Original Article

The first attempts made towards the domestication of sea cucumbers in Kenya

Western Indian Ocean
JOURNAL OF
Marine Science

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Open access

Citation:
Magondu E, Holeh G, Munguti J. (2023) The first attempts made towards the domestication of sea cucumbers in Kenya. Western Indian Ocean Journal of Marine Science 22(1): 15-24 [doi: 10.4314/wiojms.v22i1.2]

Received:
January 27, 2022

Accepted:
January 10, 2023

Published:
May 12, 2023

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Abstract

The potential for culture of sandfish Holothuria scabra in Kenya was investigated based on a sample of 1000 wild individuals with an average weight of 40-80 g. This experiment was conducted to identify suitable methods of collection, transportation, acclimatization, and growth at different stocking densities. Packing methods tested during collection were oxygen filled plastic bags and open basins. For method 1, Sample 1 sandfishes were carried individually in oxygen filled plastic bags with sea water. Sample 2 included a total of five sandfishes per bag, and Sample 3 had a maximum of ten sandfishes. Under method 2 specimens were transported using open basins containing sand and aerated sea water in densities of 10, 20 and 30 individuals per basin. The mean (±SD) percentage evisceration rate during transportation in method 1 was 0 for a density of 1, 3.33 ± 5.77 % for a density of 5, and 20 ± 10 % for a density of 10. In method 2 evisceration occurred at all the three densities; 23.3 ± 15.28 % for the low density, 23.33 ± 2.8 % for the middle density and 36.6 ± 3.33 % for the higher density. The findings of this study provide information to contribute to the development of marine aquaculture of sea cucumber in Kenya.

Keywords: sea cucumber, *Holothuria scabra*, collection, transportation, acclimatization

Introduction

Sandfish *Holothuria scabra*, Jaeger 1883, has been classified as the most commercially valuable species of sea cucumber commonly found in tropical and sub-tropical countries (Conand and Muthiga, 2007). The species *H. scabra* has high grade of beche-de-mer (dried body wall) that over the years has commanded the highest prices in the international market (Purcell *et al.*, 2018). The main uses of the processed products from sea cucumbers include food applications, medicinal purposes, and as an aphrodisiac that are highly prized in Asian countries like China and Malaysia (Rahman, 2014). It has been sold in Hong Kong at prices ranging from USD 115-640 kg^{-1} dried (Purcell *et al.,* 2012). Due to these traits the organism has been vulnerable to exploitation resulting in a decline in populations in the wild that has rendered the species endangered. With the market being so lucrative worldwide, fishermen are searching for and expanding to new fishing grounds (Rahman, 2014).

Community-based sea cucumber fisheries have been on the increase in the Western Indian Ocean region in countries like Madagascar and Tanzania (Beltran-Gutierrez *et al*., 2014; Robinson and Pascal, 2012). The main attributes of the fishery include the sedentary behavior of sea cucumbers, high product value, low processing cost and huge international market which is mostly in Asian countries (Lovatelli *et al.,* 2004; Bruckner, 2006; Conand and Muthiga, 2007). On the Kenyan coast, the sea cucumber fishery is mostly artisanal, where it has been in existence since the early 1900's but there has been no tradition of consuming sea cucumber in Kenya. The fishery involves collecting sea cucumbers either as bycatch or targeting them through hand picking and fishing by using snorkel or

SCUBA equipment (Conand and Muthiga, 2007). The processed sea cucumbers are purchased by dealers at the landing beaches who in turn sell the products to exporters based in the county capital of Mombasa who then export to Hong Kong. The major landing beaches for *H. scabra* are on the southern coast of Kenya in Vanga, Shimoni and Majoreni.

Studies have shown that over 50 species of tropical sea cucumbers have been commercially exploited and traded including *H. scabra,* the most valuable sea cucumber species exploited in tropical areas (Purcell, 2010; Purcell *et al*., 2012). Other holothurians facing high exploitation are *H. fuscogilva* and *H. nobilis,* which are also found in Kenyan waters and are highly valued (Conand and Muthiga, 2007). Overexploitation in the sea cucumber fishery has created a worldwide management concern with the main reasons being worldwide demand, high value, serial local depletions, and fishermen migration to new fishing areas (Lovatelli *et al.,* 2004). A study by Uthicke (2004) states that the slow nature of sea cucumber population recovery after depletion has led to a situation that has compromised sustainability. Further research by Hasan (2005) and Friedman *et al.* (2011) found that a heavily exploited sea cucumber population could take more than 50 years to recover. In addition, low *H. scabra* densities may decrease chances of successful spawning thus impeding population recovery and increasing the risk of an Allee effect (Bell *et al*., 2008).

