Muumin I. Hamad et al. / Afr.J.Bio.Sc. 1(4) (2019) 32-41.
https://doi.org/10.33472/AFJBS.1.4.2019.32-41

ISSN: 2663-2187

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper

Open Access

Comparative growth and survival performance of sea cucumber (*Holothuria scabra*) in co-cultured pen system with commercial macroalgae

Muumin I. Hamad[1]*, Augustine W. Mwandya[2], Renalda S. Munubi[3], Sebastian Chenyambuga[4] and Heiromin A. Lamtane[5].

[1]Assistant Lecturer, Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, Morogoro, Tanzania. E-mail: Muumin1m@hotmail.com
[2]Augustine W. Mwandya, Senior Lecturer, Sokoine University of Agriculture, Morogoro, Tanzania. E-mail: mwandya@yahoo.co.uk
[3]Lecturer, Sokoine University of Agriculture, Morogoro, Tanzania. E-mail: rmunubi@gmail.com
[4]Associate Professor, Sokoine University of Agriculture, Morogoro, Tanzania. E-mail: chenyasw@yahoo.com
[5]Senior Lecturer, Sokoine University of Agriculture, Morogoro, Tanzania. E-mail: hlamtan@yahoo.co.uk

Article Info

Volume 1, Issue 4, October 2019
Received : 03 June 2019
Accepted : 17 August 2019
Published : 01 October 2019
doi: 10.33472/AFJBS.1.4.2019.32-41

Abstract

Mariculture has recently been adopted in many parts of coastal East Africa as a source of income and employment to many women and heartbroken fishermen who are the main victim of dwindling wild stock of aquatic resources. The sea cucumber (*Holothuria scabra*) has for long time been collected and sold as export marine product. Macroalgae (*Eucheuma denticulatum* and *Kappaphycus alvarezii*) are the common cultured seaweed species that provide hope for future increase in mariculture production. An experiment was conducted along the intertidal lagoon of Unguja Ukuu village in Zanzibar to assess the survival and growth performance of sea cucumber (*H. scabra)* in two separate pens under co-cultured systems with *E. denticulatum* and *K. alvarezii.* Juvenile sea cucumber *H. scabra* with mean weight (± se) of 67.18 ± 2.06 were integrated with the two common commercial seaweed in pen system for 10 weeks. The results revealed that the growth rate and survival of *H. scabra, E. denticulatum* and *K. alvarezii* were better under integration system. The growth of *H. scabra* was higher (1.038 g d^{-1}) in pen systems co-cultured with *K. alvarezii* compared to 0.898 gd^{-1} in pen systems co-culture with *E. denticulatum*. Survival rate of *H. scabra* was higher (76%) in the pen systems co-cultured with *E. denticulatum* compared to that (70%) observed in pen systems co-cultured with *K. alvarezii*. The results suggest that the best integration of sea cucumber and macroalgae is between *H. scabra* and *K. alvarezii.* However, reliable source of *H. scabra* juvenile is essential for the future expansion of pen co-culture system.

Keywords: *Mariculture, Seacucumber, Macroalgae, Co-culture*

© 2019 African Journal of Biological Sciences. This is an open access article under the CC BY license (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

1. Introduction

Seaweed (*Eucheuma denticulatum* and *Kappaphycus alvarezii*) farming in coastal areas like Zanzibar has become the solitary income source to many women and fishermen whose main income was obtained from capture fishery, which has now experienced a dwindling decline. Seaweed farming was introduced in Zanzibar about two decades ago as a research trial. Following its astonishing growth performance, many coastal communities got involved into the business (Hayashi *et al.*, 2010). Nowadays seaweed farming is practiced in

* *Corresponding author: Muumin I. Hamad, Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, P.O. Box 3004, Morogoro, Tanzania. E-mail: muumin1m@hotmail.com*

2663-2187/© 2019 African Journal of Biological Sciences. All rights reserved.

Electronic copy available at: https://ssrn.com/abstract=3467424

every village along the coast of Zanzibar Island and more than 170 hectares are used adjacent to every farming village (Frocklin *et al*., 2012). In Zanzibar two species *E. denticulatum* and *K. alvarezii* are commonly cultured. Though seaweed farming is given high priority by coastal people in Zanzibar, farming activities are still of small-scale and many farming sites are located close to the shore within intertidal lagoons. Recently, seaweed farming under small-scale farming system has been reported to face a number of challenges, specifically low production and poor quality of the product (Hayashi *et al.,* 2010). Low price due to poor product quality as a result of poor farming technology puts farmers' expectations from this business into delusion (Msuya *et al*., 2014). Beside several setbacks that seaweed farming business is experiencing in Zanzibar, still this small island is the leading seaweed producer in the region (Msuya, 2002) and contributes 5% of the global seaweed supply (FAO, 2010).

Recently changes in local climate have been observed in Zanzibar and the devastation from these changes in global climate threatens the growth of seaweed (Bryceson, 2002). Another challenge that has recently been observed is that, increase in seaweed farming activities has resulted into competition for land use along the intertidal area where almost all other mariculture, fishing and tourism activities are taking place (Bryceson, 2002). This threatens the future expansion of the business. Considering the value of seaweed farming to local community in Zanzibar, new farming inventions and technologies that will not only improve production, but also increase farmers income to pay off their labor and time they spend in the water is needed. In the last decade, integration of seaweed with marine fish or shellfish has been practiced and studied in many parts of the world (Troell *et al*., 2003). Recently there been several trials to test the validity of this system in Tanzania (Davis *et al*., 2011; and Beltran, 2014).

