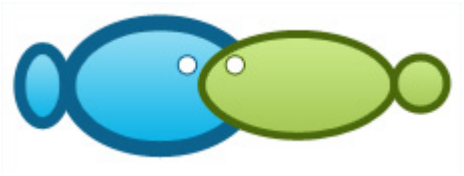

The growth rate of seaweed (*Eucheuma denticulatum*) cultivated in longline and floating cage

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Abstract. This aims of the present study was to evaluate the growth of *E. denticulatum* in floating cage and longline. This study was conducted in one of cultivation areas in Southeast Sulawesi, Indonesia. This research was carried out by comparing the growth rate of *E. denticulatum,* which cultivated with floating cage and longline. This study revealed that the growth rates of *E. denticulatum* by floating cages are much better compared than longline. The results showed that the growth rates of *E. denticulatum* in floating cage was slightly faster and appeared to be better in thallus morphology. Average total growth rate of *E. denticulatum* which was cultivated in longline and floating cage during 50 days in 5 kg of first weight (Wo) are 23.7 and 38.9 kg respectivelly. Specific growth rate (SGR) of *E. denticulatum* cultivated on floating cage was the highest in June as 3.32% day^{-1}. And using a longline, the SGR in July was the highest with 2.91% day^{-1}. The cultivation by using floating cages proved to be better in growth rates with no effect of herbivorous attacks.
Key Words: floating cage, longline, herbivorous, *Eucheuma denticulatum*.

Introduction. Seaweed cultivation has developed since the demand for rough material of carrageenan to develop industries in many countries, in particular at Southeast Asia. This spurred the development of seaweed production rapidly and provides expectations for the improvement of farmer's life. Seaweed cultivation in some countries such as Philippines has started with the cultivation of *Kappaphicus alvarezii* since 1971 (Doty & Alvarez 1973; Doty 1973; Parker 1974); Fiji island started since 1970 (Prakash 1990; Luxton et al 1987); Tuvalu started since 1977 (Gentle 1990); Malaysia has begun since 1978 (Doty 1973); in Indonesia has started to be cultivated since 1985 (Adnan & Porse 1987; Luxton 1993); Maldives began to develop in 1986 (Wu et al 1988); India and Tanzania started to develop cultivation since 1989 (Tanaka 1990; Smith 1990; Lirasan & Twide 1993); and some countries such as Vietnam, Brazil, and Venezuela began to develop over 1990 (Ohno et al 1996; de Paula et al 1999; Rincones & Rubio 1999).

Eucheumatoid cultivation methods were commonly modified by raft bamboo and developed to a longline method. Longline method has been used at some countries such as Philippines where is known as tie-tie (Azanza-Corales 1990; Ask & Azanza 2002). In some countries longline methods were applied for *K. alvarezii* cultivation, as commonly cultivation methods such as Indonesia, India, Malaysia, India, Tanzania, Vietnam, Brazil, Kenya and Madagascar (Luxton 1993; Lirasan & Twide 1993; Luxton et al 1987; Bindu 2011; Mollion & Braud 1993; Ohno et al 1996; Hayashi et al 2007; Ask & Azanza 2002). The development of cultivation method in Indonesia started since 1985 with a bamboo raft and developed into longline since 1992. Until now the longline method is developed by farmers and is estimated that it has been used in more than 70% of the total coastal area at every village with potential for seaweed farming. This method provides open access to some herbivorous fish. Recently, various problems appears due herbivorous fish continue to graze seaweed. Herbivorous fish activity can decrease total production of seaweed up to 60% (Kasim & Asnani 2012).

This study tried to explore the latest cultivation technology in Indonesia using PVC pipe as a substitute for bamboo with closed method, named floating cages. This method was used recently in 2014 by some farmers in eastern Indonesia. This method is expected to be the best solution for the problems that occurred with the previous method.

