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Growth and survival of Mud Crab, *Scylla serrata*, reared in bottom and floating cages within Mida Creek mangroves, coastal Kenya

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Mud Crab fattening is a relatively new business idea in Kenya and is highly lucrative due to the reasonable prices offered at tourist hotels. This study was aimed at developing appropriate culture techniques for Mud Crabs to maximize harvestable biomass by the local communities and avoid recruitment overfishing. Growth and survival rates for mixed sex Mud Crabs was investigated for a period of 230 days in Mida Creek, Kenya, using bottom and floating cages, and two feed types in a crab fattening experiment. Crabs attained harvestable weight by the third month for both floating (466.2 ± 137 g) and bottom cages (542.2 ± 109.3 g). There was no significant difference in mean total weight of mixed-sex crabs in the two culture systems ($t = 1.75$, $p>0.05$), however males showed significantly higher total weight gain compared to females. A higher overall survival rate was found for crabs cultured in floating cages (63.8%), compared to bottom cages (44.9%). There was no significant difference in growth performance between crabs fed gastropod tissues and those fed fish offal. The long-term specific growth rate for floating cages (0.69 g d^{-1}) was not significantly different from that of bottom cages (0.92 g d^{-1}). An analysis of potential return on investment showed the floating cages to be more profitable per production cycle compared to the bottom ones. The floating cage system and mono-sex male crab culture are recommended to farmers within mangrove tidal flats in Kenya.

Keywords: fattening, total weight, survival rate, specific growth rate, return on investment

Introduction

The Mud Crab (*Scylla serrata*), also known as the Mangrove Crab, is sought after as a quality food item because of its taste, texture and nutritive value. In addition to its high nutritive appeal the species is a suitable aquaculture candidate due to its preference for estuarine habitats and less aggressive behaviour (Lindner, 2005). Its potential for commercial aquaculture production has long been recognized in the Southeast Asia primarily on capture and fattening of juvenile crabs (Linder 2005; Shelley, 2008; Begum et al., 2009). In Taiwan for example, *Scylla serrata* is reared in both polyculture (together with shrimps and milkfish) and monoculture ponds (Chen, 1976). In the Philippines, the species is cultured in ponds (Trino et al., 1999) and cages (Baliao et al., 1999). In Bangladesh, the species forms the most important crab for food and trade and is extensively cultured in ponds together with shrimps in mangrove tidal flats (Giasuddin and Alam, 1991; Kador, 1991). In these countries, the culture of Mud Crabs and other species in mangrove tidal flats has served to

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integrate environmental conservation with income generating activities (Mahmood, 1991; Fitzgerald, 1997).

In Kenya and most of coastal Eastern Africa, *Scylla serrata* forms a premium commodity in local tourist hotels (1 kg = Ksh.500-800 ~ 10 USD). They are harvested within mangrove tidal flats by local fishers. However, the current harvest methods are labour intensive, time consuming and unsustainable as they target mature crabs thus threatening populations with a possibility of recruitment overfishing (McManus, 1997). Additionally, mangrove forests are threatened by unsustainable exploitative activities mostly driven by poverty levels of the surrounding communities.

Although exploitative practices that integrate conservation of coastal systems with commercial production of fisheries resources have long been practiced in South-East Asian countries (also see, Chen, 1976; Chang, 1997; Fitzgerald, 1997; Mahmood, 1991), in Africa and specifically in Eastern Africa, this form of culture is new (Mwaluma, 2002, 2003; Mirera, 2009, Mirera 2014) but necessary for integrating resource utilization with environmental conservation. In Kenya, 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). Crab culture in Kenya is still at infancy and the potential is high given that there is a ready market at both local and international levels.

Crab fattening involves the fattening of crab seeds obtained at about 250 gm to a harvestable size of 400-500gms depending on the market requirements. In Southeastern Asian countries crab fattening has been done in encircled earthen ponds, bamboo and net cages, ponds and canal systems (Begum et al., 2009). The introduction of Mud Crab fattening in cages is new in our country and this research investigated the appropriate culture method for Mud Crabs in both bottom and floating cages within Mida Creek mangroves. Most of the villagers are fishermen but few members (Dabaso Creek Conservation Group) started crab fattening in drive in cages 2004 but experienced challenges mainly related to high mortality and limited technical skills.