Apart from seaweed farming, for about a century, there has been an active sea cucumber fishery within the East African coast and along Western Indian Ocean region (Muthiga, 2010). Tanzania, including Zanzibar, is involved fully into this history of collecting sea cucumber for production of Beche-der-mer to feed the Asian dry sea food market (Eriksson *et al*., 2012). Increasing demand of this precious product in the Asian market and drastic decline in the wild capture due to over exploitation have raised an ecological and economical attention to many coastal venders. In recent year, efforts for sea cucumber farming along the region have been made (Eriksson *et al*., 2012). Sea cucumber farming has recently been adopted and considered as an important mariculture component along the East African coastal region, especially in Tanzania (Bryceson, 2002). Sand fish *Holothuria scabra* has proved to be the best farmed species as it has ability to sustain the rough condition of intertidal area and shallow lagoon (Giraspy and Walsalam, 2010). Farming of sea cucumber in Tanzania is going together with other old mariculture practices of finfish and seaweed farming (Eriksson *et al*., 2012).

Sea cucumber farming is considered as an economically viable business. However, in recent years sea cucumber production has become so complex and for several decades now, many coastal countries and the world at large have been struggling for appropriate production systems to sustain production (FAO, 2014). The challenges to sustainable sea cucumber production have been linked to the technology and commercial point of view. Although technology and system for sea cucumber production have for several decades been invented, most farmers have not adopted the improve reliable farming technology / system (Chopin *et al*., 2001). When searching for the best approaches for modern and profitable sea cucumber farming system and the mitigation of farming impacts to the environment, two main practical approaches are considered positively, farming indoor using biological water purification or integrating farming system.

Integrated Multi-Trophic Aquaculture (IMTA) is considered as a suitable and profitable mariculture system (Purcell *et al*., 2006). IMTA has proved to be the best method for integration of sea cucumber farming and it maximizes space utilization. IMTA system is becoming increasingly popular and it has been adopted by many coastal farmers as the system guarantee double harvest and occupy a very little area, hence, reduces competition between aquaculture and other form of coastal economic activities (Chopin *et al*., 2001). There are several published successful IMTA trials around the globe which proves its potential for economic profitability and environmental solution over monoculture system (Buschmann *et al*., 2008; Chopin *et al*., 2001; and Troell *et al*., 2003).

Integration of sea cucumber (*H. scabra*) and seaweed farming is desirable because sea cucumbers are deposit benthic feeders and seaweed is autotrophic macroalgae that can filter nutrients and creates nutrient balance around cultured area (Slater and Carton, 2009). Thus, there is every reason that, integration of these two species is a viable option and can benefit both the farming environment and farmers. Sea cucumbers provide relief to the farmers as the animals depend on the organic matter, hence, reduce the cost of production by 50% (Slater and Carton, 2009). On the other hand, seaweeds utilize nutrients from the sea cucumber while themselves

Electronic copy available at: https://ssrn.com/abstract=3467424

create shading and nutrient settlement to sea cucumber. IMTA of the two species of seaweed (*K. alvarezii and E. denticulatum)* and sea cucumber in a pen is an important route for increasing production and can be adopted as an alternatives farming method for rapid and sustainable aquaculture development in the coastal areas of Tanzania. The present study intended to investigate the implications associated with biology and ecological aspects of co-cultured seaweed (*K. alvarezii* and *E. denticulatum)* and sea cucumber (*H. Scabra*) under pen farming system. The main objective was to assess the survival and growth performance of the sea cucumber and that of the two species of cultured macroalgae (*K. alvarezii* and *E. denticulatum)*) when they are integrated with sea cucumber in the intertidal shallow water lagoon.

2. Materials and methods

2.1. Study area

The experiment was conducted in the southern part of Unguja Island, Zanzibar in the intertidal water of Unguja Ukuu village which is located about 25 km from Zanzibar town (Figure 1). The area is well-known for seaweed farming and collection of sea cucumber. Another advantage for this study site is that the area is under management of the Menai bay conservation area and has got favorable climatic conditions for seaweed and sea cucumber farming.