From the aforementioned discussion it is clear that sea cucumber have been under intense fishing pressure, warranting need for effective conservation measures. The organisms provide an important contribution to livelihoods of coastal communities which has fostered the need for domestication to ascertain viability of culture and farming options. Further, cultivation of *H. scabra* has increasingly become necessary to support stock enhancement programmes (Giraspy and Ivy, 2005) and to meet the export market demand (Purcell *et al*., 2012). Domestication will protect the organisms from identified threats such as habitat destruction and unsustainable fishing until the sea cucumbers reach marketable size or a minimum size for restocking. Hatchery production of *H. scabra* has been carried out in different countries across the globe (Kumara and Dissanayake, 2017). Other countries have initiated restocking and sea ranching (Purcell *et al.,* 2012; Eriksson *et al*., 2014; Watanabe *et al*., 2014). In China, *H. scabra* aquaculture has achieved milestones where 5 g juveniles have been produced and cultured to commercial harvestable adults of 300 to 500 g weight (Purcell and Wu, 2017). Studies have shown that success of *H. scabra* aquaculture is limited to hatchery production with reliance on viable broodstock collected from wild populations (James, 2012).

Hatchery production of *H. scabra* juveniles relies on control of broodstock collection, maintenance, spawning, fertilization, larval rearing, and post larvae settlement rearing (Hamel *et al*., 2022). For domestication purposes, transportation of wild collected individuals is essential and it follows different procedures which vary from one hatchery to another (Hamel *et al*., 2022). Studies by Battaglene (1999) mentioned that sea cucumber collection needs to be done under minimal salinity and temperature variations to avoid evisceration during transport. In other studies, individuals have been placed individually in oxygen filled bags with seawater (Ito, 2014; Abidin *et al*., 2016; Kumara and Dissanayake, 2017). Studies by Tuwo *et al* (2019) assessed the evisceration rate of *H. scabra* using closed and open transportation modes and their findings showed that evisceration was triggered by the presence of decaying individuals in the transportation bags that had eviscerated before transport. Acclimatization in pre-prepared holding tanks aids in the quick recovery of *H. scabra* individuals that survive during transportation (Hamel *et al*., 2022).

In Kenya, there has been no culture trials of *H. scabra* so far. The aim of this study was therefore twofold; to identify a suitable method of sea cucumber transportation, and to understand and establish optimal acclimatization conditions at different densities. This article documents the first attempts made towards domestication of sea cucumber in Kenya as initial steps towards *H. scabra* culture for natural stock enhancement and as an opportunity for an alternative livelihood for the fisher communities.

Materials and methods

Experimental design

The study tested conditions for sea cucumber transportation and acclimatization. Two transportation modes were investigated including varying packing methods and sandfish density. Plastic aerated bags were used for Method 1 (closed model) and aerated open basins for Method 2 (open model). The treatment had three replicates for both methods. Potential evisceration using both methods was monitored while transporting the sea cucumbers. Water quality parameters including salinity, temperature, dissolved oxygen, pH, total dissolved solids (TDS) and conductivity were monitored before transport, during transport and also within the culture facility by using a multi-parameter meter kit (Hanna Instruments). After acclimatization, a three-month study was designed using a portion of the sea cucumbers that survived during transportation to determine growth performance at three different stocking densities (5, 10, and 15 individuals) with replicates in flow through culture tanks.