The main objective was to develop an appropriate culture technique for Mud Crabs to maximize harvestable biomass by the local communities and avoid recruitment overfishing of the crabs. Potentially, the results would have a lot of relevance in terms of uptake, expansion and utilization of the Blue Economy by coastal communities. We tested the hypothesis of no growth and survival rate differences between crabs cultured in bottom and floating cages under different diet.

Materials and methods

Study site

The study was carried out within Mida Creek, Kenya (Fig. 1). Mida is a mangrove creek located 100 km north of Mombasa City, Kenya. The total area of the creek, including that covered by mangrove trees, is 32 km^2 and it forms an important nature conservation site. It is part of the Watamu Marine National Park (created 1968) and Reserve designated Man and Biosphere site, under the management of Kenya Wildlife Service and is surrounded by several fishing villages.

Experimental design

A randomized 2 x 2 factorial experimental design with feed (gastropod tissue and fish offal) and cage placement (bottom and floating cages) as the main factors was used to test the effect of cage type and feed on crab growth and survival rates in a crab fattening experiment. Bottom and floating cages measuring approximately 1 × 2 m (Fig. 2 a and b) were constructed using locally available mangrove poles and bamboos fastened with manilla ropes were used in this experiment. Each cage contained 10 individual compartments measuring 1 × 1 × 0.9 ft. A total of 10 replicate bottom and floating cages were used in the experiment. Floating cages were secured firmly on mangrove trees and buoyed using plastic cans (Fig 2 b). The cages were placed under intact mangrove canopies (Fig. 2) to provide shelter for the crabs and were inundated in water at both low and high tides throughout the experiment. The bottom cages were only inundated in water only during high tides. Before stocking, initial crab weights and carapace

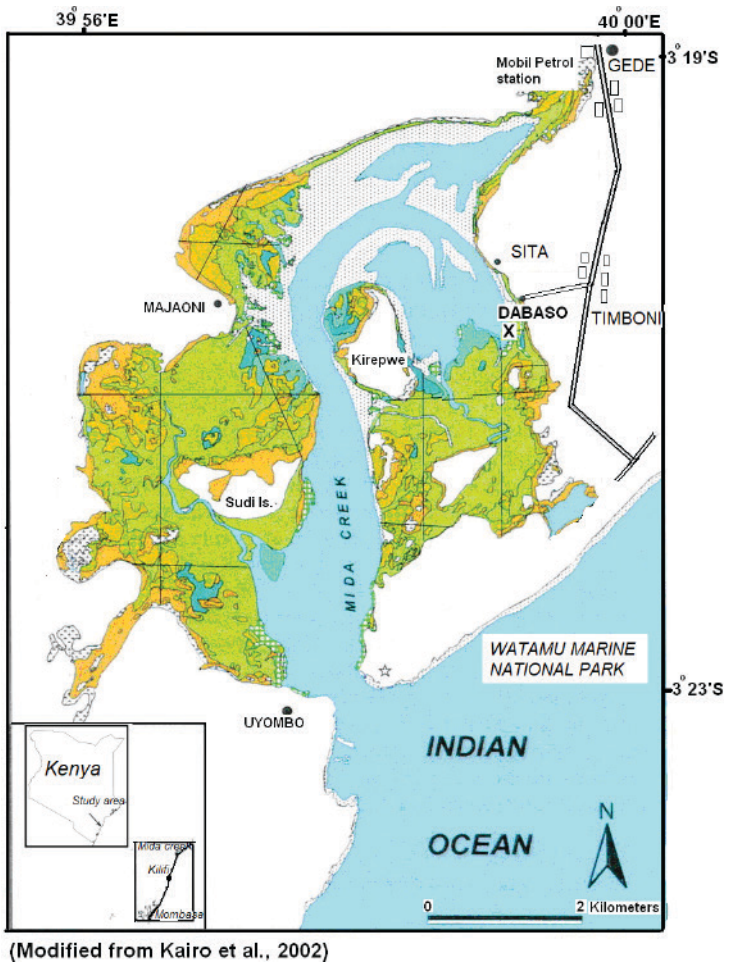

Figure 1. A map of Mida Creek and the adjacent mangrove forests. X indicates the project site at Dabaso village within the mangrove channels.