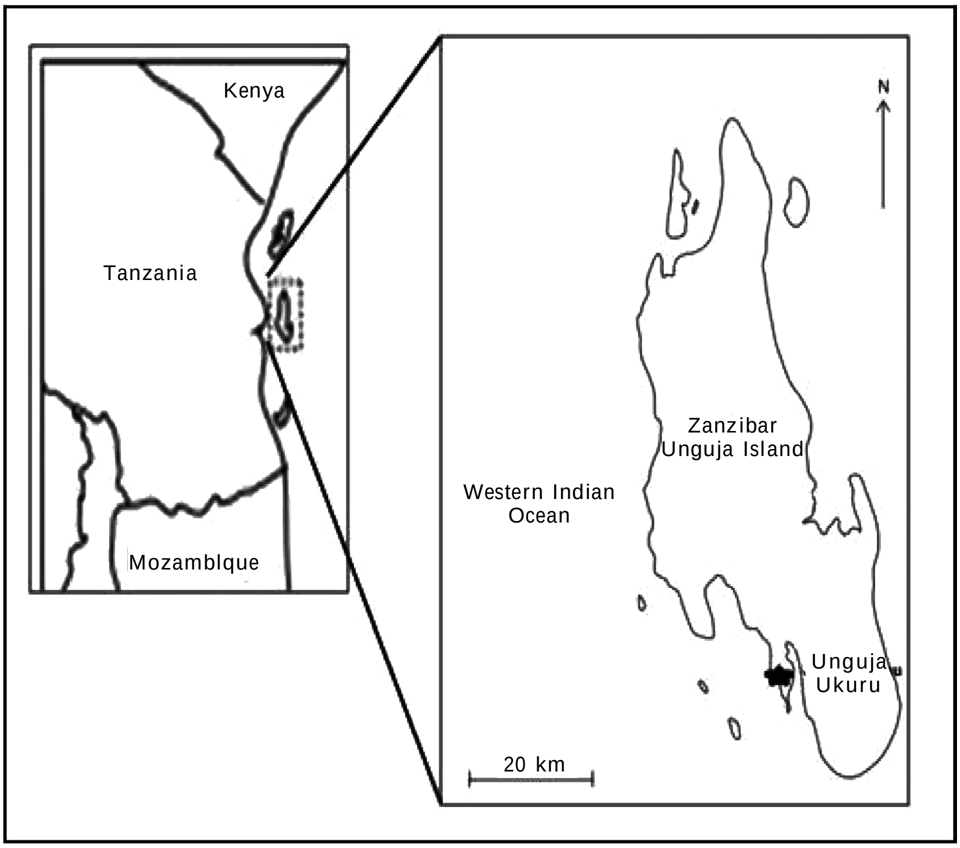

Figure 1: Map of Zanzibar Island, Tanzania showing study site

2.2. Experimental setup

A total of 18 pens, each with a size of 2 m × 1 m, were installed using net material with mesh size of 0.25 cm supported by wooden sticks. Pens were kept open at the surface to allow water circulation and at the bottom surface to allow cultured animal to utilize the bottom sediments. The experimental pens were installed at 500 m from the shore, the area where water level was about 0.75 m deep during low tide.

2.3. Macroalgae collection

Seaweed (*E. denticulatum* and *K. alvarezii*) were purchased from local farmers. The species were identified using identification manual of common cultured macroalgae. The macroalgae were purchased and stocked

Electronic copy available at: https://ssrn.com/abstract=3467424

not very far from the experimental area and all procedures were followed to prevent it from desiccation. For this experiment 25 kg of each species of seaweed was purchased, followed by weighing and cutting them into frond of 100 g and stocked in pens.

2.4. Sea cucumber collection

A total of 180 individuals of live sea cucumber *H. scabra* (Purcell *et al.*, 2012) medium-sized with average weight of 67.18 ± 2.06 SE were purchased from foot fishers and gleaners. The sea cucumber were then stored in a plastic bucket containing seawater, before and during measurement. The water in the bucket was exchanged regularly to ensure that the animals were supplied with oxygenated water to avoid stress. After measurement, the animals were stocked in one of the constructed pen and left for three days for acclimatization before they were put in the experimental pens.

2.5. Experimental design

A 2 x 3 factorial experimental layout was adopted. Pens were divided into two groups of nine pens per group. The first group had *E. denticulatum* co-cultured with *H. scabra* while the second group had *Kappaphysus alvarezii* co-cultured with *H. scabra*. Three treatments replicated three times were set for each group and off bottom tie-tie method was used for seaweed farming in the experimental pens. The treatments were seaweed farming without sea cucumber, seaweed farming with sea cucumber and sea cucumber farming without seaweed. In the first group, three pens were stocked with seaweed *E. denticulatum* at an average weight of 300 g per line and five lines were installed per pen making a total of 1,500 g without introducing sea cucumber inside the pens. Other three pens were stocked with seaweed weighing 1,500 g and were also stocked together with sea cucumber *H. scabra* at a density of five individuals / m^2. The last three pens were stocked with sea cucumber (*H. scabra*) only at a stocking density of five individuals / m^2 without seaweeds.

In the second group, three pens were stocked with seaweed *Kappaphycus alvarezii* at an average weight of 300 g per line and five lines per pen making a total of 1,500 g of seaweed per pen without sea cucumber. Other three pens were stocked with seaweeds weighing 1,500 g and were also stocked together with sea cucumber (*H. scabra)* at a stocking density of five individuals / m^2. The last three pens were stocked with sea cucumber (*H. scabra*) only at a stocking density of five individuals / m^2 without seaweeds. All experiments were run concurrently for 10 weeks.

2.6. Seaweed and sea cucumber growth assessment

Information on percentage survival of seaweed was collected throughout the experimental period. Measurement of growth and determination of survival of *H. scabra* was done after every two weeks while growth data of seaweeds were recorded after every six weeks. Initial weights of seaweed were measured and recorded at the beginning and then weight data were collected after 21 days. At the end of 42 days (two production cycles) seaweed biomass was measured to get final weight and weight gain was computed as the difference between initial and final weight. Specific Growth Rate (SGR) (%) was computed using the following formula: SGR = $[(\ln Wt - \ln Wt_0) / t] \times 100$; where Wt_0 is the initial weight at $t = 0$; and Wt is the weight at t cultivation days. Seaweed survival was calculated using the following formula; [(Total number of fronds remain during the cycle / Number of fronds planted) × 100]. For sea cucumber weights were recorded every two weeks and before every measurement the animals were kept on the surface for two minutes to allow them release the water from the stomach (Slater and Carton, 2007). During weight measurement, the pens were also inspected to estimate survival of the animal in the pens.

