Long Line Seaweed Farming as an Alternative to other Commonly used Methods

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Abstract

To counter the rampant fishing pressure on the over exploited fisheries resources, seaweed farming is gaining momentum as an alternative livelihood among the Kenya coastal communities. There is also a worldwide growing interest in the use of seaweed in food and chemical industries, not forgetting its contribution to the blue economy. In this regard, various methods of seaweed farming like raft method and off bottom method have been used but production is still low. This study aimed at assessing the growth rate and yield of *Kappaphycus alverazzii* (cotonni) and *Eucheuma denticulatum* (spinossum) using the long line floating method. The experiment was performed on 3 plots per species of seaweed with a plant stocking density of 36 seedlings per plot. Measurements of production were done fortnightly. The highest production was realized with *E. denticulatum* during the North East Monsoon (NEM) period (1321.47±93.3 g) with a Daily Growth Rate (DGR) of 6.59% and a yield of 19.9 tonnes/ha. During the South East Moonson (SEM) a weak yield relationship was manifested. *K. alvarezzii* showed a production of 826.27±20g during NEM with a DGR of 5.96% and yield of 14.95 tonnes/ha. During SEM poor daily growth rate of 1.47% and yield of 1.892 tonnes/ha was realized. Based on highest daily growth rate and yield, culture of *E. denticulutum* during the NEM season was optimal.

Key words: Longline method, Kappaphycus alverazzii, Eucheuma denticulatum, seaweed

INTRODUCTION

Globally there is a decline and depletion of fisheries stocks (Naylor et al., 2000), due to overfishing, effects of climate change and pollution. Degradation of these aquatic ecosystems has become a major concern to managers and aquatic resource users (Masese et al., 2013). The dwindling stocks in the capture fisheries have acted as a precursor for rapid growth in aquaculture (Naylor et al., 2000). This is due to the ever mushrooming of human population resulting into more demand for food, employment and poverty eradication. With the world population projected to skyrocket by the year 2050, the demands from the blue economy will be tenfold. However, it is argued that rapid expansion in aquaculture (production of finfish) may solve some of the above challenges man is facing, but it may also aggravate these problems further as far as sustainability of ocean fisheries is concerned. For instance, the farming of crustaceans such as shrimps and finfish (i.e. salmon) farming, may result in habitat destruction, pollution, manifestation of invasive species and to a larger extent depletion of the wild fish stocks via the production of fish meal and fish oil. The growth of aquatic plants (seaweed) may well be a good alternative to fin fish farming in the expansive oceans of the world. This is because of many advantages that it abhors including but not limited to shorter period of time to maturity, easy to culture, poses no