lengths and widths were measured to the nearest millimeter. Mixed sex crabs were then randomly stocked in each compartment of the cages. The crabs in both bottom and floating cages were fed *in situ* with mashed mangrove gastropod tissue for the first three months, the feed was then changed to fish offal diet during the last 4 months. The crabs were fed at 10% of their total body weight twice daily. The daily feed ration was adjusted every two weeks based on the mean biomass of the crabs in the cages. Small juvenile Mud Crabs of about 200 grams were purchased from local crab fishers for stocking. Measurement of crab weight (g), carapace length and width (mm) and surviving crabs was done at weekly intervals for a period of 230 days from July 2008 to February 2009.

Data Analyses

The mean body weight, weight gain, specific growth rate (SGR, % day^{-1}), survival rate and net production were derived for each cage type. Means of these parameters were compared by multi-factorial analysis of variance (Zar, 1990). The Specific growth rate (SGR) and total weight gained (TWG,) for each feed type for the crabs in the cages were compared and derived using the relationships:

SGR, % day^{-1} = Loge (change in body weight)/ culture period in days x 100……(1)

The variation in SGR and TWG were analyzed for temporal trends in order to determine appropriate time of harvest. The economic feasibility of the

two culture methods with diet and harvest regimes being nested factors were evaluated by a cost-return (see Shang, 1990).

Figure 2. Some of the bottom (a) and floating (b) cages used in the culture of Mud Crabs *Scylla serrata* within the Mida Creek mangrove channels.

Results and discussion

The parameters under investigation in the study are summarized in Table 1 at three months period for weights, carapace size and specific growth rates and by the end of the study (six months) for survival rates. Although floating cages showed higher total weight gained and carapace size compared to bottom cages, these were not significantly different ($p < 0.05$). However, the floating cages had significantly higher long-term survival rate (63.8%) compared to the bottom cages (44.9%) (Fig. 3b). The differences in survival rates of the crabs between the cages was more pronounced at month- three (floating 80%; bottom 45%) when crabs had attained a mean harvestable size of 466.2 ± 137g for floating cages and 456.2 ± 109.3g for bottom cages. Sex based differences in survival rate analyzed for floating cages indicated similar survival rates between males and females during the first 3 months, however, males significantly outlived the females after 3 months (Fig. 3a).

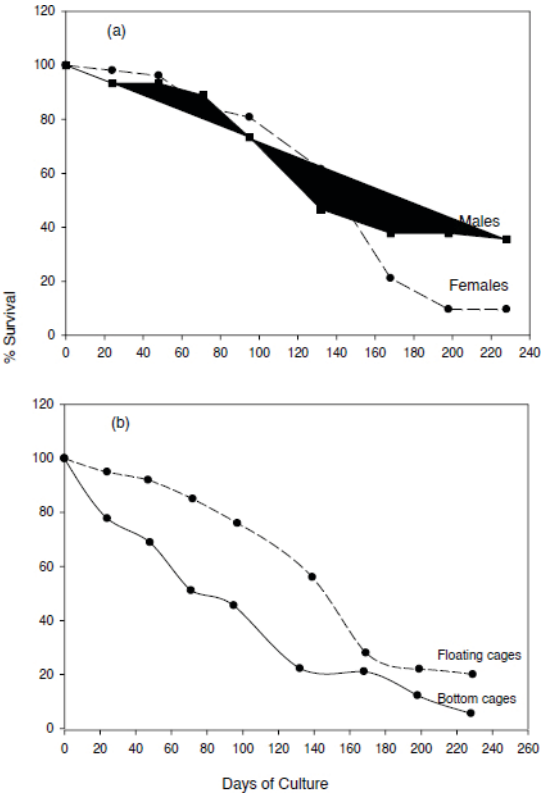

Figure 3. Survival rates of Mud Crabs, *Scylla serrata*, within Mida Creek mangrove channels. (a) Survival rates of male and female crabs analyzed for floating cages, (b) survival rates of both sexes for each cage type.