2.7. Assessment of water quality parameters

Surface Surface Temperature (SST) and salinity were recorded every day for 10 weeks at different points in the lagoon where the experiments were conducted. The measurements were taken twice per day, in the morning and late afternoon. Four points were demarcated and measurements were taken at the same time for both parameters (SST and salinity).

2.8. Organic matter

At the beginning of the experiment, sediment sample for the estimation of Total Organic Matter (TOM) were taken randomly from the surface (up to 3 cm depth) inside each pen before stocking sea cucumbers and then after eight weeks final sampling of sediment for TOM were taken. Sediment samples were immediately transported to the laboratory at the Department of Soil and Geological Sciences, Sokoine University of Agriculture for TOM analysis. Analysis was done using the ash method (Slater and Carton, 2009).

Electronic copy available at: https://ssrn.com/abstract=3467424

3. Results

3.1. Water quality parameter

Throughout the experimental period salinity ranged from 33 to 40‰ and the average value was 37.2 ± 1.35‰. The values for SST ranged from 27 to 30 °C with an average SST of 28.4 ± 0.509 °C.

3.2. Growth and survival performance of sea cucumber and seaweeds

The results revealed that the growth performance of sea cucumber (*H. scabra*) was higher (mean final weight was 132.18 ± 8.56 g) in pens co-cultured with seaweed (*E. denticulatum*) than in pens without seaweeds (116.83 ± 2.25 g). SGR was also found to be slightly higher (0.89 gd^{-1}) in pens where sea cucumbers were integrated with *E. denticulatum* than in pens without *E. denticulatum* (0.731 gd^{-1}). Results for weekly weight gain of individual sea cucumber were found to be higher in pens with *E. denticulatum* (99.84 ± 8.55 g) than in pens with sea cucumber only (76.97 ± 8.05 g). Individual weight differed ($p = 0.0151$) between pens stocked with *H. scbra* and *E. denticulatum* and pens stocked with *H. scabra* only (Figure 2).

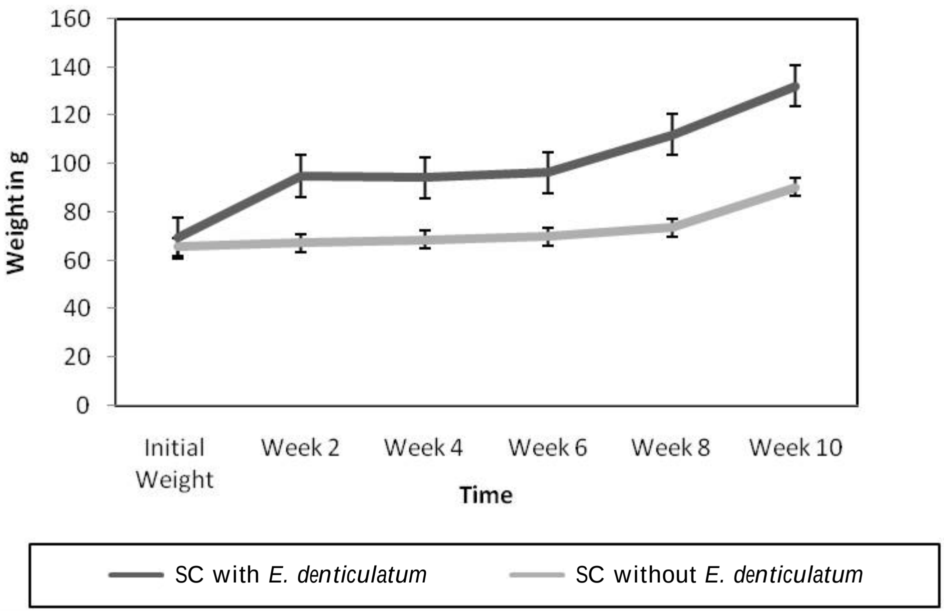

Figure 2: Comparison of mean (± SD) weekly body weight of individual sea cucumber co-cultured with *E. denticulatum* and without *E. denticulatum*

Similarly the survival of *H. scabra* was higher (80%) in pens in which it was co-cultured with *E. denticulatum* than in pens (76%) in which it was cultured without *E. denticulatum*. For the seaweed *E. denticultum*, both growth rate (7.31 g d^{-1}) and survival (58.89%) were higher in pens with *H. scabra* than in pens without *H. scabra* (growth rate = 6.801g d^{-1} and survival = 56.67%). However, the analysis of variance reveals no significant differences in growth rate among the treatments ($F = 2.81$, $p = 0.144$) (Figure 3).

The final biomass weight of *H. scabra* in pens co-cultured with *K. alvarezii* was higher (140.76 ± 10.16 g) compared to that recorded in pens (118.89 ± 6.94 g) without *K. alvarezii*. SGR was also higher (1.038 gd^{-1}) in pens with *K. alvarezii* than in pens without *K. alvarezii* (0.734 gd^{-1}). Results for weakly measurements revealed slight variation in growth rate between co-cultured *H. scabra* (93.62 g ± 10.16 g) and sea cucumber cultured without *K. alvarezii* (87.48 ± 10.16 g) (Figure 4). No significance difference on growth was observed between the treatments ($p = 0.377$).