Material and Method. This research was conducted in the seaweeds cultivated area in coastal waters of Lakeba, Bau-Bau, and Southeast Sulawesi, Indonesia during April-September 2014. *Eucheuma denticulatum* was collected at Lakeba cultivation areas (50 48'78.2" N, 122 056'26.3" E). Main material of this experiment is floating cages. The floating cage used was a strung confinement of PVC pipe and a box with a dimension of 100 x 440 x 50 cm (Figure 1). The outer wall of the cage was wrapped with multifilament nets with a diameter of 1 cm while the upper side was fully opened to allow the control of *E. denticulatum*. The floating cages were designed to be partially in the water and a small portion of it remains on the surface of the water. The number of floating cages used was 3 units. Each floating cage had different experiments (treatments). Units of cages were conducted to explore the total growth rates in one cage. Each cage was divided into with 3 replicates with the same first weight (W0 = 5 kg).

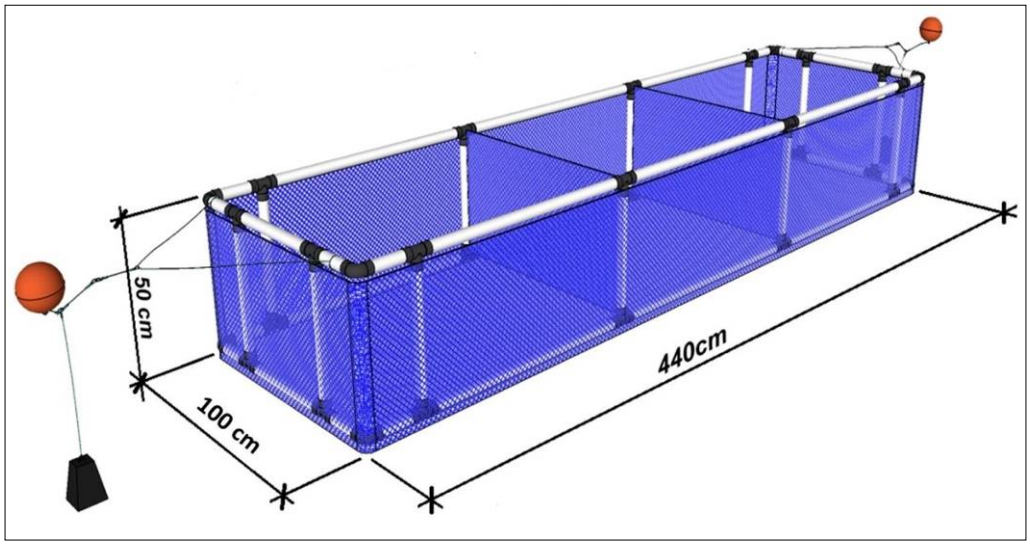

Figure 1. Floating cage used in the experiment.

First experiment was used to explore the effectiveness of using the cages against pests (herbivorous fish). The research was done by looking at the morphology and shape of the thallus of *E. denticulatum* scattered in a floating cage.

The second experiment was used to observe the effectiveness of floating cages for avoid attaching of epiphyte (*Enteromorpha* sp.) on the thallus of *E. denticulatum* where may bloom during the cultivation periods. Experiments were conducted by exploring growth rate of epiphytes on the thallus of *E. denticulatum*.

The third experiment was eventually used to explore the effectiveness of using the floating cages in accelerating the growth and production of *E. denticulatum*. Experiments were conducted by calculating the growth rate of new thallus of *E. denticulatum* in gram and the production in kg for the period of 90 days of field experiment. Growth rate was calculated for each cage (replicated) by the increase in wet weight and presented as percentage growth per day using the formula of Penniman et al (1986):

$$SGR = \% [(Gt/Go)1/t - 1] \times 100$$

Where: SGR = specific growth rate (% in wet weight per day), Gt = weight after t days, Go = initial weight, t = time in days.