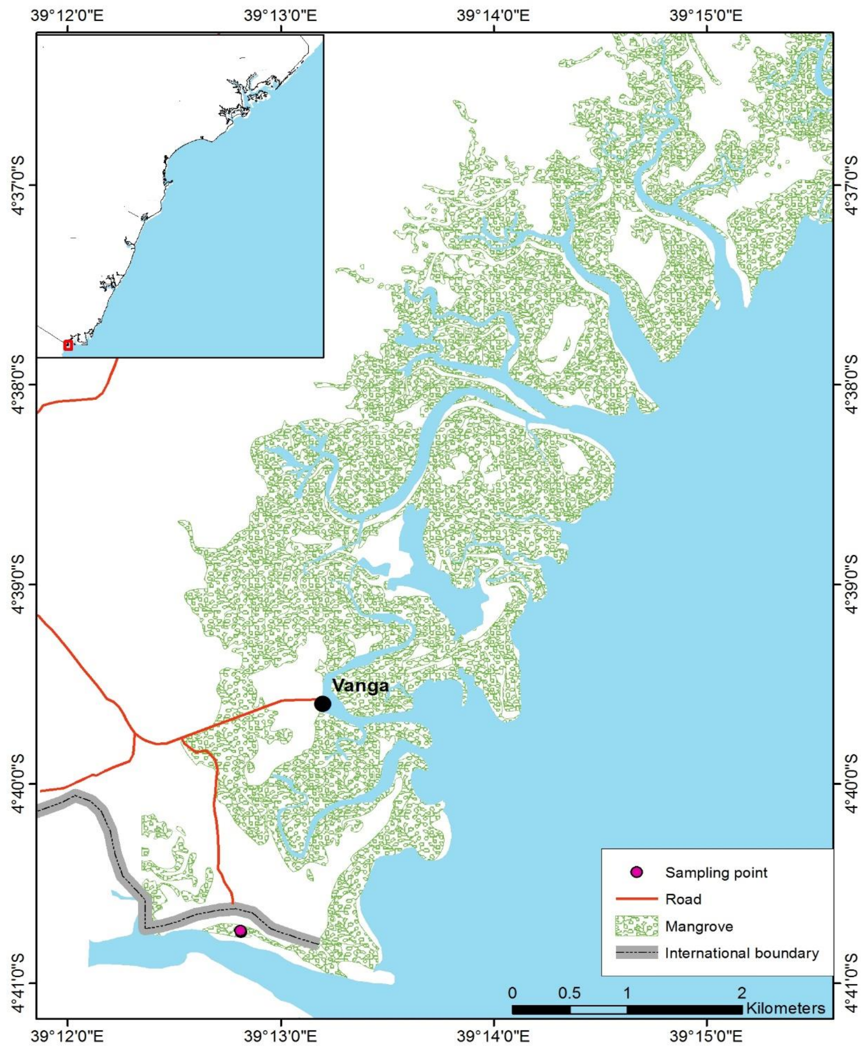

Figure 1. Collection site of the experimental organisms.

Culture site and systems

The marine hatchery at Kenya Marine and Fisheries Research Institute (KMFRI) located 5 km from Mombasa town (GPS 4.0552°S and 39.6821°E) was used as the experimental site to conduct the *H. scabra* hatchery trials. A concrete outdoor tank measuring 5m x 3m x 1m was used as a holding facility for the *H. scabra* specimens collected from the wild. The bottom of the tank was covered with 15 cm of sand to provide the sandfishes with an environment that simulated their natural habitat. This provided a burrowing medium to allow for their usual behavioral patterns as well as to provide a source of food and shelter from adverse environmental conditions and sometimes predation (Wiedemeyer, 1992; Mercier *et al.*, 2000). The holding tank was continuously supplied with seawater extracted from a borehole with a salinity of 27 ppt and a temperature of 25 °C. An air blower maintained continuous aeration to the water as the sandfish acclimatized for a period of two weeks before subjecting them to different experimental treatments.

Collection of specimens

During this study a total of 1000 individuals with an average weight of 40 g to 80 g were collected in four trips from the Jimbo area of Vanga ward based at Kwale County, Kenya (Fig. 1), with 250 individuals collected per trip,. Transportation was carried out by road for four hours to the hatchery at KMFRI. Local sea cucumber fishermen with indigenous knowledge about the fishery were engaged to do the collection through hand picking at low spring tide during the dark moon phase after obtaining a permit from the Kenya Wildlife Service (KWS).

Handling of collected organisms

The sampling points were chosen based on ease of accessibility and availability of the organisms within the sandy seagrass beds. Upon arrival and after retrieving the sandfishes, the water quality parameters of the sea water that was used to hold the organisms were measured including salinity, temperature, dissolved oxygen, pH, TDS and conductivity. These were taken at 1:00 am using a multi-parameter kit followed up by counting and packing the organisms for transportation. The animals were carefully handled to avoid evisceration, then they were cleaned by washing their body with seawater in preparation for transportation using the two test methods.

