DEEP WATER DEVICE FOR FARMING SEAWEED: A WAY OF PRODUCING THE HIGHER VALUED *Kappaphycus* FOR COASTAL COMMUNITIES IN TANZANIA

Flower E. Msuya

Institute of Marine Sciences, Mizingani Road, P.O. Box 668, Zanzibar, Tanzania

Tel: +255 777 490807, Email: flowereze@yahoo.com, msuya@ims.udsm.ac.tz

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ABSTRACT

Seaweed farming in Tanzania is facing a serious problem of die-off of the higher valued *Kappaphycus* cultivated in the shallow waters. Attempts have been done to develop innovative methods of cultivating this species in deeper waters. These methods have, however, been hampered by rough sea that causes breakage of the seaweed leading to loss of the product. This study was carried out to test the feasibility of a novel method, the tubular net method, in cultivating *Kappaphycus* in deeper water. It was found that tubular nets can be used effectively to cultivate *Kappaphycus* where monthly average growth rates of 2.1±0.1 d^{-1} recorded in July 2015 to 12.6±4.7 % d^{-1} recorded in September 2015 were obtained. The seaweed was growing at average temperatures of 29.0±0.4 – 32.7±0.4 ^{0}C and salinity of 26±0 – 35±0 ‰. Breakage of seaweed was less than 30% depicting the suitability of the tubular net method in cultivating *Kappapphycus* in Tanzania.

ACKNOWLEDGEMENTS

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LIST OF SYMBOLS/ACRONYMS

IMS	= Institute of Marine Sciences
ZaSCI	=Zanzibar Seaweed Cluster Initiative
DW	= Dry weight
PVC	=Polyvinyl Chloride
SGR	=Specific growth rate
WIOMSA	= Western Indian Ocean Marine Science Association
ANOVA	=Analysis of variance
^{0}C	=Degrees Celsius
‰	=Parts per thousand

1 INTRODUCTION

Since the start of seaweed farming in 1989, farmers in Tanzania have produced and sold seaweed to buyers who export to Denmark, France, USA, Spain, China, and so on. Production was 15,000 t of dry seaweed per year in 2014 (Msuya et al. 2014), dropping to 13,000 in 2014 (Msuya 2015). Most of this production is *Eucheuma denticulatum* (also known as Spinosum). The current production is low compared with other countries such as The Philippines and Indonesia which produce over 200,000 tonnes each (Hurtado 2013, Neish 2013). The produced seaweed is exported in bulk, with limited use in the country; small quantities of value added products are produced mainly for domestic market (Msuya et al. 2014, Msuya 2011a, 2010). Exporting in bulk leads to low prices paid to the producers (farmers). As a result, complaints from the farmers over the seaweed prices are not uncommon. It is a general feeling of the farmers that the prices given are not equal to the efforts/work done (Fröckling et al. 2012 Msuya 2012).

Production of *Kappaphycus alvarezii* which used to be at equal tonnage to *E. denticulatum* in the early 2000s has been affected by a number of problems believed to be an effect of climate change especially high surface seawater temperatures, ice ice disease, epiphytes, fouling and so on (Valderrama et al. 2015, Msuya 2013, Neish and Msuya 2013, Valderrama et al. 2013, Msuya et al. 2012, Msuya 2011b, Hayashi et al. 2010, Msuya et al. 2007, Mmochi et al. 2005). The species is more prone to environmental changes compared with *Eucheuma* and massive die-offs are experienced in Tanzania. Unfortunately also the world market prefers *Kappaphycus* to *Eucheuma* owing to its stronger gel-kappa carrageenan- compared with the weaker iota carrageenan from *Eucheuma*. As a result the price of the former is double that of the latter-US$ 0.5 vs. 0.25. The die-offs are experienced all over Tanzania, decreasing the production of *Kappaphycus* from 1,000 tonnes in 2001 to less than 100 tonnes in 2011 (Msuya et al. 2014). Experiments and trials in deep water farming involving coastal communities have been carried out in Zanzibar where *Kappaphycus* production was increased from 13 tonnes during the onset of the experiments in 2010 to 500 tonnes in 2014 (Msuya 2015). These cultivation efforts, however, have not yielded higher tonnage of the seaweed owing to challenges of rough seas causing the breakage and loss of the seaweed (Msuya et al. 2014, Msuya 2012, Msuya 2011c, Msuya et al. 2010, Msuya et al. 2007). One of these efforts was trial farming with the floating lines system (Msuya 2013, Msuya et al 2007) and bamboo rafts in Zanzibar which did not work because the rafts were breaking off and carried away by waves (Msuya and Salum 2006). Similar trials in Pemba where the sea is relatively calmer faced the same problem (Msuya 2015, 2011c). Thus, the rough seas have been repeatedly mentioned as a challenge to the farming of the higher valued seaweed in deeper waters in Tanzania (see e.g. the Zanzibar Seaweed Cluster Initiative-ZaSCI-www.secitz.com, Msuya 2015, Msuya 2011c, Msuya et al. 2014).

It has been learnt that there are devices such as tubular nets that can be successfully used in deep water rough seas e.g. in Brazil (Goes and Reis 2011, Pellizzari and Reis 2011, Reis et al. 2011) and India (Mr. Kumar, Personal Communication). Production of *Kappaphycus* from tubular nets is higher than that of ropes (Goes and Reis 2015, Pellizzari and Reis 2011). In addition, communities in Rio de Janeiro have been using this method for more than 3 years (Ms. Hayashi Personal Communication, see also www.youtube.com/watch?v=7b02D72x-nA, 2010). It is with this knowledge and information that the work reported in this report was carried out.