The relationship between survival rate of the crabs in the cages and days of culture (d) (Fig. 3b), followed a linear model of the form:

Floating cages: % survival rate = 107.35 – 0.40 d ± 4.27, r^2 =0.96 ……..(2)
Bottom cages: % survival rate = 87.39 – 0.40 d ± 4.87, r^2 = 0.94…….(3)

Patterns in growth were similar between the cages and showed increasing trends up to days 132 (4 months) of culture (Fig. 4). There was no significant difference in mean total weight of the crabs (both sexes) between the bottom (378.6 ± 76.9) and floating cages (377.4 ± 65.7) over the project period ($t = 1.746$, $df = 16$, $p > 0.05$). A regression of weight of crabs on days of culture (d) gave the following significant relationships:

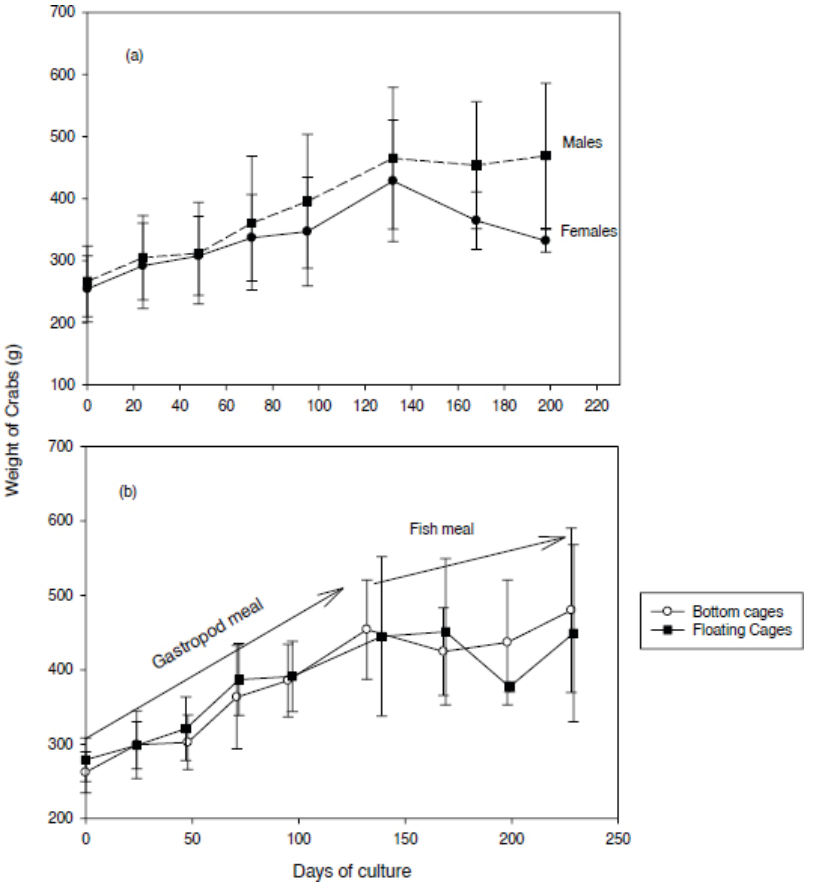

Figure 4. Changes in total weight gained (gm) of Mud Crabs cultured in bottom and floating cages within Mida Creek mangrove channels.(a) growth patterns for male and female Mud Crabs (b) growth patterns for both sexes following a gastropod feeding phase alternated with fish offal feeding phase.

Bottom cages: Weight (g) = 280.5 + 0.92 d, r^2 = 0.89, $p<0.05$……(4)

Floating cages: Weight (g) = 302.0 + 0.69 d, r^2 = 0.71, $p<0.05$……..(5)

These relationships indicate that the long-term specific growth rate for crabs in bottom cages (0.92g d^{-1}) was higher than that of floating cages (0.69g d^{-1}). However, analysis of covariance showed no significant difference between the specific growth rates (ANCOVA, $p<0.05$).