Transportation

The first experiment (Method 1) was carried out by packaging the sea cucumbers in 10 l plastic bags at densities of 1 individual per bag, 5 individuals per bag, and a maximum of 10 individuals per bag. The plastic bags used were transparent and filled in with 4 l of seawater. Each treatment had three replicates. Pure oxygen was used to inflate the packaging bags after adding water and sandfishes. The ratio of oxygen to water was 40 % to 60 %. The bags were sealed with a rubber band and placed in a 1 m^3 plastic tank quarter-filled with seawater to maintain a temperature within the range of 24 to 26 °C in the bags during the four-hour trip to the KMFRI hatchery. The collection was carried out on four different occasions. The second transportation mode (Method 2) entailed the use of 20 l open basins filled with a layer of sand and half-filled with seawater. Individuals of average size were cleaned with sea water and placed in the transportation basins at a density of 10, 20 and 30 individuals per basin. A battery pump (E-jet BP-3) was used to aerate the water in the basins during transportation. Table 1 shows the treatment detail of sandfish during transportation.

Acclimatization

Upon arrival at the KMFRI hatchery, the test organisms were checked for mortality and evisceration that might have occurred during transport. The test organisms were acclimatized while still in the transport bags with ambient culture water for 30 minutes and later transferred to the holding tank with running oxygenated sea water from the KMFRI borehole. Water quality parameters of the holding tank were monitored using a multi-parameter meter kit before releasing the organisms from the transport bags.

Acclimatization was carried out by carefully placing the basin inside the holding tank and slowly introducing the water and releasing the sea cucumbers. Water quality was monitored on a daily basis in the morning and afternoon while allowing water to flow into the holding tank. The organisms were left to rest and recuperate for a day after which feeding was introduced gradually from day two while still monitoring the water quality parameters at 9 am and 4 pm daily. Feeding of all sea cucumbers was carried out once a day by applying portions of seaweeds mixed with broken pellets and also by using muddy sand collected from mangroves, mixed with the sand substrate in the holding tank. This was done in order to test feed acceptability for one week, after which a daily feed ration of 3 % body weight per day (Broom *et al.*, 2021) was introduced.

During the acclimatization period, the water exchange rate in the holding tank was maintained at 50 % per day to remove waste and supply oxygen. Periodic cleaning of the tank was carried out fortnightly with renewal of the sand substrate according to Purcell *et al*. (2012) and

Table 1. Treatment detail of sandfish during transportation.

Transport model	Treatment	Density	Replicates
Open model	Low density	5	3
Open model	Medium density	10	3
Open model	High density	15	3
Closed model	Low density	10	3
Closed model	Medium density	20	3
Closed model	High density	30	3

Table 2. Evisceration rate of broodstock during transport using the two trial methods.

Sandfish density	Number of sandfishes that evicerated		
(Individuals/Bag or basin)	Replicate 1	Replicate 2	Replicate 3
Method 01			
1.1 (1)	0	0	0
1.2 (5) 0 0 1	0	0	1
1.3 (10) 2 3 1	2	3	1
Method 02			
1.1 (10) 2 4 1	2	4	1
1.2 (20) 5 5 4	5	5	4
1.3 (30) 12 11 10	12	11	10

Duy (2011). Mortality in the acclimatization tank was recorded every day.

Monitoring of sea cucumber growth at three different stocking densities

After acclimatization, the growth rate of test organisms was observed for three months in different stocking densities of 5, 10 and 15. Total Length (TL) and total weight measurements were recorded after every two weeks using a string and meter ruler and an analytical weighing balance with the precision of 0.01 g to obtain length and weight gain in grams. The Specific Growth Rate (SGR) of the three stocking densities was calculated as described by (Novoa *et al.*, 1990) as follows:

$$\text{Specific growth rate (SGR)} = \frac{\text{Log}_e\,\text{(final weight)-log}_e\,\text{(initial weight)} \times 100\%}{\text{Culture Days}}$$

Data analysis

Comparisons of the different treatments for transportation Methods 1 and 2 and among the sandfish density treatments were analyzed by calculating the mean values of different variables and expressing the results in table and graphical formats. Statistical analyses such as the T test were conducted using Excel version 2013 to test the equality of means. Data are presented as mean (±SD). Prior to the analysis, data sets were examined for normality and homogeneity of variances with an F test. Results were considered significant at $p < 0.05$.