The survival rate of *H. scabra* was higher (70%) in pens without *K. alvarezii* compared to 60% recorded in pens where *H. scabra* was cultured with *K. alvarezii*. For the seaweed *K. alvarezii*, the mean biomass yield per pen was higher (2891.57 ± 141.489 g) in pens with sea cucumber *H. scabra* compared to that observed in pens where *K. alvarezii* was cultured without *H. scabra* (2782.77 g ± 176.84 g). SGR was higher in pens with *H. scabra* (8.04% d^{-1}) than in pens without *H. scabra* (7.81% d^{-1}). Similarly the survival rate was higher (48.8%) in pens with *H. scabra* than in pens without *H. scabra* (46.6%). No significant difference was recorded between growth of seaweed *K. alvarezii* cultured with and without sea cucumber *H. scabra* ($p = 0.637$) (Figure 5).

Electronic copy available at: https://ssrn.com/abstract=3467424

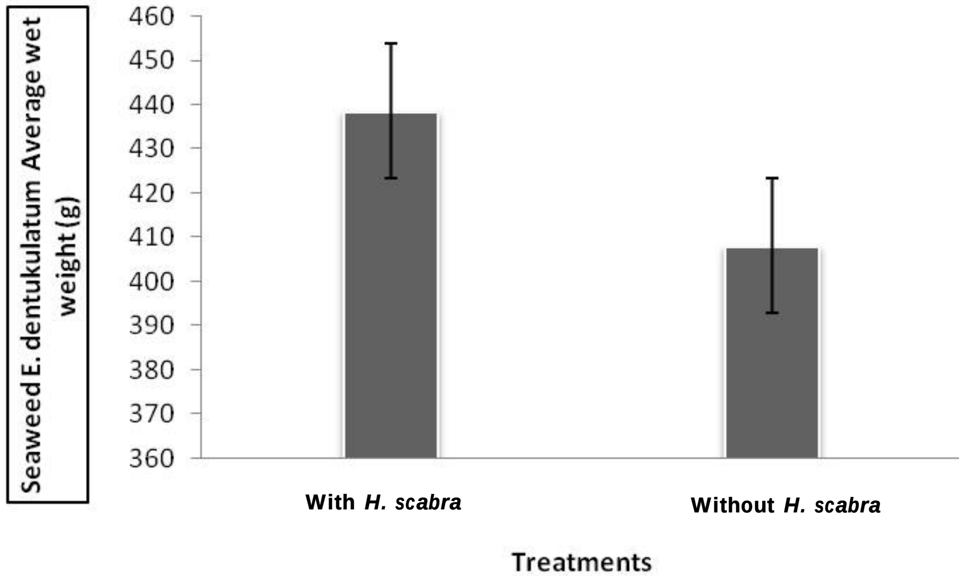

Figure 3: Mean (± SD) final wet weight of *E. denticulatum* co-culture with *H. scabra* and without *H.scabra* in one harvest cycle of eight weeks

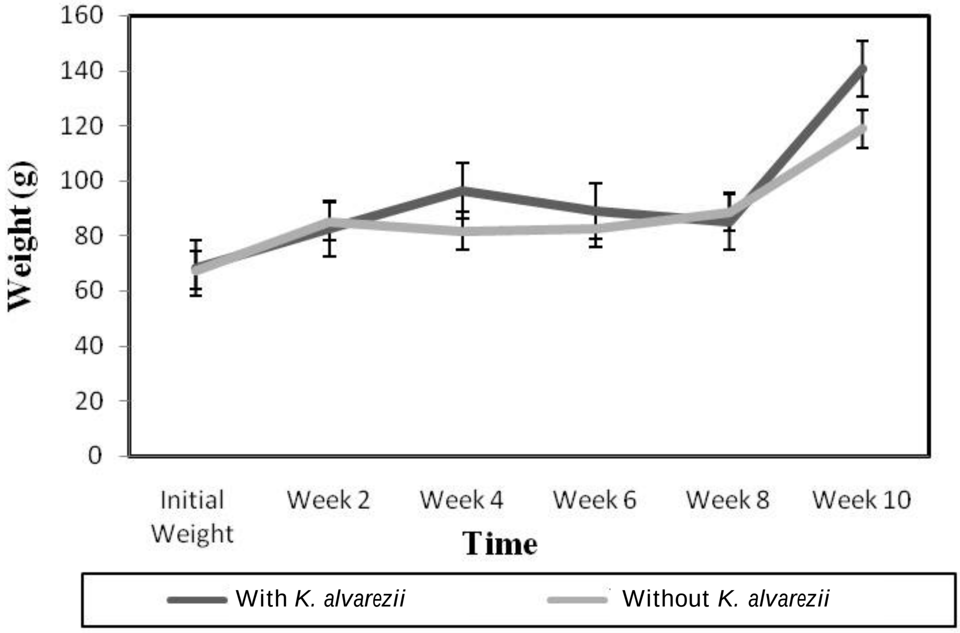

Figure 4: Comparison of average (± SD) weight gain of *H. scabra* co-cultured with *K. alvarezii* and *H. scabra* cultured in pens without *K. alvarezii*

3.3. Total organic matter in the sediments

The results show that the amount of organic matter (OM) in the sediments was higher (3.11 ± 0.01%) in pens stocked with seaweed *K alvarezii* only and significant higher OM was also recorded in pens with *E. denticulatum* (2.67 ± 0.05%). Significant difference in OM was observed among pens with sea cucumber *H. scabra* only and those in which *H. scabra* was co-cultured with sea weed (*K. alvarezii and E. denticulatum*) (p = 0.0015). Exception was observed in the samples collected outside the pen where there was almost no differences in OM content throughout the experimental period (Table 1).