2 OBJECTIVES

The main objective of the study was to design a device for farming seaweed in deep waters (the tubular nets), use them in experimental farming of the higher valued seaweed *Kappaphycus* in deep water and disseminate the technique to seaweed farmers in Zanzibar. Specific objectives were:

To design and construct tubular nets for the farming of seaweed in deep water

To culture and study the growth rate of *Kappaphycus* cultivated in tubular nets and off-bottom methods in relation to environmental conditions in Zanzibar

To determine carrageenan content and quality which determine the commercial value of carrageenophyte seaweeds

To disseminate (at a later stage) the tubular nets technique to seaweed farmers in Zanzibar

3 LITERATURE REVIEW

The problems of *Kappaphycus* cultivation which occurred in the past ten years or so have been reported worldwide. Several authors report on problems of ice-ice disease, epiphytism, fouling, and increased seawater surface temperatures as the main problems facing *Kappaphycus* cultivation (Hurtado et al. 2006, Vairappan 2006). In The Philippines, Fiji, Solomon Islands and Kiribati for example, it was reported that surface seawater temperatures were already above the threshold and that *Kappaphycus* production was severely affected (Hurtado et al. 2006, Pickering 2006, Vairappan 2006). To address the problem of *Kappaphycus* cultivation, interventions through research have been done worldwide including research on causes and effects of ice ice and epiphytes (Vairappan 2006, Hurtado et al. 2006), the use of seaweed extracts to cultivate *Kappaphycus* (Baweja et al. 2009, Hurtado et al. 2009,) and tissue culture to produce biomass for cultivation (Hurtado and Biter 2007, Yungue et al. 2011, Yeong et al. 2014). Recently, deep water farming methods have been tried including tubular nets to minimise the problems and, thus, cultivate *Kappaphycus* (Góes and Reis 2011, Pellizzari and Reis 2011, Reis et al. 2015).

In Tanzania, cultivation of *Kappaphycus* began in 1989. Up until around the year 2000 the seaweed was cultivated without any problems. However from 2000 on, *Kappaphycus* started to face problems leading to die-off, problems that are linked to climate change (Msuya 2015, Msuya et al. 2014, Hayashi et al. 2010, Vairappan et al. 2008). The climate change factors that are reported to cause the die-off in Tanzania are increase in surface seawater temperature, epiphytes, ice-ice disease, fouling, and so on (Msuya 2015, Msuya et al. 2014, Hayashi et al. 2010, Vairappan et al. 2008). *Kappaphycus* failure to grow has affected the Tanzanian farmers because its price is higher (US$ 0.6 per kilogram DW) than the less sensitive *Eucheuma* (US$ 0.3). Research work has been done to combat these problems including research on innovative farming methods especially floating lines system and bamboo rafts (Msuya et al. 2014, Msuya 2013, Msuya 2011c, Msuya et al. 2007). These innovative farming methods have proved to minimise the problem of *Kappaphycus* cultivation by showing that it can be grown in deeper waters. However, the innovative methods have faced the problem of rough seas where the seaweed breaks off from the anchored devices and is lost (Msuya et al. 2014, Msuya 2015). Therefore, the more advanced device, the tubular nets, experimented in Brazil by Reis et al. (2015) as mentioned above, is being researched upon starting with the research results presented in this report.

4 METHODOLOGY

The study was conducted in two sites, Bweleo and Muungoni villages in Zanzibar (Unguja) Island (5° 40', 6° 30' S, 39° E). In these villages, farming of the two seaweeds *Eucheuma* and *Kappaphycus* has been going on for more than 20 years.

Netting materials, PVC pipes, and nylon ropes that are used to farm seaweed in Zanzibar (4mm diameter) were purchased from commercial shops in Zanzibar. The netting material was used to make nine-1.5 inch-mesh size tubular nets (Fig. 1). The nets were then cut into 5m long pieces. Nine such tubular nets were made.

The PVC pipes purchased from the shops were 12m long pieces. From one of the pipes, two-1m-long pieces were cut; these pieces were used for placing seaweed into the net during planting. The rest of the pipes were cut into eight-5m-long pieces that were used to make rafts for cultivating the seaweed.

Seaweed seeds were purchased from the farmers in Muungoni village where *Kappaphycus* is farmed.

Fig. 1 The constructed tubular nets

5 EXPERIMENTAL DETAILS

5.1 Experimental set up

The tubular net method described by Góes and Reis (2011) was applied. Fifteen seaweed seedlings weighing 100 g each were placed inside each tubular net to make an initial weight of 1500g per net. The tubular nets were placed on the outside of the PVC pipes (Fig. 2) and the seaweeds were inserted inside the pipes and the pipes were removed slowly so that the seaweeds were spaced uniformly in the nets (Fig. 2). The nets were then loaded into a boat and transported (together with the PVC pipes) to the experimental area and tied to the rafts by using nylon ropes. The rafts were anchored by using stones and fertiliser bags filled with sand as the anchors. Distance between the nets was 1m so that each raft held 5 nets. The rafts were anchored at a depth of 1 – 2m during lowest spring tides. For comparison purposes, an off-bottom farm-the traditional method of farming seaweed in Zanzibar was also set. In each set up, three replicates were used. The seaweed was planted in August 2014 and grown for six weeks each time from September 2014 – July 2015. The tubular nets and foo-bottom lines were cleaned every low tide to remove fouling organisms and sand.

Fig. 2 Placing tubular nets outside PVC pipes, seaweed inside the nets, and anchoring the nets by using PVC pipes as rafts

5.2 Sample collection and analysis

5.2.1 Growth rates and total biomass yield

The seaweeds were harvested after six weeks, the period recommended for fully growth of seaweeds. After harvesting, the seaweeds were shaken to remove excess water and weighed using a commercial weighing scale to obtain fresh weights. From the fresh weights, growth rates (SGR, %) of the seaweeds, were calculated as:

$$SGR = 100 \text{ X } [\ln (w_t/w_0)]/t$$

where w_o is the initial biomass and w_t is the biomass at t culture days.

5.2.2 Carrageenan content

Carrageenan content was measured by extraction over water due to lack of funds to purchase the extraction chemicals. This method in this study gives preliminary results only.

5.2.3 Nutrients

Water samples in three replicates were collected and transported to the laboratory and filtered through GC/F Whatman filter papers. Measurements of absorbencies were done using a spectrophotometer with methods of Parsons et al. (1984). Concentrations of growth limiting nutrients, i.e. total ammonia-nitrogen (ammonia-N), total nitrate (nitrite/nitrate), and phosphate (soluble reactive phosphorus) were calculated.