Results

Evisceration rate of the sandfish for the different methods and different densities is shown in Table 2. The mean (±SD) percentage evisceration rate of the collected stocks of *H. scabra* in Method 1 was 3.33 ±5.77 % for the density of 5, and 20 ± 10 % for the density of 10 as shown in Table 3. Density 1 had no evisceration. In Method 2 evisceration occurred at all the three densities; 23.3 ±15.28 % for the low density of 10 individuals, 23.33± 2.8 % for the middle density of 20 individuals, and 36.6 ± 3.33 % for the higher density of

Table 3. Evisceration of *H. scabra* transported by Method 1 showing the mean and standard deviation (SD).

NO	Bag No	Density in bag	Evisceration in bag	
			Σ	%
1	5	1	0	0
2	4	1	0	0
3	10	1	0	0
	Average		0	0
	SD		0	0
1	8	5	0	0
2	6	5	0	0
3	3	5	1	10
	Average		0.33	3.33
	SD		0.58	5.77
1	9	10	2	20
2	7	10	3	30
3	1	10	1	10
	Average		2	20
	SD		1	10

Table 4. Evisceration of H. scabra transported by Method 2 showing the mean and standard deviation (SD).

NO	Basin no	Density	Evisceration in basin	
			Σ	%
1	3	10	2	20
2	5	10	4	40
3	4	10	1	10
	Average		2.33	23.33
	SD		1.53	15.28
1	2	20	5	25
2	6	20	5	25
3	1	20	4	20
	Average		4.67	23.33
	SD		0.58	2.89
1	9	30	12	40
2	7	30	11	36.67
3	8	30	10	33.33
	Average		11	36.67
	SD		1	3.33

30 individuals as shown in Table 4. The sea cucumbers that had been packed in plastic bags were assessed and found to be in good state except for the eviscerations in the replicate bags carrying 10 individuals. While assessing the second method of transportation using the open basin it was found that eviscerations occurred in every basin. The individuals in the Sample 3 basin that carried 30 individuals appeared weak on arrival, and experienced more evisceration. However, they became more active after putting them into the acclimatization tank. Sample 1 which had 10 individuals had the least number of eviscerations among the replicate basins. Statistical analysis proved that a significantly higher rate of evisceration occurred when *H. scabra* specimens were transported in aerated open basins (t-test, $p<0.05$, n=6).

Twenty sea cucumbers died on the fourth and sixth day during the first three weeks of acclimatization. Water quality parameters collected before transport, during transport and in the culture facility are presented in Table 5. Temperature, pH, salinity, transparency, and dissolved oxygen did not show marked variations between the treatments during transportation and acclimatization.

The stocking density treatments showed a 100 % survival of the test organisms. The final mean weight of sea cucumbers stocked at a density of 5 in plastic tanks was the highest at 88.96 ± 4.09 g compared to the stocking density of 10 and 15 which had a final mean weight of 60.93 ± 21.11 g and 46.91± 1.11 g respectively. The weight gain of sea cucumbers stocked in different stocking densities of 5, 10, and 15 decreased with an increase in stocking density (Table 6; Fig. 2). The specific growth rate of sea cucumbers stocked at a density of 5 was 1.03± 0.56 g followed by 0.22± 0.41 g for the stocking density of 10 and -0.37 ± 0.02 g for the stocking density

Table 5. Water quality parameters taken during the three-week acclimatization period showing the mean and standard deviation in the morning and evening.

Water quality parameters	Morning	Evening
Temperature (°C)	25.62 ± 0.25	25.86 ± 0.38
Salinity (ppt)	27.27 ± 0.45	27.17 ± 0.25
TDS (mg/l)	27624.13 ± 0.32	27517.93 ± 0.55
DO (mg/l)	4.52 ± 0.42	4.63 ± 0.38
Conductivity (mmho/cm)	42795.93 ± 0.28	42156.23 ±0.3
pH	8.49 ± 0.22	7.77 ± 0.24

Table 6. Results of analysis for the initial weight (IW), final weight (FW) and weight gain (WG) in grams, and specific growth rate (SGR) for three stocking densities (ind./m3) in replicate tanks. Data are represented as mean ± standard deviation.