Electronic copy available at: https://ssrn.com/abstract=3467424

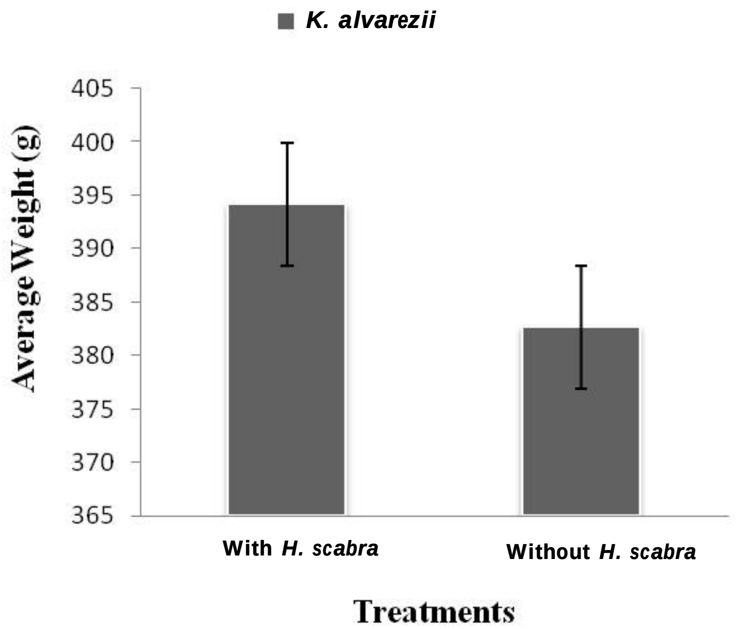

Figure 5: Mean (± SD) final wet weight of *K. alvarezii* co-culture with *H. scabra* and without *H. scabra*

Table 1: Comparison of mean % (± SD) surface organic matter content before and after the experiment among different treatments

Mean % Total Organic Matter (TOM) in the Sediments

Experimental Period (days)	Outside Cultured Pens	*E. Denticulatum* Only	*K. alvarezii* Only	*H. scabra* Only	*H. scabra* with *E. dentculatam*	*H. scabra* with *K. alvarezii*
Before	2.505 ± 0.015	2.505 ± 0.025	2.475 ± 0.015	2.51 ± .04	2.51 ± 0.03	2.425 ± 0.045
After	2.585 ± 0.035	2.665 ± 0.045	3.105 ± 0.005	2.37 ± 0.04	2.45 ± 0.01	2.34 ± 0.02

4. Discussion

Sea cucumber *H. scabra* can be co-cultured with commercial macroalgae as the results in this study show that *H. scabra* performed better under integration with both seaweed species. Although the growth performance of *H. scabra* varied between the two seaweed species (i.e., *K. alvarezii* and *E. denticulatum*), the observed growth and survival performance when they were integrated with the two seaweed provide evidence that IMTA is suitable for commercial production of seaweed and *H. scabra.*

The higher growth and survival rate of *H. scabra* observed when they were co-cultured in pens with *E. denticulatum* corresponds to the result reported by Davis *et al*. (2011) and Beltran (2014). High survival rate of *H. scabra* was noticed in both integrated pens and nonintegrated pens, although there was a slight different in survival of *H. scabra* in pens in which it was co-cultured with *E. denticulatum.* This finding indicates the ecological benefit of integration, as sea cucumber seems to benefit from the presence of seaweed for shading (hibernation) and accumulation of organic matter which is the best food for *H. scabra*. Similar results for positive growth of *H. scabra* and *Eucheuma* and *Gracilaria* sp was reported by Hamel *et al*. (2001), Madeali *et al*. (1993) and Tangko *et al*. (1993b). Although their results were obtained from open plyculture system, they correlate with the findings of the present study. High SGR of *H. scabra* observed when co-cultured with *K. alvarezii* is also another positive step toward adoption of IMTA of *H. scabra* and commercial macroalgae in Zanzibar. Similar results were reported by Beltran (2012) when *H. scabra* was integrated with seaweed in closed cages under various stocking density. The highest performance in growth of *H. scabra* in pens with *K.*

Electronic copy available at: https://ssrn.com/abstract=3467424

alvarezii corresponds to the higher amount of organic matter recorded in pens where *K. alvarezii* was cultured alone. The results suggest higher ability of *K. alvarezii* to trap organic matter in pens which could serve as source of food for *H. scabra*. Also high survival rate of *H. scabra* in pen with *K. alvarezii* could be influenced by stocking density as reported by Mills *et al.* (2012) and Pitt and Duy (2004). These authors strongly recommended that special consideration should be given on stocking density and suggested that better growth and survival performance can be attained when cucumbers are cultured at rate of 30 g per m^2. Stocking size of individual sea cucumber seemed to have positive impact on survival rate of *H. scabra* in pens. Hamel *et al*. (2001) observed that small and medium sized individuals actively remain in the sand in the intertidal water until they attain large size and move to deeper water.