In order to clarify the comparison with other methods, 6 units of longline were used in this experiment. In each longline unit, there were two PVC pipes on two different sides. Each side has one pipe with a length of 5 m. Among the two pipes tied rope with a length of 10 meters. Distance between one rope and other rope is 100 cm. On one unit

there are 10 ropes used to tie the seeds. Distance between *E. denticulatum* seed tied at the rope is 25 cm so that one unit contained 25 kg wet weight of *E. denticulatum*. The experiment for growth rate of total in kg was performed in 3 replicates with same first weight (5 kg) that are used in floating cage. Each replicate was signed with different color of line.

Seawater parameters were measured in situ by using the suitable equipment such as thermometer for temperature, refractometer for salinity, current meter for current velocity. Every measurement was done in every 3 days in day time and night time. Total (dissolved) nitrogen and phosphorus in water around the cages were determined spectrophotometrically according to the methods described by Strickland & Parsons (1972).

Correlation coefficients between growth rate and environmental factors were calculated using simple linear models (Pearson's r). Statistical analyses were performed using the SPSS package.

Results and Discussion

Growth rate. During May to November, the growth of *E. denticulatum* appeared to be different between the one growth in floating cage and longline. *E. denticulatum* growth in floating cage was found faster and appeared to have better thallus morphology.

Average production of *E. denticulatum* which used floating cage with more than 50 days of cultivation period was measured to be 74 and 78 kg per cage (100 x 440 x 50 cm), respectively. We observed differences in production at the cultivation periods of 40 and 50 days were 63 and 70 kg per unit, respectively when using longline (Figure 2). The difference in production between *E. denticulatum* cultivated by floating cage and longline appeared to be significant ($p < 0.05$). Cultivation of more than 50 days appeared to grow in a constant rate on the floating cage, and extremely decreased for longline.

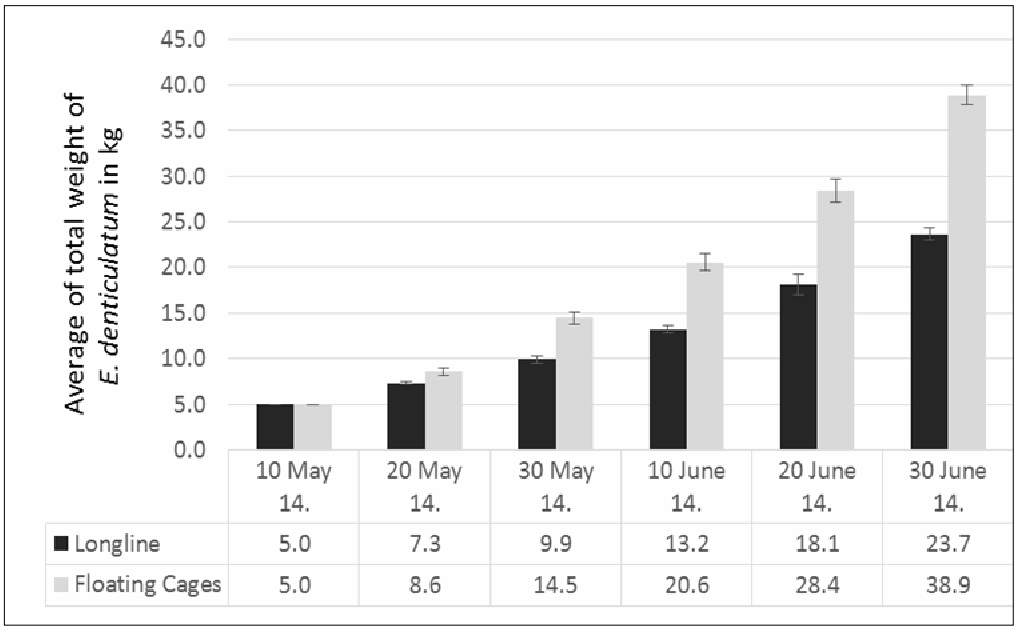

Figure 2. The different in average of total growth rate of *E. denticulatum* cultivated in floating cage and longline during 50 days.

