crab changed colour to green that reverted slowly to its original colour over the next 2 months after moulting. The shade exoskeleton of the crab (old shell) accounted for 30 - 38% of the newly moulted crab body weight, which implies that over 60% of the crab body is meat. In preparation for the moulting process, growth rates of individual crabs decreased to near zero from spring tide rates of 1.0 - 2.5 g/day (Figure 2) while the other crabs lost weight of 10 - 30 g during this process due to reduced feedng. After moulting process, a dramatic increase in weight was observed followed by a plateau of relatively constant weight until the next moulting period.

General behavioural of crabs in drive-in cages

The cultured crabs were more active at high tides as displayed through swimming unlike low tides when they stayed buried in mud. Crab activity was observed to be high in late evening high tides than at mid-morning or mid-day and also during spring compared to neap.

Drive-in cage walls were damaged most at high tides thus coinciding with crab actively. Activity swimming crabs looked for escape points of weakness leading to tearing of cage lids and walls with their chelipeds. They occasionally found their way out by making holes through the cage walls. At neap high tides the crabs crawled along the cage bottom while at spring high tides they swarm actively on the water surface in the cages. Active feeding was observed in the crab at high tides but at low tide crabs were passive and feeding was rarely observed since they were buried in mud/sand. High mortality was observed more at neap tides compared to spring tides possibly due to high moulting frequency then. In fighting for adjacent crabs in cages was frequent and occasionally lead to, broken chela, cheliped and pierced carapace with rare cannibalism especially when a smaller crab entered the cage compartment of a larger crab.

DISCUSSION

The study recorded an overall average survival of 48% and growth of 33 - 48% body weight and carapace width increment for the 120 days experiment period. A daily growth rate of between 0.5 and 0.6% was established for *S. serrata* under the current experiment. Feed type strongly affected growth and survival of crabs. Significantly, higher growth rate was recorded in the mixed feed (gastropod meat and fish offal) while survival was highest in crabs feed with only gastropod meat. Growth rate of 1.23 ± 0.72 g/day was recorded for crabs fed a mixed feed (gastropod meat and fish offal), compared to 0.97 ± 0.64 g/day for crabs fed on gastropod meat and 0.96 ± 0.79 g/day for crabs fed on fish offal. Previous mud crab studies have also found out that crabs obtained more nutrition from mixed diets that included combinations of mollusc, fish and crustacean material over any one item on its own (Jayamane and Jinadasa, 1991; Marasigan, 1997; Triño et al. 1999), an indication that the current study supports findings of other workers.

Marasigan (1997) and Triño et al. (1999) recommend a mixed diet of 75% mussel meat and 25% trash fish for mud crabs with an elaboration that fresh brown mussel-based diet attained better performance. In current study, lower growth with either feed alone is indicative of lesser nutrient content than mixed feeds. However, nutrient analysis was not done to investigate the nutrient composition of the different feeds.

Baliao et al. (1999) established that purchased feeds comprised 40 to 60% of the total cost of production in mud crab pen culture which reduced the profit margin. This has been raised as one of the constraints for mariculture development in Africa since most marine fish are carnivorous and thus their feed under culture need to have high protein which is in most cases supplied by fish meal which in itself threaten human food security

(Brummett et al., 2008). In the current study, the feeds used were mainly wastes from processing and cooking fish or collected from the mangroves (gastropod meat) with little or no monetary value attached to them apart from the transport costs that were not considered under the current study. With minimal monetary value attached to feeds (which require higher costs), mud crab culture technology may be summarised as being accessible to low income coastal communities. Wedjatmiko and Dharmadi (1994) indicated that mud crab would eat any kind of low-value fish, however, these may in some areas be contributing significantly to human consumption as a source of protein (Brummet et al., 2008) which hinders our options for using low value fish in the current study.

Moulting is a basis by which crabs achieve growth and was influenced by feed type in the current study. Its occurrence was higher in crabs fed with gastropod meat treatment compared to the other treatments. Therefore the assumption that gastropod meat may contain an active ingredient which induces moulting, need to be investigated in future studies. However, from the present results crab farmers need to be advised to include gastropod diet in their culture practices.