Overall, male crabs showed a higher total weight gained compared to females (Fig. 4a). A multi-factorial ANOVA indicated that sex significantly affected harvestable weight of the crabs (Table 2). Total weight (g) gained by male crabs (378.6 ± 79.6) in bottom cages was significantly higher than that of females at the end of the experiment (332 ± 51.9) ($P< 0.05$). Similarly, for the floating cages males showed higher final weight (415 ± 115.9) compared to females (376.6 ± 82.3). Although the inception of fish offal diet at the fourth month depressed growth of the crabs (Fig 4), ANOVA results showed no significance effect of diet on growth (Table 2), indicating inconsequential effect of choice of the two diets on crab growth. Additionally, there was no interaction effect of diet and sex on growth of the crabs suggesting non-conditional effects of the two parameters on growth.

The relationship between crab carapace length (CL, cm) and body weight (g) was strongly correlated for the males (r^2 = 0.50) but not for the females (r^2 = 0.39) (Fig. 5). These relationships were:

Males: Weight = 6.7 $CL^{1.84}$, r^2=0.50, $p<0.05$……(6)

Females: Weight = 5.15 $CL^{1.88}$, r^2=0.39, $p>0.05$…….(7)

Table 1. Summary comparison of growth variables for the Mud Crab *Scylla serrata* cultured in bottom and floating cages within Mida Creek Magrove channels.

Parameter	n	Bottom Cage	n	Floating Cage
Initial Weight (g)	100	262.1 ± 55.5^{a}	100	278 ± 51.0^{a}
Final weight (g)	42	379.4 ± 101.8^{a}	76	394.6 ± 99.9^{a}
Carapace length (cm)	42	9.05 ± 0.76^{a}	76	7.10 ± 0.72^{a}
Carapace width	42	12.4 ± 0.99	76	13.1 ± 3.64
% Survival		44.9 ± 32.5^{a}		63.8 ± 32.9^{b}
Specific Growth Rate (g d^{-1})		1.17 ± 0.29^{a}		0.98 ± 0.31^{a}
Identical superscripts (a,b) indicate statically similar parameters between cages				

Table 2. A Multi-factor ANOVA table on the effect of growth, feed and sex of the Mud Crab, *Scylla serrata* cultured within Mida Creek mangrove channels.

Effect	SS	DF	MS	F	P
Intercept	11757.55	1	11757.66	78.32	0.000
Feed type	52.19	1	52.19	0.35	0.559
Sex	623.12	1	623.12	4.15	0.048*
Sex x Feed	1.00	1	1.00	0.01	0.935
Error	6005.16	40	150.13		
*Significant at P< 0.05					

Combined Sex: Weight = 7.5 $CL^{1.75}$, r^2=0.33, p>0.05……(8)

The poor weight-carapace size relationship for the crabs suggested that carapace size is not a good predictor of body weight for females and provides a reliable prediction only for the male body weight.

The cost-benefit analysis for the project based on community adoptions of the cage culture systems is shown in Table 3. The annualized return on investment indicates a high profit margin on the floating cages compared to the bottom cages. The high profitability of the floating cages results from high crab survival rates and the assumption that community labour will be contributed at no cost.

The experiment indicated higher survival rate of the crabs reared in floating cages compared to the bottom cages. The percentage is even higher (~ 80%) at month three when the crabs have attained a harvestable size of > 300g. Although males show a higher survival rate than female crabs, this difference was not significant statistically. However, the males have a significantly higher growth rate than the females. This finding is significant and supports recommendations for male mono-sex culture as being more viable. Male based mono-sex culture of *Scylla serrata* are practiced in the South Asian countries based on similar research findings (Baliao et al., 1981). Although there is no significant total weight gain and specific growth rates between the two cage systems, the high survival rate, ease of maintenance, deployment and feeding, makes floating cages recommendable as the appropriate culture method for *Scylla serrata* in coastal Kenya. This notion is reinforced by the higher profitability of the floating cage system.

In this study the two feed types of gastropod tissues and fish offals did not show significant effect in weight gain by the crabs. This indicates that choice of the two feeds is inconsequential in the crab farming. This results support the findings by Mirera and Mtile (2009). However, inception of fish offal feeding depressed average growth of individual crabs indicating that crab tissue meal may be of relative superiority. The crabs attained harvestable weights at month three of culture with peak weights at months 4-5, and a consequent decline in weight beyond the sixth month. This implies that given market demands the crabs can be harvested at month-three thereby lowering costs of production.

Table 3. Investment costs and returns from floating and bottom cage culture system for the Mud Crab, *Scylla serrata* cultured within Mida Creek mangrove channels.