Results show that *H. scabra* co-cultured with seaweed has slight effect on the growth of both species of seaweed. The observed higher growth of both *E. denticulatum* and *K. alvarezii* when co-cultured with *H. scabra* shows the potential of *H. scabra* as nutrient distributer due to its burrowing and feeding behavior (Wolkenhauer *et al*., 2010). However, the effect of nutrients recirculation and availability to the adjacent animal, in this case macroalgae, depend on the number of sea cucumber in a particular area. Higher growth results could have been obtained if stocking density was kept higher in the pens. Water parameter during the experimental period could also be a reason for low effects of *H. scabra* on the growth of seaweed. Msuya and Porter (2014) observed that optimal growth of seaweed can be obtained at 23 -30 °C, and growth declines at the temperature below 20 °C and above 30 °C. The lowest survival of seaweed, specifically *K. alvarezii* could be due to the effect of season as the experiment was conducted during the rainy season when water temperature and salinity in the lagoon was very low and varied significantly during the experimental period. Msuya (2013) and Beltran (2014) reported that cultured seaweed are affected greatly by environmental parameters and seasons.

Results show that both seaweed species increased TOM in the area, but *K. alvarezii* performed better in comparison to *E. denticulatum.* This could be due to the nature and growth behavior as well as morphological structure of *K. alvarezii* which traps sediments and deposit them underneath it. Variation in TOM in terms of percentage in pens in which *H. scabra* was culture with both *K. alvarezii* and *E. denticulatum* revealed the feeding nature of *H. scabra*. Thus, IMTA with sea weed could give a positive growth and survival of *H. scabra* under mariculture systems. This experiment which aimed at comparing the growth and survival of *H. scabra* when co-cultured with commercial seaweed under pens system revealed positive effects of IMTA in the Unguja Ukuu intertidal lagoon, Zanzibar. The farming of both species of seaweed gives good results, although the integration of *H. scabra* with *K. alvarezii* results in better performance in terms of growth and survival. The sediment results observed when sea cucumber integrated with *K. alvarezii* can be taken as an advantage to farmer to improve nutrient deposition along the intertidal area which is the best food for sea cucumber.

5. Conclusion

Based on the results obtained during this study, co-culturing of seacucumber and seaweed is highly possible and profitable along the coast of Tanzania. However, this study considered only the interaction between species and growth, there is still room for further study to investigate the effect of stocking density and size of the sea cucumber to be stocked.

References

Beltran-Gutierrez, M., Ferse, S.C.A., Kunzmann, A., Stead, M.S., Msuya, F.E., Hoffmeister, S.T. and Slater, M.J. (2014). Co-culture of sea cucumber *Holothuria scabra* and red *Kappa - phycus striatum. Aquacult Res*, doi: 10.1111 / are.12615

Bryceson, I. (2002). Coastal aquaculture developments in Tanzania: sustainable and non-sustainable experiences. *Western Indian Ocean Jopurnal of Marine Sciences*. 1 (1), 1-10.

Chopin, T., Buschmann, A.H., Halling, C., Troell, M. and others (2001). Integrating seaweeds into marine aquaculture systems: a key towards sustainability. *J Phycol,* 37, 975-986.

Davis, B.M., Stead, S.M., Jiddawi, N. , Hamad, M. and Slater, M. (2011). A novel polyculture system for sea cucumber *Holothuria scabra* and seaweeds (*Euchemadenticul atum* and *Kappaphycus alvarezii*) in Tanzanian lagoons. Research report. University of New Castle. England.

Eriksson, H., Robinson, G., Slater, M. J. and Troell, M. (2012). Sea cucumber aquaculture in the western indian ocean: Challenges for sustainable livelihood and stock improvement. *Ambio*. (41), 109-121. 10.1007 / s13280-011-0195-8.

Electronic copy available at: https://ssrn.com/abstract=3467424

FAO (Food and Agriculture Organization of the United Nations). (2014). The state of world fisheries and aqua-culture 2014. FAO, Rome. www.fao.org/3/a-i3720e.pdf

FAO. (2010). The State of World Fisheries and Aquaculture 2010. Food and Agriculture Organization of the United Nations, Rome, 197p.

Frocklin S., de la Torre-Castro, M., Lindstrom, L. , Jiddawi, N. and Msuya, F. (2012). Seaweed mariculture as a development project in Zanzibar, East Africa: A price too high to pay?. *Aquaculture.* 356, 30-39.

Giraspy, D. A. B. and Walsalam, I. G. (2010). Aquaculture potential of the tropical sea cucumbers *Holothuria scabra* and *H. lessoni* in the Indo-Pacific region. *spc.int*. (March), 29-32.

Hamel, J. F., Conand, C., Pawson, D. L. and Mercier, A. (2001). The sea cucumber *Holothuria scabra* (Holothuroidea: Echinodermata): Its biology and exploitation as beche-de-mer. *Advances in Marine Biology*. *41*, 129–223.