Stocking Density	IW	FW	%WG	SGR
5	39.07 ± 16.76	88.96 ± 4.09	184.56 ± 1.33	1.03 ± 0.56
10	42.13 ± 0.2	60.93 ± 21.11	29.47 ± 45.34	0.22 ± 0.41
15	55.21 ± 0.31	46.91 ± 1.11	-28.06 ± 0.7	-0.37 ± 0.02

of 15 sea cucumbers (Fig. 3). The test organisms showed a high acceptance of the mangrove mud as a feed as compared to the seaweed and pellet mixture.

Discussion

During this study transportation took place at night to avoid high temperature fluctuations. The sandfish that were transported in open basins were higher in density and most likely the shock and friction from the walls of the transporting basins could have exposed the sandfishes to greater stress during the four-hour transport time as compared to those that were packaged in lower densities in oxygenated polythene bags. The study indicated that with the 40-60 % ratio of oxygen to water used, 0 evisceration, 3 % and 20 % evisceration occurred at the low, middle, and high sandfish densities in Method 1. In Method 2, an evisceration rate of 23 %, 23 %, and 36 % was experienced with the low, middle, and high densities. From this analysis the middle density seems to be most appropriate for transportation from a cost effort benefit perspective. Oxygenation is therefore essential for long distance transportation as results show low evisceration rates in samples that had oxygen provision (Ito, 2014; Tuwo *et al*., 2019).

Of the total transported individuals, 2 % mortality (20 individuals) occurred in acclimatization tanks. Upon investigation these individuals seemed to have been injured during collection and transportation and while adapting to the new tank culture conditions. The findings of the study indicated that the open basin model did not work well as evidenced by the high evisceration during transport which was attributed to shock and friction of basin walls as compared to the aerated plastic bags. This is in accordance with the findings of Tuwo *et al.* (2019).

The physico-chemical parameters monitored during the acclimatization period (Table 5) were within the optimum range required for sea cucumber rearing (Agudo, 2006). Wild collected holothurian species have been observed to eviscerate as a reflex response to danger, adverse environmental conditions and handling stress that makes them release their internal organs to the surrounding environment (Battaglene *et al*., 2002). In this study, most organisms were found to be in good condition since most did not eviscerate. However, viscera were always removed from the water once noticed during transport in order to maintain good water quality and the well-being of the sea cucumbers. Studies have shown that *H. scabra* are relatively hardy organisms that can tolerate low dissolved oxygen levels (Agudo, 2006).

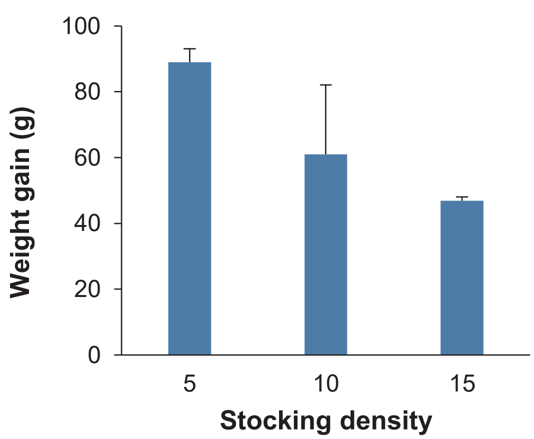

Figure 2. Weight gain in grams of sea cucumber in different stocking densities with standard deviation indicated for each density.

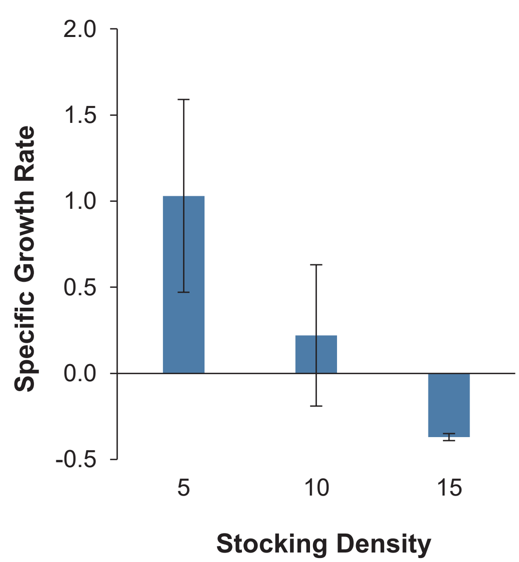

Figure 3. Specific growth rate (SGR) in different stocking densities with standard deviation indicated for each density.