5.2.4 Abiotic parameters

Abiotic parameters of salinity and temperature were monitored. The other parameters of pH and dissolved oxygen could not be measured because of lack of instruments. Salinity (‰) and temperature (^{0}C) were measured *in situ* using a refractometer (Sper Scientific Ltd. USA, Model no. 300011) and hand thermometers that were purchased from the shops following the lack of oxygen-temperature meter. These parameters were measured at each sampling day.

6 RESULTS

6.1 Construction of tubular nets

Tubular nets were successfully constructed by using netting material (Fig. 1&2) purchased from commercial shops in Zanzibar. Two mesh sizes from 2 types of nylon materials were used; 20mm and 70mm-these were used purposely to compare the suitability for growing the seaweed. It was observed that the tubular nets with smaller mesh were prone to fouling (needing more time for cleaning) while the large mesh ones were not. Seaweed growth was, however not affected. Therefore, data on seaweed growth from the two mesh-sized tubular nets were combined during analysis.

6.2 Seaweed growth conditions

Bweleo site had problems of extreme fouling (see section 5 below) and thus no seaweed farms (owned by villagers) were in the vicinity. This caused overgrazing of the experimental seaweed resulting in yellowing and thickening of the seaweed without branching (Fig. 3). Most of the seaweed was grazed and only few branches remained. During the writing up of the proposal in 2013 Bweleo was chosen as one of the experimental sites. However, at the time of experimental set-up in 2014 Bweleo site had been affected by severe fouling (Msuya 2015), a situation related to climate change and farmers had not harvested the seaweed for almost 1.5 years. The seaweed that was planted in Bweleo was overgrazed by fish because of lack of seaweed in the vicinity. To overcome this, a new site with similar features was chosen in Ng'ambwa on the other side of Muungoni, and named Muungoni2. Therefore, Bweleo site was not used for routine sampling, but instead it was used as a monitoring station to see what will happen over time. Seasonal sampling generated data on environmental parameters shown below.

Fig. 3 Yellowing and stunted seaweed *Kappaphycus striatum* because of overgrazing at Bweleo

6.3 Environmental parameters

6.3.1 Salinity

Salinity of the water in Muungoni site varied from 26 – 35 ‰ (Fig. 4) in the deep water with monthly averages of 26±0 to 35±0 ‰ (Fig. 5). The shallow water results showed salinity at 26 – 35 ‰ (Fig. 4 & 5). There were no significant differences in salinity between shallow and deep water (ANOVA, F=0.5, P>0.05) In Bweleo, seasonal measurements showed that salinity of the water varied from 29.5±0.6 during October 2015 to 35.0±0.0 during January and February 2015 (Table 1).

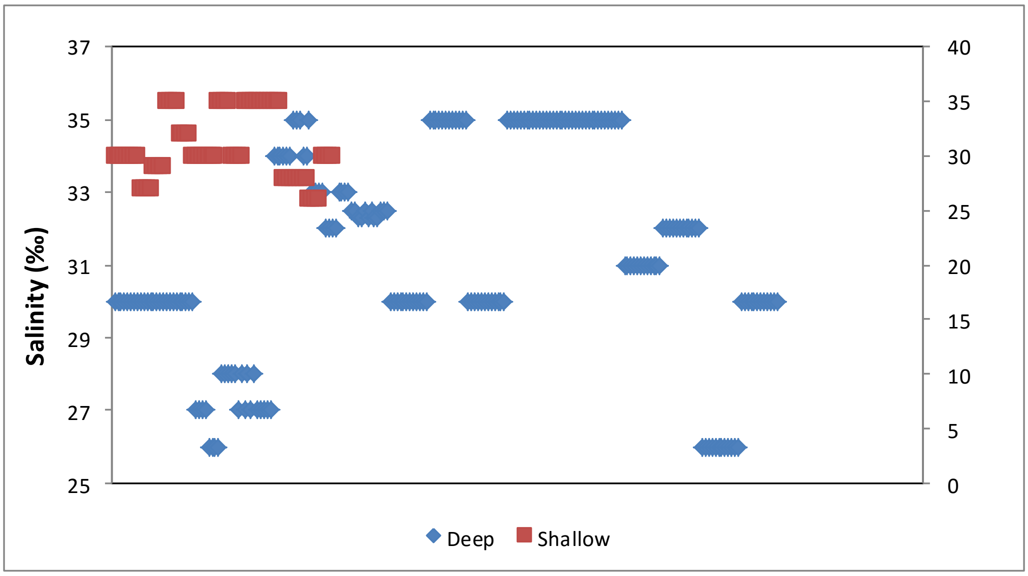

Fig. 4 Variation in salinity values (‰) in Muungoni, Zanzibar, September 2014-July 2015

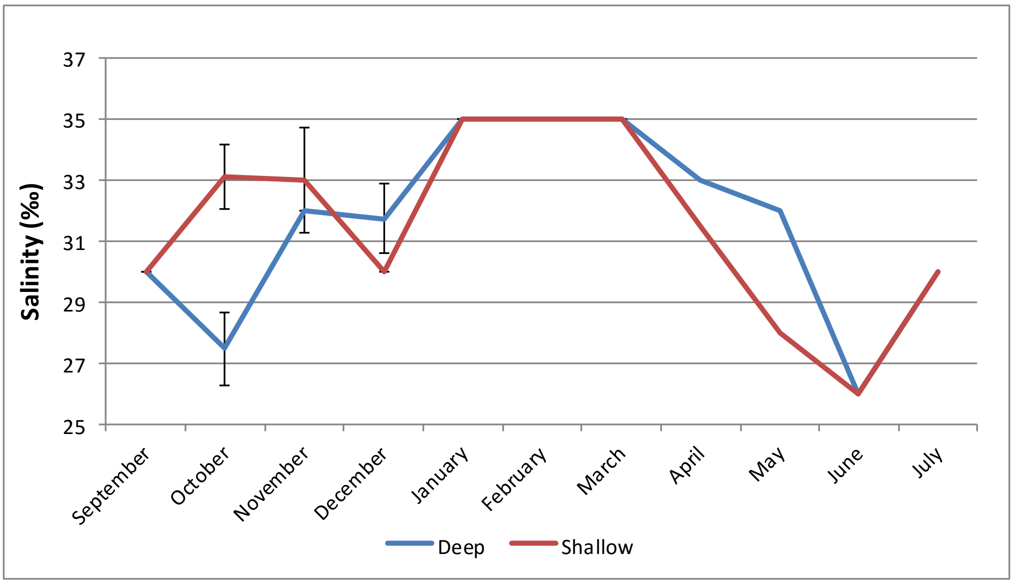

Fig. 5 Monthly variation in salinity (‰±stdev) in Muungoni, Zanzibar, September 2014-July 2015