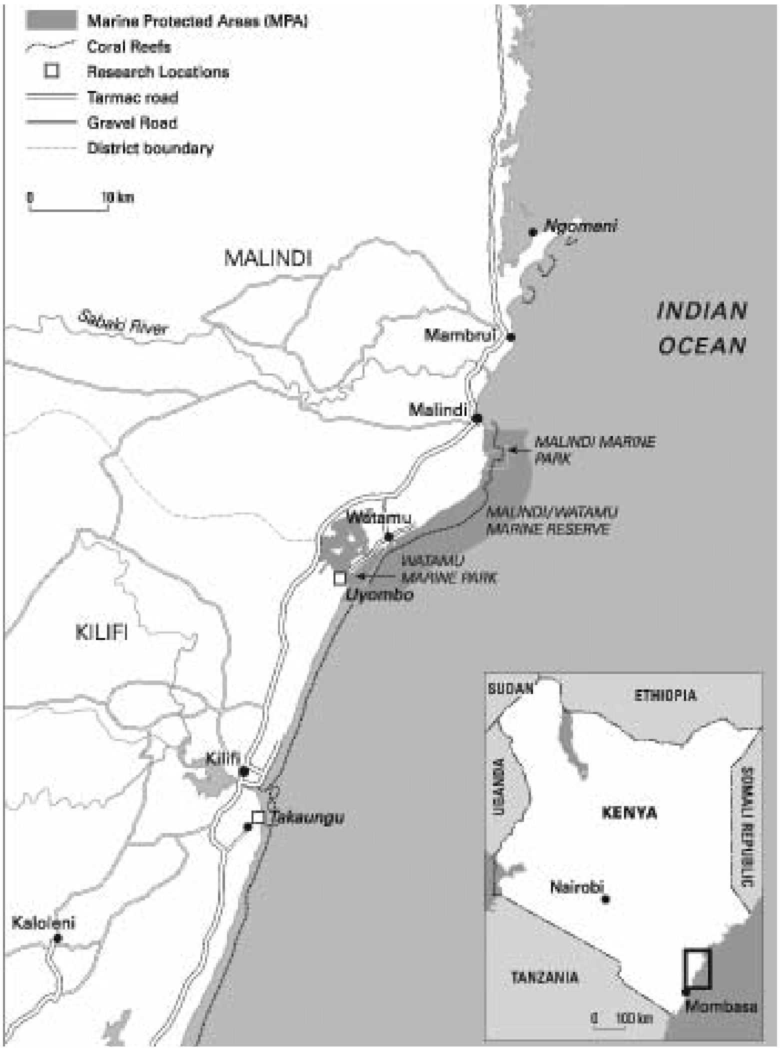

Fig 1. Study area, Takaungu at the northern part of Kenya coastline.

pollution threats given that they mainly utilize the available nutrients, does not require feeding and consequently the cost of production is low. To boost mariculture activities, farmers have embarked on seaweed farming which has been incorporated into many community-based coastal resources management projects and fisheries management initiatives as an alternative livelihood option for fishers in tropical developing countries (Msuya et al., 2014; Msuya, 2006).

Along the Kenya coastline seaweed farming is now being practiced in the south coast at Kibuyuni, Nyumba Sita, Mkwiro, Funzi and Gazi areas. The main species cultured are *Eucheuma denticulatum* (*J. Agardh*) commonly known as 'spinosum' and *Kappaphycus alvarezzi* known as 'cottonni'. Kenya is not endowed with vast well sheltered beaches to venture into sustainable seaweed farming enterprise. To excarbate the challenge even further, it is only *E. denticulatum* that has shown a potential of doing well as compared to *K. alvarezzii*, which is in high demand in the international market hence fetches high prices (Msuya et al., 2014). Other reasons that have been advanced to low production of *K. alvarezzii* include high temperatures due to climate change, invasion by the epiphytes, 'ice ice' condition (a condition associated with the seaweed thallus turning whitish and breaks easily) and high predation by the foraging fishes such as Rabbit fish.

In order to overcome the challenge of suitable sites of seaweed farming in Kenya and more particularly those of farming *K. alvarezzii*, there is need to modify the traditional off-bottom method, employ the use of long line floating method that can make use of deeper waters (Msuya, 2014). Other methods of farming in deep waters include bamboo rafts (Zuberi 2000; Msuya & Salum 2006; Msuya 2011c).

Although farming in deeper waters using the above said alternative methods pose several challenges such as women's participation and a majority can't swim, access to boats and frequent conflicts with fishermen (Msuya 2006b; Msuya et al. 2007b), the methods offer faster growth rates and high production. It has been reported that farming with long line floating method produces 0.35 Kg per unit area compared to off-bottom line method (Msuya et al., 2007a; Msuya 2013a). Higher production has been reported in other countries where deeper water methods have been tried in relation to shallow waters (Hurtado & Agbayani, 2002). The aim of this study, therefore, was to investigate the growth rate and yield of *E. denticulutum* and *K. alvarezzii* grown in longline floating method as an alternative to the commonly used techniques in Kenya.

MATERIALS AND METHODS

Study Area

A preliminary survey of potential study sites along the Northern Kenya coast was done. Takaungu located in Kilifi County at latitude of S 03° 43' 4.09" and a longitude of E 039° 51' 41.60" proved the best. The site was selected because it is sheltered from wave action, accessible and represent a range of environmental conditions in Kenya. The coastal belt of Kenya experiences a tropical monsoon climate dominated by two seasons, the Southeast Monsoon (SEM) locally referred as *Kusi* prevailing from May to October and the Northeast Monsoon (NEM) locally referred as *Kaskazi* December to March. The study period fell under the two seasons and therefore growth comparisons was done for SEM and NEM. The two seasons are characterized by distinct differences in physical and chemical conditions of the coastal waters (Church & Obura, 2004).

Long Line Seaweed Farming Method

A plot measuring 5 m X 1.5 m was made with 3 lines made up of 12 seedlings each. Therefore there was a plant stocking density of 36 seedlings per plot. To make the plot, a 3 mm thick polypropylene rope of 5 m long was stretched between anchors and floaters. 15 pieces of raffia (polypropylene strings) were attached to the 3mm rope. 3 lines of the same size were made and tied to bamboo (floaters) at both ends.