Hayashi, L., Hurtado, A.Q., Msuya, F.E., Bleicher-Lhonneur, G. and Critchley, A. T. (2010). A review of Kappaphycus farming: Prospects and constraints, pp. 255-283. in Israel A., Einav, R. and Seckbach, J. (Eds.), *Seaweeds and their Role in Globally Changing Environments*. Springer Editor, 480p.

Madeali, M. I., Tangko, A.M., Pantai, D. E. R. and Maros, B. P. P. B. (1993a). Polyculture of sea cucumber, *Holothuria scabra* and seaweed, *Eucheuma* sp. in Botta waters, Polmas Regency, South Sulawesi. *Prosidling Seminar Hasil Penelitian*. 11, 105-109.

Mills, D. J., Duy, N. D. Q., M. A. Juinio-Menez, M. A., Raison, C. M. and Zarate, J. M. (2012). Overview of sea cucumber aquaculture and sea ranching research in the South-East Asian region. In: Hair C.A, T.D. Pickering & D.J. Mills. Asia–Pacific tropical sea cucumber aquaculture. Proceedings of an international symposium held in Noumea, New Caledonia February 2011. ACIAR Proceedings No. 136. Australian Centre for International Agricultural Research, Canberra. pp. 22-32.

Msuya, F. (2002). *Ulva reticulata* and *Gracilaria crassa*: macroalgae that can biofilter effluent from tidal fishponds in Tanzania, (1999). *Western Indian Ocean Marine Science Association* (WIOMSA). 1 (2), 117-126.

Msuya, F.E. (2013). Social and economic dimensions of carrageenan seaweed farming in the United Republic of Tanzania. In: Valderrama D, Cai J, Hishamunda N, Ridler N (eds) Social and economic dimensions of carrageenan seaweed farming. FAO Fish Aquaculture Technical Paper 580, FAO, Rome. 115-146.

Msuya, F.E. and Porter, M. (2014). Impact of environmental changes on farmed seaweed and farmers: the case of Songosongo Island, Tanzania. *J Appl Phycol*. 26, 2135-2141.

Msuya, F.E., Buriyo, A., Omar, I, Pascal, B., Narrain, K., Ravina, J.J.M., Mrabu, E. and Wakibia, J.G. (2014). Cultivation and utilisation of red seaweeds in the Western Indian Ocean (WIO) Region. *Journal of Applied Phycology*. (26), 699-705.

Muthiga, N., Ochiewo, J. and Kawaka, J. (2010). Strengthening capacity to sustainably manage sea cucumber fisheries in the Western Indian Ocean. *SPC Beche-de-mer Inf Bull*. 30, 3-9.

Pitt, R. and Duy, N.D.Q. (2004). Breeding and rearing of the sea cucumber Holothuria scabra in vietnam. in Lovatelli, A., Conand, C., Purcell, S., Uthicke, S., Hamel, J. F. and Mercier A. (Eds). *Advances in Sea Cucumber Aquaculture and Management*. FAO Fisheries Technical Paper. No. 463. Rome. pp. 333-346.

Purcell, S.W., Samyn, Y. and Conand, C. (2012). Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes. No. 6. 30 colour plates. Rome, FAO. 2012. 150 pp.

Purcell, Steven W., Patrois, J. and Fraisse, N. (2006). Experimental evaluation of co-culture of juvenile sea cucumbers, *Holothuria scabra* (Jaeger), with juvenile blue shrimp, *Litopenaeus stylirostris* (Stimpson). *Aquaculture Research*, 37 (5), 515-522.

Slater, J.M. and Carton, A.G. (2009). Effect of sea cucumber (*Australostichopus mollis*) grazing on coastal sediments impacted by mussel farm deposition. *Marine Pollution Bulletin.* 58, 1123-1129.

Slater, M.J. and Carton, A.G. (2010). Sea cucumber habitat differentiation and site retention as determined by intraspecific stable isotope variation. *Aquaculture Research* (41), 695-702.

Tangko, A. M., Rachmansyah, M. M. I., Tonnek, S. and Ismail, A (1993b). Polyculture of sea cucumber, *Holothuria scabra* and seaweed, *Eucheuma* sp. In Sanisani Bay waters, kolaka regency, Southeast Sulawesi. *Prosidling Seminar Hasil Penelitian*. 11, 85-89.

Electronic copy available at: https://ssrn.com/abstract=3467424

Troell M., Halling, C., Neori, A., Chopin, T., Buschmann, A.H., Kautsky, N. and Yarish, C. (2003). Integrated mariculture: asking the right questions? *Aquaculture.* 226, 69-90.

Wolkenhauer, S., Uthicke, S., Burridge, C., Skewes T. and Pitcher. R. (2010). The ecological role of *Holothuria scabra* (Echinodermata:Holothuroidea) within subtropical seagrass beds. *Journal of the Marine Biological Association of the United Kingdom.* 90 (2), 215-223.

Cite this article as: Muumin I. Hamad, Augustine W. Mwandya, Renalda S. Munubi, Sebastian Chenyambuga and Heiromin A. Lamtane. (2019). Comparative growth and survival performance of sea cucumber (*Holothuria scabra*) in co-cultured pen system with commercial macroalgae. *African Journal of Biological Sciences.* 1 (4), 32-41.

Electronic copy available at: https://ssrn.com/abstract=3467424