Growth rate of new thallus of *E. denticulatum* cultivated with floating cage and longline for each month was observed during August, September and October. The average growth of new thallus after 45 days in August, September and October were 97, 73.3 and 47.5 g, respectively. During April-June, growth rate did not vary from the other months (Figure 3). SGR of *E. denticulatum* during 45 days on longline was decreased in July (1.67% day^{-1}) and increased in August (2.91% day^{-1}) (Figure 4). The SGR was low in April with 2.68% day^{-1} and the highest in June with 3.32% day^{-1} (Figure 5).

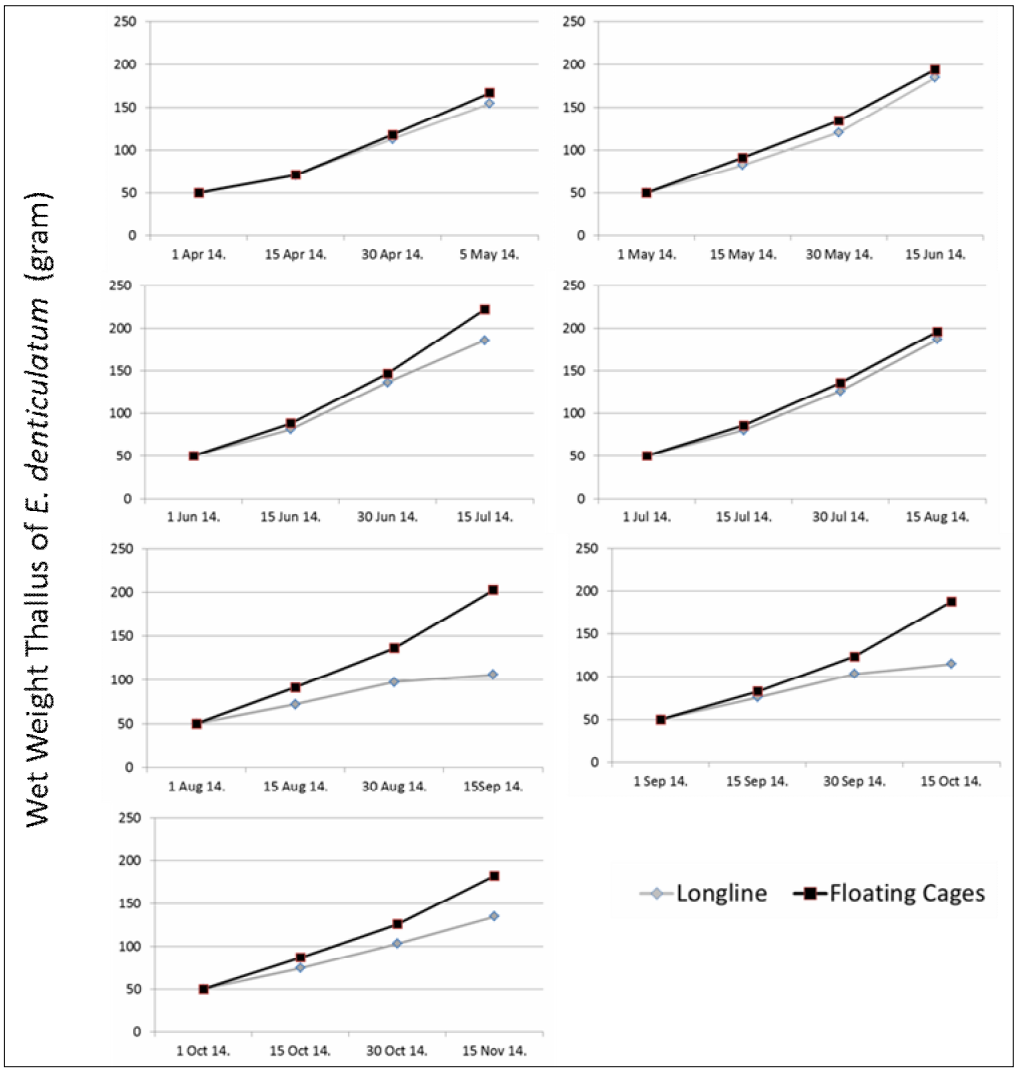

Figure 3. Monthly growth rates of *E. denticulatum* during 45 days in floating cage and longline.