Luxuriant and strong branches of seaweeds sourced from Kibuyuni were used as seed for planting, where cutting was done using a sharp knife, cleaned of silt and the associated plants and animals. The two species of seedlings *E. denticulatum* and *K. alvarezzi* were weighed differently using a laboratory spring balance (single/dual scale capacity) to determine the initial weight before planting. The initial weight ranged between (35-75 g). The seedlings were then tied on the ropes at their strongest points.

A clear site was chosen with clear water, tidal range, moderate water current and protected from large waves and strong winds, water temperature between 27°C to 30°C, salinity ranged from 30 to 35 ppm, water depth of 1-4 m at the lowest tide (Msuya, 2006a). Anchors were placed into the substratum; the seaweed lines were then carried to the growing site and tied to the floaters. The experimental set up was done in triplicate for both species. A total of 6 plots were made and 3 groups from the Takaungu community assigned 2 plots each to take care of. Monitoring was scheduled to take place after every 2 weeks during low tide for 45 days. Growth rate was evaluated during the NEM and SEM seasons of the year.

Data Analysis

Data on growth rate was presented as means (±SEM). Productivity as specific percent per day was based on the increase in biomass per unit time and calculated as daily growth rate (DGR)% d^{-1} and determined from the following formula: (Wakibia *et al,* 2006; Evans, 1972)

$$RGR = [(Wt/Wo)1/t - 1] \times 100$$

Where, Wo = average cutting wet weight at start,

Wt = average cutting wet weight at time t and

t = time intervals (days).

Plant yield (Y) expressed as estimated kg/m^2 was determined using a formula modified by Hurtado *et al.* (2001):

$Y=(W_t/W_o)/A_t$

Where W_t and W_o are as in equation 1

A_t= total area of the plot

The results from the plots were extrapolated to determine what one hectare of seaweed plot could produce in tonnes. The data was plotted and the growth rates calculated in Excel for Windows 2011. The Kolmogorov-Smirnoff test was used to test for normal distribution of the data. ANOVA was used to test for differences in mean growth rates and yield between the replicates of each method and all inferences were accepted at α=0.05.

RESULTS

Growth Rate and Yield of *E. denticulatum*

E. denticulatum performed very well under the long line floating method in both seasons of the study period (SEM and NEM). Its growth rate during NEM is as illustrated in Fig.s 2 and 3.

By the time of maturity/harvest (i.e. 45th day), *E. denticulatum* in plots 1, 2 and 3 attained 830.6167±93.703g, 1321.417±93.310g and 1080.513±90.956g of weight respectively during the NEM season. In all the 3 plots, growth rate of *E. denticulatum* increased steadily with time in spite of small variation among the plots (Fig. 2).

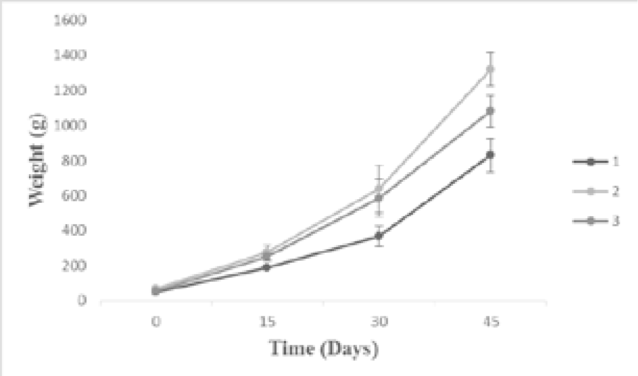

Fig.2. Growth rate of Eucheuma denticulatum in the three plots during NEM season

Generally the growth rate of *E. denticulatum* during the NEM season was 1077.516±84.651g by the 45th day of planting (Fig.3). Seaweed of this species grown in this area could attain a maximum weight of 532.62±67.17g by the 30th day of planting while it could attain a weight of 251±22g by 15th day of planting.

The Daily Growth Rate (%) of *E. denticulatum* during the NEM season was found to be 6.59% and that 19.9 tonnes could be produced from a one hectare farm. DGR%d^{-1} did not differ significantly between the plots during the NEM season of the study period. The yield also showed no significant difference between the plots. However, the yield showed a weak relationship (p=0.07) between the plots.