Table 1 Monthly variation in water salinity (‰) and temperature (^{0}C) in Bweleo, September 2014 – May 2015

	Monthly averages	
	Salinity	**Temperature**
September		
Deep	34±0.0	
Shallow	31±0.0	
October		
Deep	29.5±0.6	28±2.3
Shallow		
January		
Deep	35±0.0	29±0.0
Shallow	35±0.0	31±1.2
February		
Deep	35±0.0	30±0.0
Shallow	35±0.0	32.3±0.5
May		
Deep	32±0.0	27±0.0
Shallow	23±0.0	26±0.0

6.3.2 Water temperature

Water temperature in Muungoni varied from a minimum of 29 to a maximum of 33 ^{0}C (Fig. 6) in the deep water with monthly averages of 29.0±0.4 to 32.7±0.4 ^{0}C (Fig. 7). In the shallow water, temperature varied from 29 – 34 ^{0}C (Fig. 6) with monthly averages of 29.0±0 – 34.0±1.1 (Fig. 7). Significant differenced ($F=4.6$, $P<0.05$) were observed between deep and shallow water temperatures. In Bweleo monthly water temperature varied from 27±0.0 to 30±0.0 ^{0}C in the deep water while shallow water values were from 26±0.0 – 32.3±0.5 ^{0}C (Table 1).

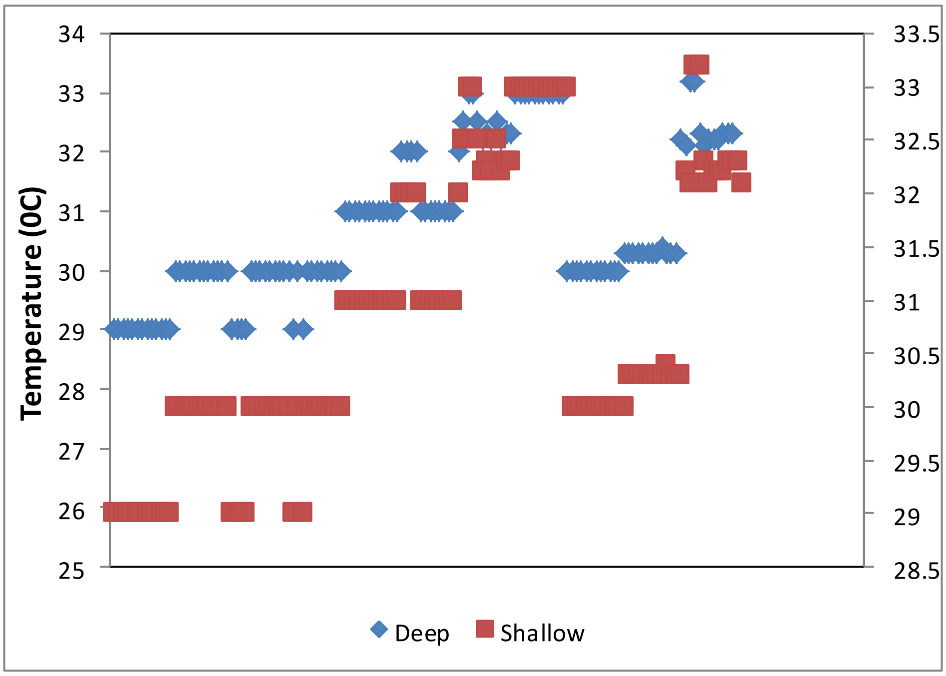

Fig. 6 Variation in temperature values (^{0}C) in Muungoni, Zanzibar, September 2014-July 2015

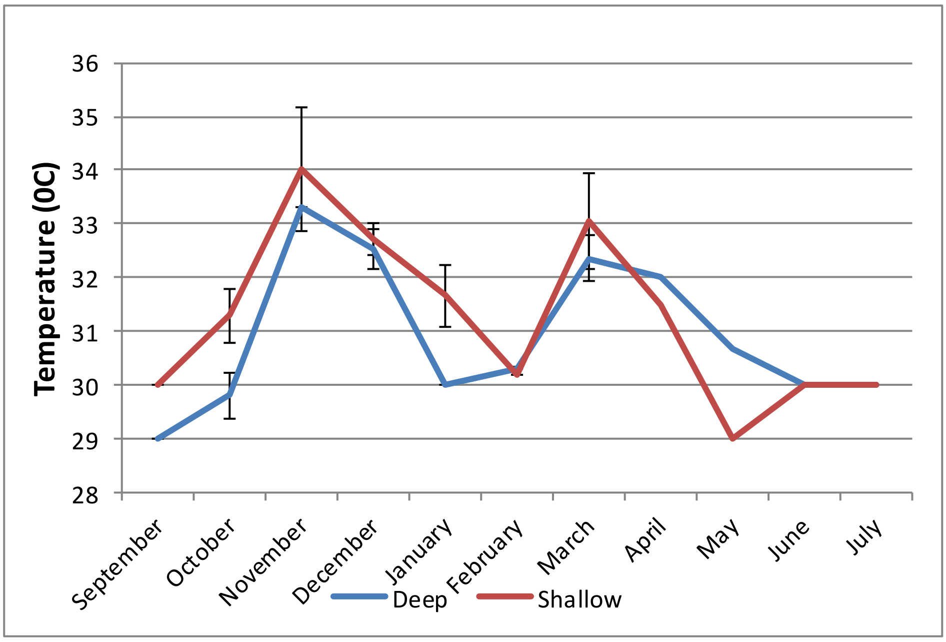

Fig. 7 Monthly variation in temperature (^{0}C±stdev) in Muungoni, Zanzibar, September 2014-July 2015