However, provision of aeration is essential during long distance transportation in order to overcome the stress encountered during fishing, manipulation at packaging and while transporting.

Holothuroids including *H. scabra* are deposit feeders and studies have shown that they normally take the available food from their surrounding by ingesting deposited materials on the surface of the substrate (Roberts *et al.,* 2000). In this study the feeds were introduced to the tank in areas where the sandfishes were observed to aggregate. Active feeding was not observed during the day. The organisms consumed the feeds on the sand substrate mostly at night when they are believed to be most active (Hamel *et al*., 2022). The feeds given were observed to reduce in quantity and topping up was done in small portions while taking care of the water quality in the culture facilities.

The current study revealed that sea cucumber survival was not dependent on stocking density after all treatments recorded 100 % survival. Stocking density was seen to be a factor in sea cucumber growth rate (Battaglene *et al*., 1999, Pitt and Duy, 2004, Lavitra *et al*., 2010). High growth rate was observed in treatments with low stocking density and the lowest in the high stocking density treatments. Competition for resources and space could have attributed to the varied growth rates observed (Davies *et al*., 2011, Slater and Carton, 2009). Improved growth rates of sea cucumber in low stocking density as seen in the present study were also observed in other studies on *H. scabra* (Battaglene *et al*., 1999; Beltran-Gutierrez *et al*., 2014).

The average daily growth rate of the 5 stocking density treatment in the current study was seen to range from 0.47-1.59 g which appeared to align with the results of Davies *et al.* (2011) who reported growth rate of 0.06-1.39 g in Zanzibar, and Beltran-Gutierrez *et al.* (2014) who reported rates of 1.6 and 0.9 g. The slight growth rate difference could have been attributed to the initial stocking weight of the organisms used (96 ± 31 g) for Beltran-Gutierrez and (39.07 ± 16.76 g) for the current study. Lower growth rates of sea cucumbers were observed in the higher stocking densities as observed by Pitt *et al*. (2004) who recorded a growth rate of 0.24 g at a stocking density of 10 ind./m-^{2}, while Battaglene *et al.* (1999) and Asha and Diwakar (2013) reported an average growth rate of 0.2 g at a stocking density of 10 ind./m2. In this study, the weight gain of the sandfish decreased with an increase in stocking density.

The findings of this study show that transport method and sandfish density affect evisceration rate. However, appropriate handling before and during transportation can increase survival even at high densities. The study further gives important information for future mariculture development in Kenya, Africa and the world. Stocking density could be of importance for initial domestication. However, gaps still remain in assessing growth of sea cucumber under different culture conditions.

Conclusions

Aquaculture of sandfishes remains the most viable option to ensure the sustainability of these species and this formed the key motivation for the current study. It is concluded that proper handling during broodstock collection, packaging, and transportation using oxygenated packaging bags reduced stress levels of the organisms. Low stocking densities contributed to high growth rates of sea cucumbers. Diversification into the culture of marine organisms like sea cucumber can be a potential livelihood for coastal communities in Kenya; especially women in self-help groups. Therefore, embracing sea cucumber culture as an alternative livelihood should be a priority on the Kenyan coast. From the findings of this study, it is recommended that further research be carried out on optimizing transport practices and stocking densities, assessing the efficacy of oxygenated closed bags as opposed to non-oxygenated closed bags, and optimizing cost-effort-efficiency transportation methods.

Acknowledgements

The authors would like to thank the Director General of KMFRI and the management for financial support that enabled us to undertake the study successfully. Assistance given by staff members of the mariculture department is gratefully acknowledged. We appreciate the Laboratory Technician Mwendwa Mbaluka, and student interns Mr David Midumbi and Mr Boniface Busolo for their enormous support in the field; working long into the night during collection, transportation and handling during acclimatization of the *H. scraba* samples.

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