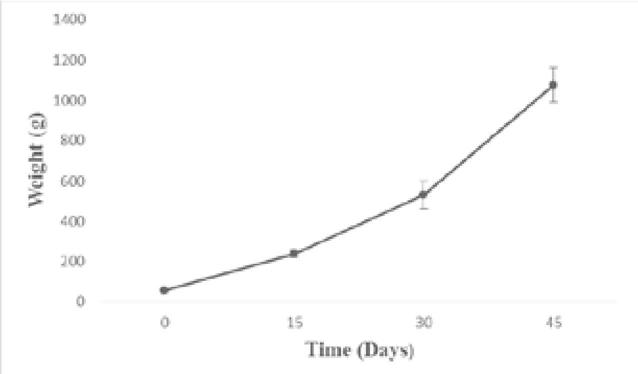

Fig. 3. General Growth rate of Eucheuma denticulatum in the study area during NEM season

The performance of *E. denticulatum* during SEM is as shown in Fig.s 4 and 5. During the SEM season of the study period, *E. denticulatum* attained a maximum weight of 982.277±81.771g. However, during the same period the seaweed increased in weight steadily (Fig. 5). DGR % d-^{1} did not differ significantly between the plots during the SEM season of the study period. However, the yield showed a weak relationship (p=0.07) between the plots. There was a weak relationship (p<0.05) observed between the growth rates of the *E. denticulatum* at day 45 during the SEM season.

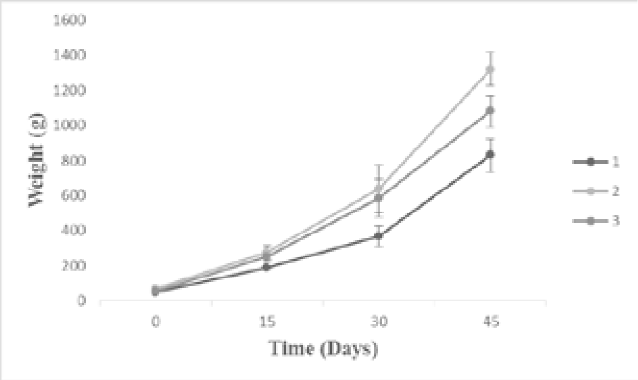

Fig. 4. Growth rate of Eucheuma denticulatum in the three plots of the study area during the SEM season

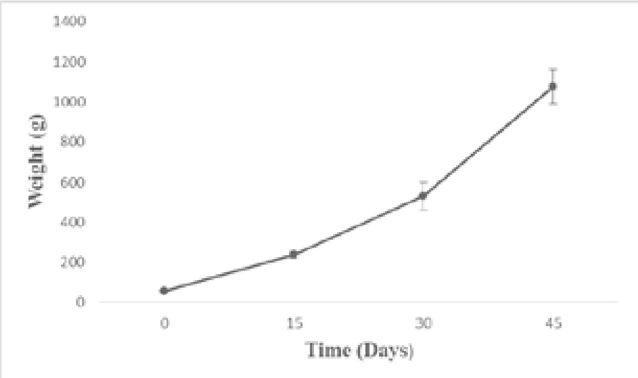

Fig. 5. The general growth rate of Eucheuma denticulatum in the study area during the SEM season

Growth Rate and Yield of K. alverazzii

The performance of *K. alverazzii* during the NEM season was

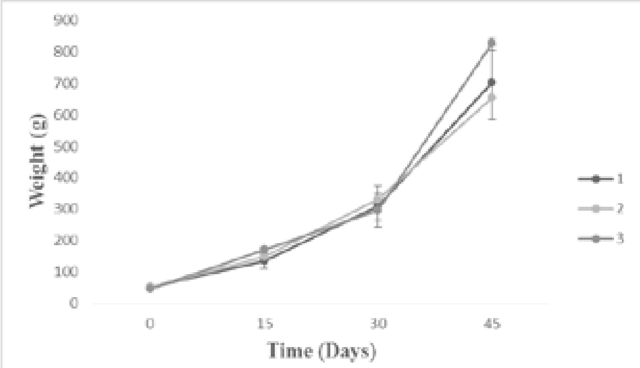

Fig. 6. Growth rate of Kappaphycus alverazzii in the three plots during NEM season

fairly good (Fig. 6). Plot 3 recorded the highest growth rate (826.27±20) followed by plot 1 (703.52±116.42g) and then lastly plot 2 with an average weight of 654.85± 1.26g (Fig. 6). The growth rates of *K. alverazzii* did not differ significantly between the plots during the NEM season.