The tidal influence on crab weight was highly pronounced in the current study. Crabs recorded higher weights at spring tides compared to neap tides, implying that cultured crabs need proper feeding at spring to gain more weight to counter the loss at neap. The key lesson to farmers is to sell crabs out at spring rather than neap due to weight fluctuations.

The 8% of mortality that occurred in the first week of stocking was associated to capture stress. This stress is due to the fact that crab capturing in Kenyan mangroves involves fishermen struggling with hook sticks to get them out of holes, crabs are piled together in a “pakacha” basket locally made from coconut leaves and prolonged capture and transport time of 4 - 6 h. Due to poor handling procedures, such crabs when used for culture in cages tend to have high mortality. The handling condition could be quite detrimental for a mud crab Aquaculture that will rely on wild collection. However, to remedy the situation, crabs can be collected at night with torches when they move around thus causing less stress (Hill, 1978) or to develop hatcheries to supply small crabs.

The current study observed that moulting was a cause of mortality for the cultured crabs due to failure to secure energy for shading the exoskeleton when due, or immediately after moulting due to vulnerability from predation or injury and other physical stresses. The observed mortality of 20% associated to moulting especially cannibalism and predation by fiddler crabs can be reduced by provision of shelter for the soft body crabs as advised by Fielder et al. (1988).

Escape contributed 25.2% of the total mortality in the current study. Crabs escaped from cages by cutting through bamboo/fito walls. Similar observations were made by Sulaeman et al. (1993) in pond culture systems, Fortes (1997) concluded that despite enclosures along the perimeter of the ponds, crabs still managed to escape by cutting the nylon nets. The observed escape in the present study can be reduced through constant cage repair during the production process.

In this study, females were observed to have similar growth with males as opposed to Mwaluma (2003) where female crabs grew faster than males. One factor appearing important is female’s reproductive performance. While reproductive costs are higher in females than males, the female crabs used on this experiment are not yet ready for reproduction hence spent energy for production is instead used for growth and development giving the similarity in growth for all sexes in the present experiment. This observation however needs more scientific research to conclusively say that both sexes have similar growth rate at an earlier stage of their life cycle.

Results of the study indicate that drive-in individual cage culture is a viable method for mud crab culture, though improved survival and growth rates are required to make it more attractive in addition to its none destructtive nature to the mangrove forest. The weight gain range of 50 - 170 g obtained within 120 days culture period illustrate a relatively fair comparison level of other studies done in Kenya comparable to and higher than 20 - 70 g for 3 months documented by Mwaluma (2003). Previous trials in Kenya have focused on the use of large cages and pens of 10 - 100 m^2 (Mwaluma, 2003) but reported mortality is much higher hence impacting growth rate. While not yet achieved in this study or elsewhere in east Africa, reducing levels of mortality from > 50% to lower levels should be possible, for example, moulting-related mortality of 5% was recorded in Indonesia where even this was considered by farmers to be too high (Cholik and Hunafi, 1991).

The efficiency of the drive-in individual cage method is explained on the basis of their small size, which confers the following advantages:

i.) Easy individual crab management and monitoring and the search time for crabs is reduced to zero.

ii.) Assured feeding ration and allotment for individual crabs, including the ability to adjust feeding on an individual basis.

iii.) Management of micro-environment of the crabs is possible, such as in modifying the substrate as was done here or such things as predator removal during moulting phase, placing levee to remove fresh water during heavy downpours etc.

iv.) Movement of crabs in the cages is limited, conserving energy expenditure for growth and development.

v.) Maintenance activities such as cleaning and repairing damaged structures are simple.

vi.) A higher stocking density and less space are required, approximately 0.1 m^2 per crab or 9 crabs/m^2 compared to stocking densities of 1 - 2 crabs/m^2 for pen culture (Trino and Rodriguez, 2002).

vii.) No mangrove forest cutting to install the cages.

Mud crab farming in drive- in cages is technologically and financially accessible to coastal fishers and other low-income coastal communities. Nevertheless, the survival and growth rates so far achieved are not yet at the level of ensuring an economic return for the investment of time and effort to maintain the crabs in culture. Further improvements are required and are the subject of future research.

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