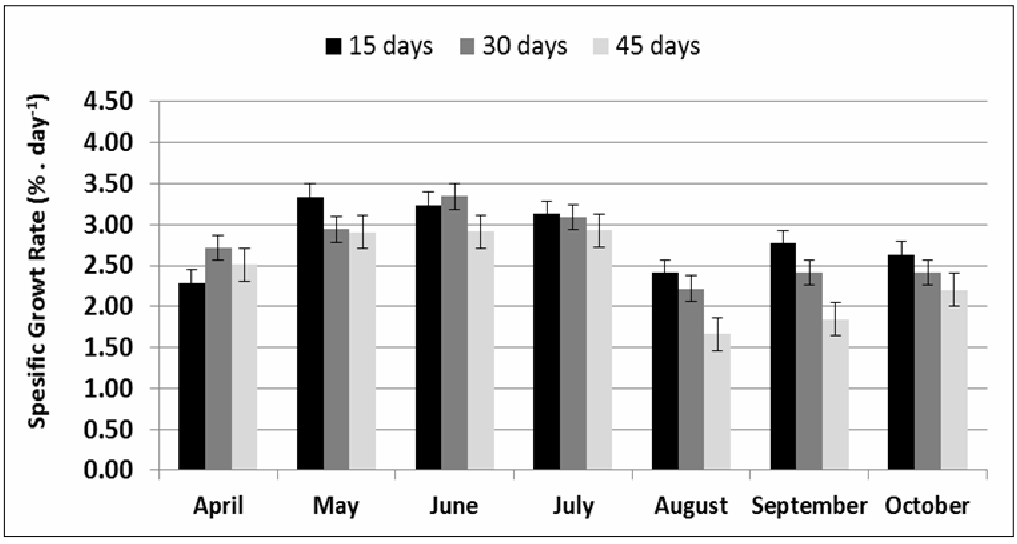

Figure 4. Specific growth rate (% day^{-1}) of *E. denticulatum* cultured on longline.

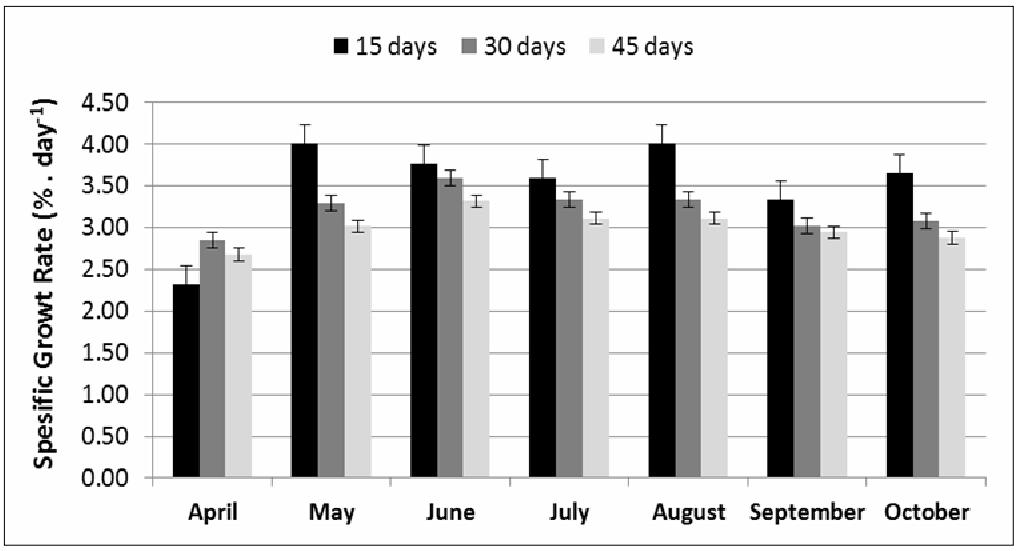

Figure 5. Specific growth rate (% day^{-1}) of *E. denticulatum* cultured on floating cage.