6.3.3 Nutrients

Ammonia concentration in Muungoni varied from 3.5±0.1 to 5.4±0.1 µ in the deep water and 3.5±0.4 to 5.5±0.1 in the shallow water (Fig. 8) with no significant difference between the deep and shallow waters ($P>0.05$). Ammonia values ranged from less than 3 to above 6 on the deep water and below 4 to above 6 in the shallow water (Fig. 9). Phosphate in the deep water was mostly less or equal to 0.3 µ except one month (December) when the value was 0.4 (Fig. 10). In the shallow water phosphate tended to increase with time especially on the onset, during, and end of the heavy rains in March – June 2015 (Fig. 10). During this time phosphate varied from 0.4 – 0.9 µ while in the rest of the time the values were less or equal to 0.3 µ. Nitrate showed a range of 0.6 – 7.8 µM with a trend of decreasing with time for both the deep and shallow waters (Fig. 11). In Bweleo, ammonia concentration varied from 0.2 to 5.4 µM in the deep water and 3 – 6.8 µM in the shallow water (Table 2). Phosphate varied from 0.1 – 0.8 µM in the deep water and 0.1 – 0.3 µM in the shallow water while nitrate varied from 0.03 – 4.3 µM and 0.5 – 54.9 µM in the deep and shallow water respectively (Tables 3 & 4). There were two very high values of nitrate in deep water (23.9µM recorded in February 2015 in Muungoni) and an extremely high value of 54.9 µM in Bweleo recorded in March 2015. These two values were omitted when drawing the graphs for Muungoni but were included in the table for Bweleo.

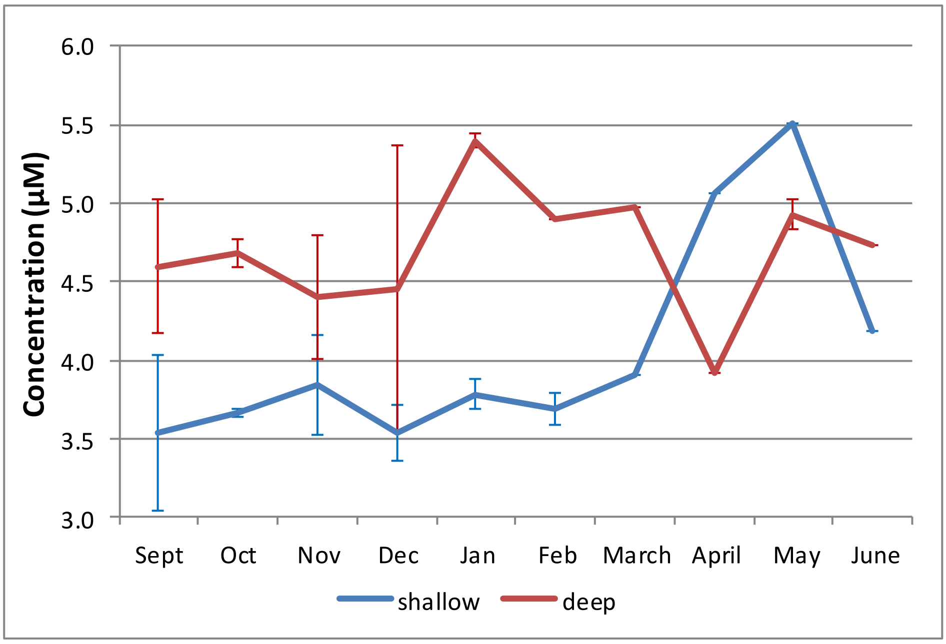

Fig. 8 Average ammonia concentration (µM±stdev) in Muungoni, Zanzibar, September 2014-July 2015

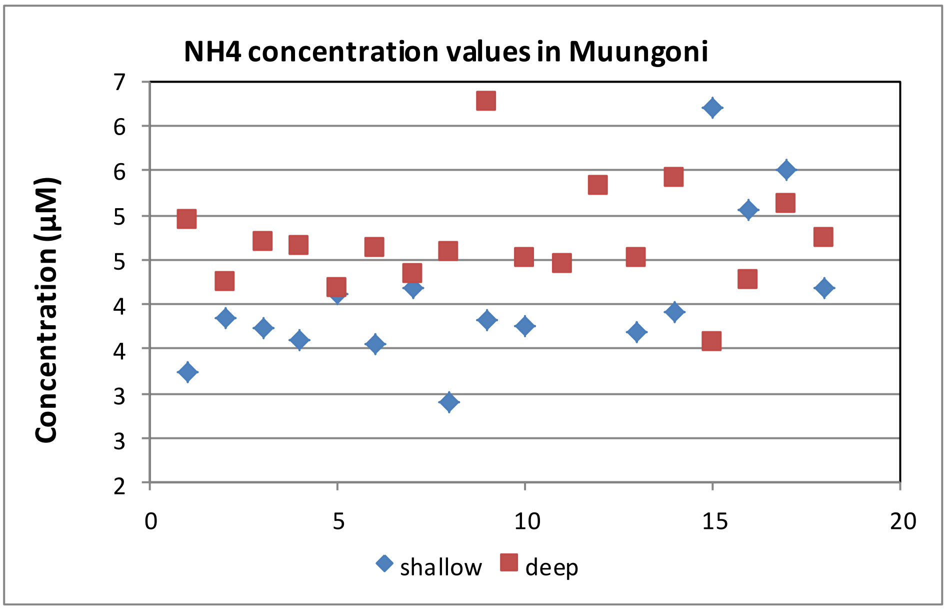

Fig. 9 Ammonia concentration (µM) in Muungoni, Zanzibar, September 2014-July 2015