The general performance of *K.alverazzii* in the study area during NEM season was as indicated in Fig. 7. This seaweed species attained a maximum weight of 728.21±42.59g at maturity (45 days). For the first 30 days the growth rate was somehow slow (311.18±22.04g) as compared to the last 15 days to maturity when its growth was accelerated. The DGR% of *K. alverazzii* during the NEM season was found to be 5.96% and the total yield during this time when extrapolated was found to be 14.95 tonnes per hectare. DGR%d^{-1} did not differ significantly (p=0.94) between the plots during the NEM season of the study period. However, the yield showed a weak relationship (p=0.063) between the plots.

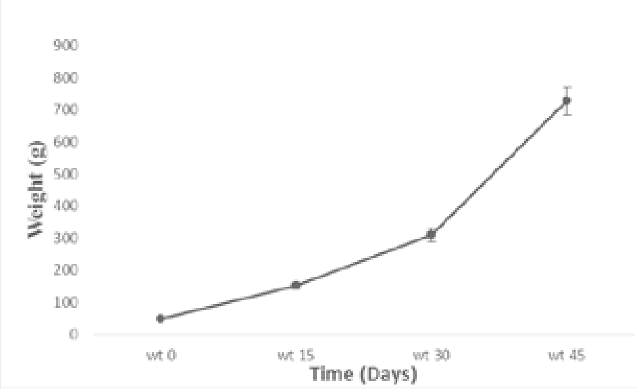

Fig. 7. General Growth rate of Kappaphycus alverazzii in the study area during the NEM season

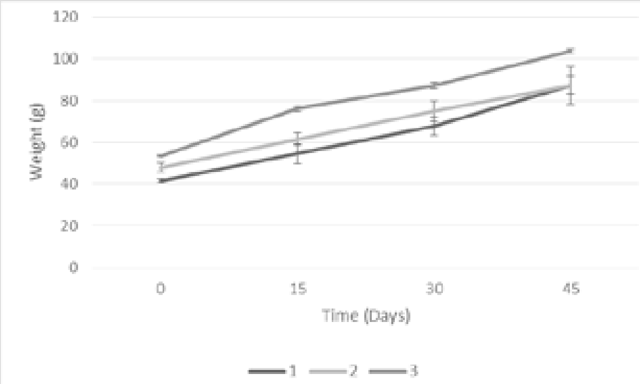

Fig. 8. Growth rate of Kappaphycus alverazzii in the three plots during SEM season

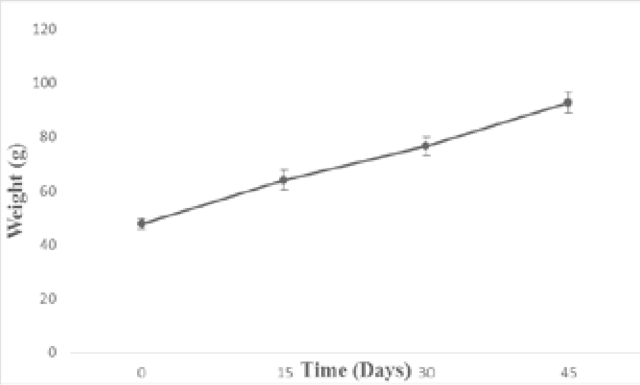

Fig. 9. General Growth rate of Kappaphycus alverazzii in the study area during the SEM season

During SEM season, *K. alverazzii* displayed a very poor growth rate (see Figs. 8 and 9). Although all the three plots performed dismally during the SEM season of the study period, plot 3 recorded the highest weight of (103.74±8.2g) followed by plot 1 (87.38±4.21g) and then plot 2 which recorded 87.323±9.0g (Fig. 9). *K. alverazzii* managed to record a maximum weight of 92.81±3.97g at maturity during the SEM season of the study period. During this season (SEM) *K. alverazzii* recorded DGR%d^{-1} of 1.47% whereas the yield was found to be 1.892 tonnes per hectare. There was no significant difference observed on the daily growth rates between the plots and yield of *K. alverazzii* during the SEM season.

When comparing the growth rates of the two seaweed species, it was found that *Eucheuma denticulatum* performed well as compared to *K. alverazzii* in all the seasons during the study period. Although *K. alverazzii* tried to perform well during the NEM season, its performance did not however out do that one of *E. denticulatum* in both seasons (i.e. SEM and NEM).