Parameter	Floating Cage	Bottom Cage	Cost Per Cage
Seed costs 27kgs @120 kg^{-1}	3240	3240	3240
Transport of seed	1750	1750	1750
Cage construction cycle^{-1}	13,000	13,000	13,000
% Crab survival cycle^{-1}	80	43	3240
Production of crabs (kg) cycle^{-1}	33	17	3240
Gross income @ 500 kg cycle^{-1}	16,500	8500	19,480
Gross Income yr $^{-1}$	66,000	34,000	
Net Profit Ksh year^{-1}	46,520	14,520	
NB: 1 Cycle= 4 months			

Morphometric analysis of the crabs provided a poor relationship between carapace size and weight of the crabs for mixed-sex samples and for the females. However, males showed a positive stronger relationship between these parameters. These results suggest that carapace size is only a suitable weight predictor for males and not for males, a useful knowledge under field situations where farmers and researchers may not have necessary weighing equipment.

Analysis of potential returns on investment indicated that the floating cage design had higher annualized profits on the assumption of community contributed labour. This profitability is facilitated by the high survivorship in floating cages compared to the bottom cages. Experimental crab fattening in Kenya has previously shown a high return on capital investment with the cost of labour not included (Mirera et al., 2009). However in most cases in Tanzania and Kenya low profits have previously been realized due to high labour costs and low scale productivity. In Southeast Asian countries Mud Crab fattening has been described as profitable due to fast turnover, low operating cost, high survival rate and good market demand for the end products (Begum et al., 2009) and only for a very short period of time (Mirera, 2014). In India, fattening can be for only 20-30 days for soft shelled crabs until shells are hardened (Duraisamy et al., 2009)

Low survival rates were found in bottom cages despite the crabs being kept in individual cages in the intertidal area due to accessing water during high tides only as compared to the floating which received water throughout the culture period. It has been found that crabs cultured in intertidal cages which access water only during high tides suffer higher mortalities due to the poor environment for completion of the moullting process (Mirera, 2014).

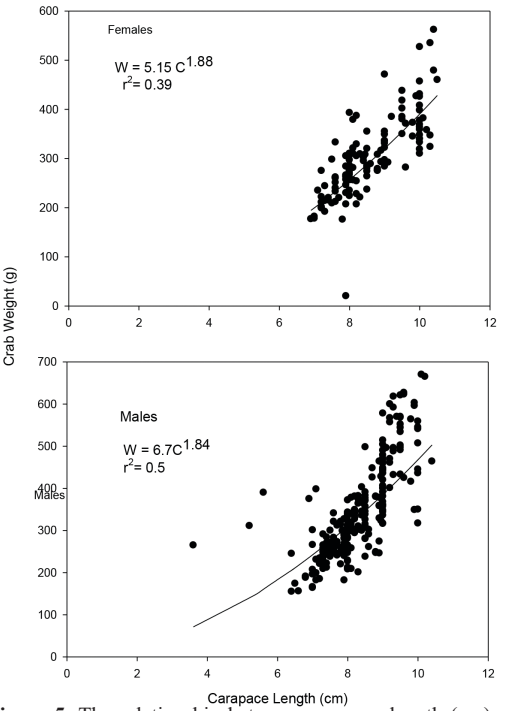

Figure 5. The relationship between carapace length (cm) and crab body weight in male and female Mud Crabs within Mida Creek mangroves.

Conclusions

In conclusion, the study showed that mono-sex male culture of the crabs will likely provide

higher returns in terms of harvestable biomass. Crabs are harvestable at three months but apparent peak total weight gain is achieved at 4-5 weeks. We recommend to local communities, the adoption of floating cage culture systems within the mangrove channels however with a short culture period (about 3 months). The often abundant mangrove gastropod *Telebralia palustris* in this creek form a suitable diet for the crabs under culture with a marginally higher weight gain over fish offal. However since in some areas these snails are also consumed by humans as food hence under a large scale production scenario they may compete with food for humans (Mirera, 2014). Therefore, there is need to find acceptable and sustainable sources of feed for the crabs. Timing of harvest to access better markets (e.g. during peak tourist seasons) and value addition would increase profitability of crab farming as well.

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