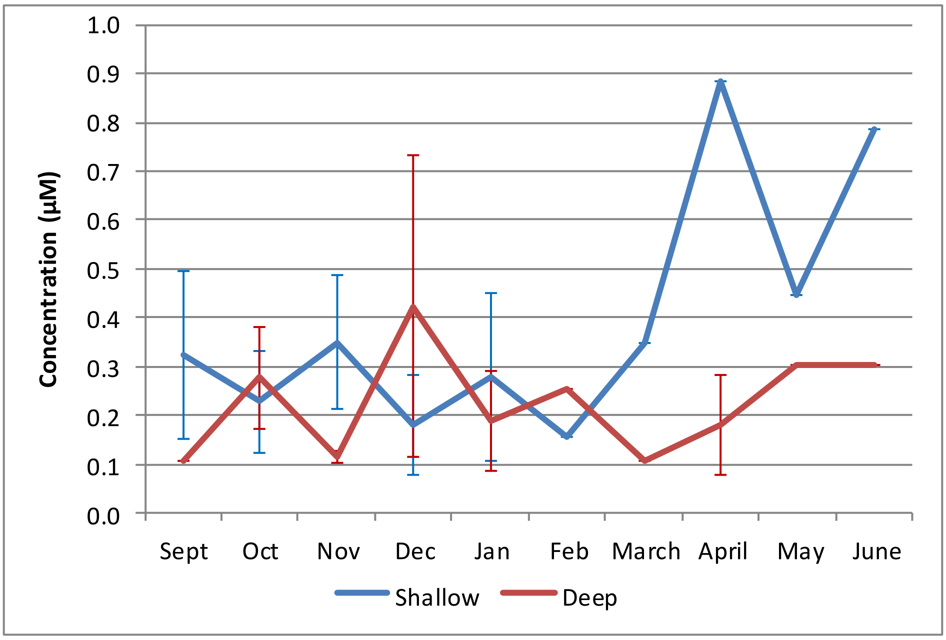

Fig. 10 Average phosphate concentration (µM±stdev**) in Muungoni, Zanzibar, September 2014**

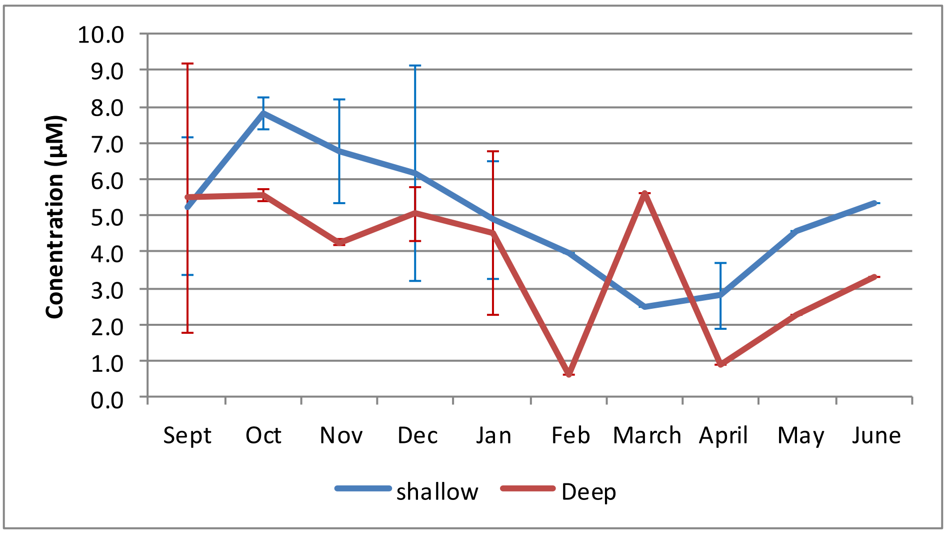

Fig. 11 Average nitrate concentration (µM±stdev) in Muungoni, Zanzibar, September 2014

Table 2 Ammonia concentration values (µM) in Bweleo, September 2014 – May 2015

	Shallow	**Deep**
Sept	6.6±0.0	5.4±0.7
Oct	5.7±0.0	4.9±0.0
Dec	5.8±0.0	
Jan	6.8±1.2	
Feb	5.9±0.0	4.5±0.0
March	5.0±0.0	4.6±0.0
May	3.0±0.0	0.2±0.0

Table 3 Phosphate concentration (µM) values in Bweleo, September 2014 – May 2015

	Shallow	**Deep**
Sept	0.1±0.0	0.1±0.0
Oct	0.2±0.0	0.2±0.0
Dec	0.1±0.0	
Jan	0.2±0.1	
Feb	0.3±0.0	0.8±0.0
March	0.2±0.0	0.3±0.0
May	0.3±0.0	0.3±0.0

Table 4 Nitrate concentration (µM) values in Bweleo, September 2014 – May 2015

	Shallow	Deep
September	3.5±2.2	
October	2.6±0.0	4.0±0.0
December		3.5±0.0
January		4.3±0.0
February	0.5±0.0	1.5±0.0
March	54.9±0.0	0.03±0.0
May	12.3±0.0	1.5±0.0

6.3.4 Seaweed specific growth rate and biomass production

Seaweed growth showed that from small branches placed inside the nets at planting (see Fig. 1&2 above), the seaweed grew to large branches that were growing outside the tubular nets (Fig. 12a&b) as was expected. The growth rate of the seaweeds measured as specific growth rate (sgr, % d^{-1}) was lowest during the cold season between May and July 2015 (Fig. 13a&b), and highest between September and December 2014 in the deep water. The least monthly average rate was 2.1±0.1 d^{-1} recorded in July 2015 and the highest was 12.6±4.7 % d^{-1} recorded in September 2014 (Fig. 14a). In the shallow water, a similar trend was observed where the seaweeds grew at lower rates during May – July 2015 and highest during September – December 2014 (Fig. 14b). The least recorded monthly average was 2.0±0.2 % d^{-1} in June 2015 and the highest was 10.3±4.5 % d^{-1} recorded in September 2014. There were no significant differences in sgr between deep and shallow water ($F=2.1$, $P>0.05$).