DISCUSSION

During the monitoring exercise weather conditions were generally variable with moments of sunny and rainy periods. Generally there was marked improvement in the growth rate of both *E. denticulatum* (Spinosum) and *K. alverazzii* (Cottonii) species in all the plots during the NEM season of the study period. This could be explained by the calm weather patterns during this time hence sedimentation was low enabling the plants to photosynthesis food because of enough penetration of light into the water system. The calm weather may have contributed to less velocity of the water thereby the seaweed propagules remaining intact i.e. they did not break away hence a bumper harvest/growth rate.

However, poor growth rate of *K. alverazzii* was evident as compared to *E. denticulatum* during both seasons. The morphological makeup of *K. alverazzii* thallus is thicker as compared to that one of *E. denticulatum* such that when it has attained a reasonable growth it becomes heavier thereby displaying a brittle like characteristic whenever there is little water current. Therefore chances are that it may have broken time and again thereby swept away. Another reason that has been advanced to this effect is that *K. alverazzii* is a good source of food for rabbit fish hence because of the small farms the grazers overwhelmed its existence accounting for poor growth rates and yields (Msuya, 2006a,b). Doty (1973) blames grazing on plants by sea urchins and siganid fishes as the cause of failure for the plantings on bottoms. Also Parker (1974) has observed non-branched appearance of native *Eucheuma* strains growing in areas densely populated by sea urchins in the Philippines. Ask (1999) observed several fish taxa eating tips of plants. This is a serious problem since the tips are the growth area of the plant, and it can take weeks for a new tip to grow. Other fish attach plants voraciously and remove the entire cortical layer of the plant. Msuya *et al.* (1996) reports that grazing on seaweeds by box fish, rabbit fish and sea urchins reduce the growth rate.

In order to overcome the herbivory nature of the fishes on this species of seaweed, it is recommended that big farms be done (Wakibia et al., 2006). Rapid grazing of the seaweed causes a disease called ice-ice that gets an opportunity to thrive well on the cut ends of the thallus, thus complicating the situation even further. This makes the seaweed to easily die hence reducing the yield of the farm.

During SEM, the performance of *E. denticulatum* was not as good as during the NEM season although in both seasons it seemed to do well. This could be explained by the fact that during SEM the velocity of the water in the sea is very fast, interfering with the seaweed thallus especially in situations where the tie ties were too tight: they could easily break away leaving behind smaller attachments. Also because of fast movement of the water, turbidity becomes high as indicated by the level of conductivity during the study period. This situation hampers the development of the plant because of low rate of photosynthesis. Msuya (2006a) argues that light is of paramount essence when growing seaweeds. She also portends that in order for the weed to do well, a well sheltered site is a must. Such a site prevents the strong currents from the open sea from interfering with the tied propagules of the seaweed. In general the performance of *E. denticulatum* was good going by the recommended net weight that should be attained by week 6 of planting (at least 650g) (Wakibia, *et al*., 2006). Some of the other factors that led to good growth rates of *E. denticulatum* included the water quality parameters although they were not measured.

During SEM *K. alverazzii* performed dismally most probably due to invasion by epiphytes that may have increased competition for food. Epiphytism is a major worldwide problem in the cultivation of *K. alverazzii*, which severely reduces the productivity and cost efficiency in open water cultivation. Large algae may overgrow the farmed plants and thereby compete with the farmed plants for sunlight and nutrients (Buschmann & Gomez, 1993). These are *Enteromorpha, Ulva, Chaetomorpha* (Chlorophyta), *Hypnea* (Rhodophyta) and *Hydroclathrus* (Phaeophyta). They reduce the inorganic carbon uptake of *E. alverazzi* due to elevated pH (Mtolera *et al.,* 1995a, b). Because farmers didn't remove the epiphytes early enough given that they had to wait until we go to the site after two weeks, this could have compounded the problem. The farmer has to remove the epiphytes and competitors physically. If removed as soon as it settles in the farm it may be possible to decrease the problem. Azanza *et al*., (1996; 1992) suggests that these algae should be taken to the shore and that they might be used as fertilizer on land, sedimentation and herbivory by the fishes.

CONCLUSION

In conclusion, long line floating method performed well in the study area. It was also observed that *E.denticulatum* did well as compared to *K.alverazzii*. Therefore, seaweed farming can do well in this area while growing spinosum using long line floating method. The study recommends up scaling of *E.denticulatum* species under longline floating method. However, should good progress be anticipated, then the community needs a technical team that will guide them on a regular basis.

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