Fig. 12a Tubular nets showing large fronds of the seaweed *Kappaphycus striatum* growing on the outside of tubular-nets in Muungoni

Fig. 12b Close up of large fronds of the seaweed *Kappaphycus striatum* growing on the outside of tubular nets in Muungoni

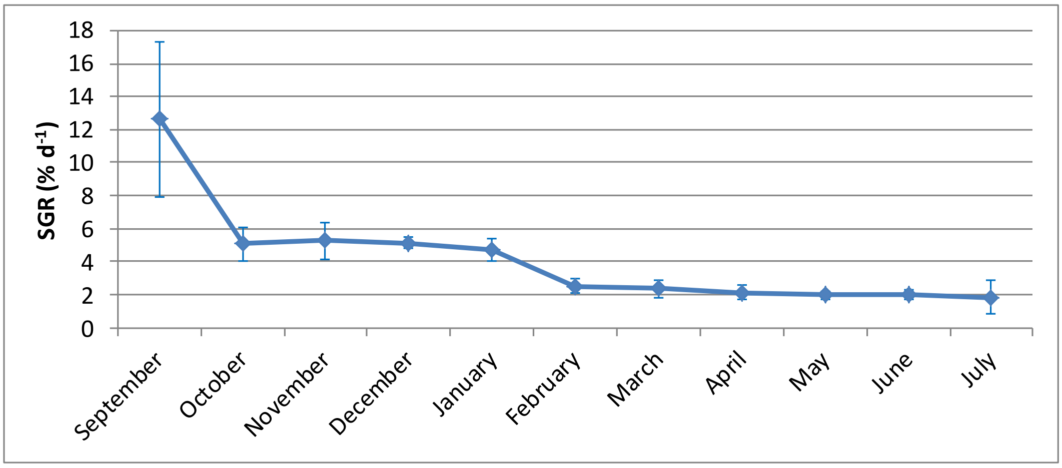

Fig. 13a Monthly average specific growth rate (%±stdev) of the seaweed *Kappaphycus striatum* growing in deep water in Muungoni, September 2014 – July 2015

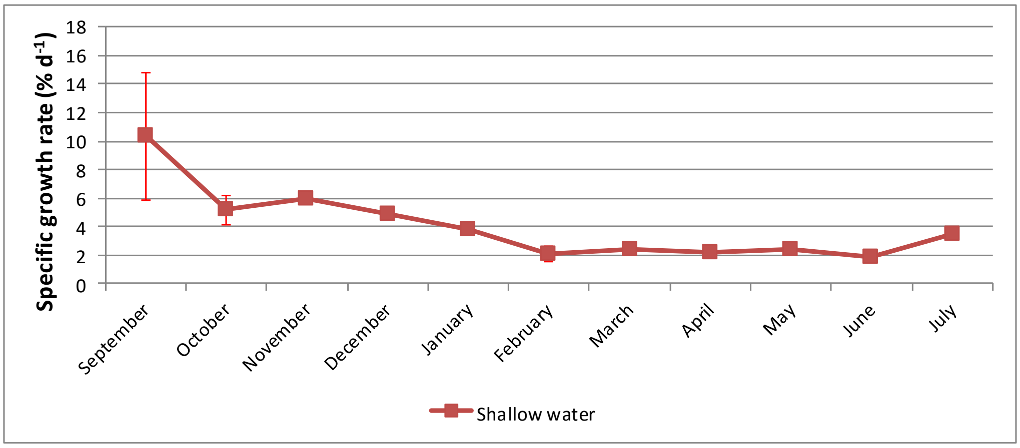

Fig. 13b Monthly average specific growth rate (%±stdev) of the seaweed *Kappaphycus striatum* growing in shallow water in Muungoni, September 2014 – July 2015

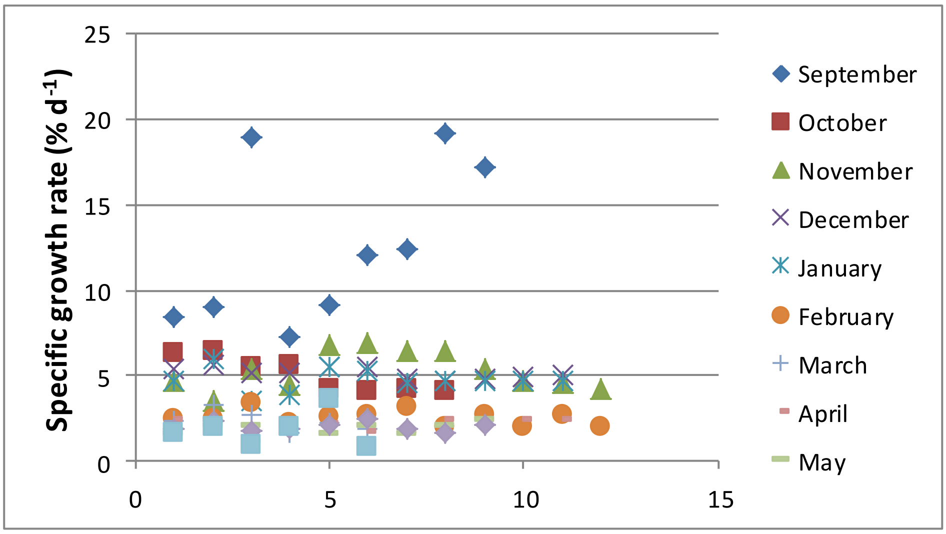

Fig. 14a Specific growth rate values (%) of the seaweed *Kappaphycus striatum* growing in deep water in Muungoni, September 2014 – July 2015

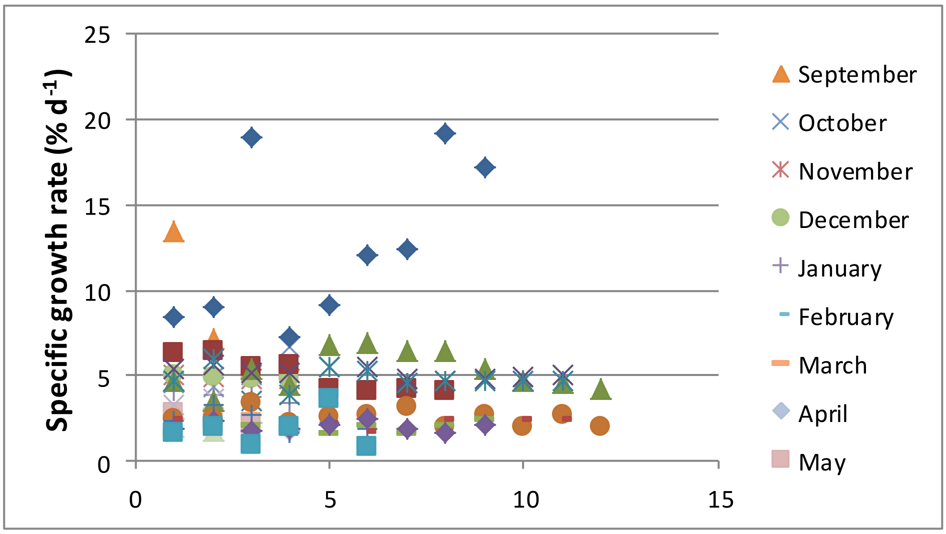

Fig. 14b Specific growth rate values (%) of the seaweed *Kappaphycus striatum* growing in shallow water in Muungoni, September 2014 – July 2015

Correlation analysis showed significant negative correlation between sgr and temperature in the deep water and shallow water (r=-0.3, P=<0.05). Likewise, there was significant negative correlation between sgr and salinity (r=-0.3, P=<0.05).

Biomass production showed that at harvesting, the seaweed increased from a weight of 500g to a maximum of above 4000g with thick fronds (see Fig12 above). Total biomass production volume produced in the tubular net method during the entire experimental period was 194,034.5 g wet weight.

6.3.5 Minimisation of seaweed breakage

Seaweed break off due to strong winds was lowered much in the deep waters. Loss of seaweed was less than 30% during the entire experimental period. In the shallow water, seaweed loss due to breaking off from the lines was as high as 80%.

6.3.6 Carrageenan content

Preliminary results of carrageenan analysis showed that carrageenan varied from 50-57% in the deep water and 45-54% in the shallow water. There was no significant difference in carrageenan yield between deep water and shallow water set ups (P>0.05).

7 ANALYSIS AND DISCUSSION OF THE RESULTS

7.1 Environmental parameters

Before the year 2001, there were no problems with *Kappaphycus* farming (& production) and at that time water temperatures in the shallow water seaweed farms did not exceed 31 ^{0}C (Msuya and Porter 2014). In the current study, water temperatures recorded in the shallow water farms were as high as 35 ^{0}C and on the deep water as high as 33 ^{0}C. This shows how water temperature has been increasing over time, and it is not surprising that *Kappaphycus* is failing to grow in Zanzibar. The negative correlation between temperature and seaweed growth rates indicates that at such high temperatures, increasing temperatures will have negative effect on *Kappaphycus* growth and vice versa. The problems of high surface seawater temperatures affecting *Kappaphycus* growth have been shown in other countries (Valderrama et al. 2013, Neish 2013, Hayashi et al. 2010).

Results of nutrient concentration especially phosphate showed an increase during the rainy season. This could be an indication of nutrients being brought to the farms by infiltration through rainy water finding their way to the farms. Increased nutrients may lead to eutrophication and die-off of *Kappaphycus*.

7.2 Seaweed growth rate

The cultivation of *Kappaphycus* has become a persistent problem in Tanzania where the production decreased from 1,000 tonnes in 2001 to less than 100 t between 2007 and 2010 (Msuya et al. 2014). Recent efforts to use innovative methods in deeper waters have increased the production over the years to 500 t in 2014 (Msuya 2015). This shows that innovative methods of farming in deeper waters can improve *Kappaphycus* farming and production. Results of studies by Msuya et al. 2007 and Msuya 2011c which shoed higher growth rates of *Kappaphycus* and *Eucheuma* in deeper waters compared with shallow waters, and supported by results of the current study, prove that farming *Kappaphycus* is possible in deeper waters.

Factors that are linked to the decreased production, and also related to climate change have been shown. Increased surface water temperatures and reduced salinities are some of the main factors. In this study both parameters were negatively correlated with seaweed growth rate meaning that these factors would negatively affect seaweed growth. High temperatures of above 30 ^{0}C have been shown to lower the growth rate of *Kappaphycus* and actually to even cause ice ice disease followed by dying off of the seaweed. Msuya et al. (2012), Msuya and Salum (2012) and Msuya and Salum (2007) showed that seaweed growth is lowered during hot seasons in Tanzania when temperatures are above 30 ^{0}C. Likewise, the authors showed that during heavy rains when salinity is decreased, seaweed growth is lowered. In other countries, similar results were obtained where high temperatures and low salinities were shown to negatively affect *Kappaphycus* growth (see e.g. Hurtado et al. 2006, Pickering 2006, Vairappan 2006, Wakibia et al. 2006).

Growth rate of the seaweed was lowest during the cold seasons and highest during the warmer seasons. This is in contrary to previous studies which showed higher seaweed growth rates during the cold season and lower during the warm season (see e.g. Msuya et al. 2012, Msuya and Salum 2012, Msuya 2011c). Whether these findings are related to climate change with a possibility of having “colder” weather during the cold seasons or they are site specific remain to be proved.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

This study has proved that tubular nets can be constructed in Tanzania using locally available netting materials and used to cultivate *Kappaphycus*. It has also shown that seaweed grows well in the tubular nets. Breakage of the seaweed which has been a persistent problem with deeper water devices was lowered by 30% showing a promising future of *Kappaphycus* cultivation in Tanzania.

8.2 Recommendations

Despite the good results, there has to be a dissemination phase where the results are used by Tanzanian seaweed farmers to produce the higher valued *Kappaphycus*. No funds could be obtained this time, and therefore an effort needs to be made to undertake the dissemination of this novel method.

Because of a one-year study, it was not possible to show seasonal variations on the performance of the tubular method. It is recommended that a longer (at least two years) study is conducted to include the seasonal variations and thus show how the method will work in the varying-and-changing-climate-impacted seasons.

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