Morphological characteristics. Thallus morphology of *E. denticulatum* cultured by longline and floating cage looks different in August and September. In August, there were many herbivorous fish around longline methods that graze *E. denticulatum* (Figure 6A). In September, *E. denticulatum* covered by epyphite *Chaetomorpha* sp. (Figure 6B). The shape of *E. denticulatum* seen immaculate with lots of thallus and does not indicate an attack herbivorous fish (Figure 6C). Floating cage was useful in avoid of herbivorous fish attack (6D).

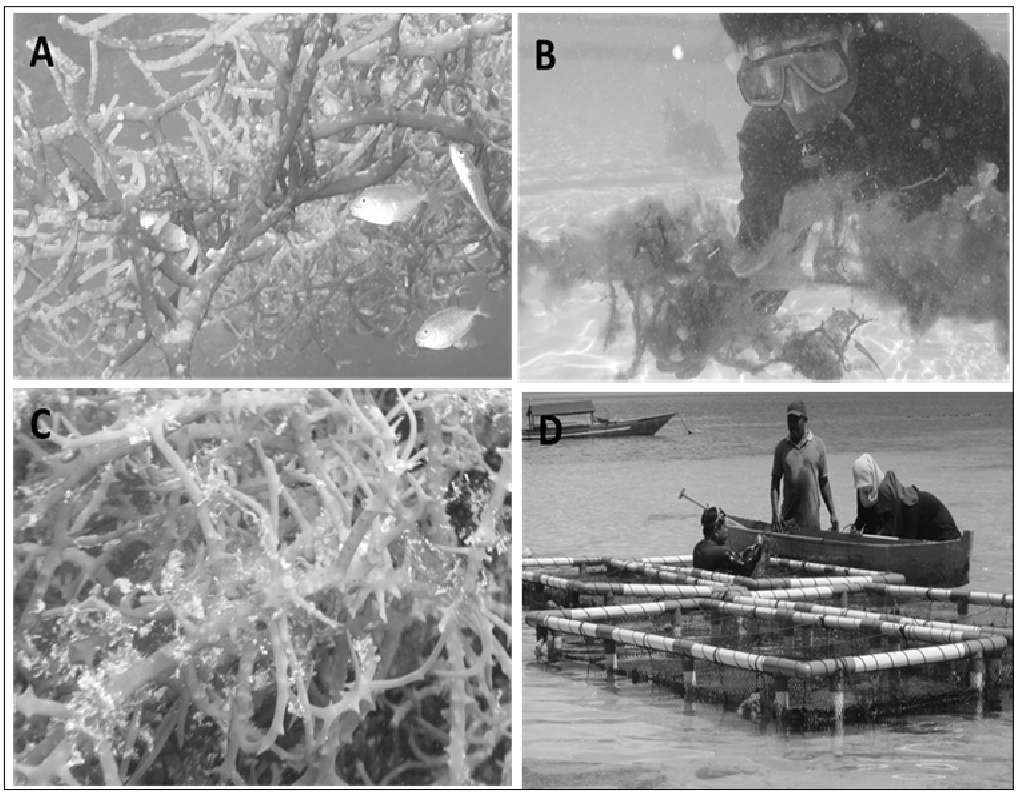

Figure 6. Herbivorous fish that are grazing *E. denticulatum* (A), *Chaetomorpha* sp. covered *E. denticulatum* on longline (B), appearance of *E. denticulatum* inside the floating cages (C), and floating cages which are used during the experiment (D).

Growth of *Chaetomorpha* sp. on each thallus of *E. denticulatum* (eight of 100 g), which is cultured by longline, seen to increase at the beginning of August and the end of

September was 2.9 and 2.78 g, respectively. Growth of *Chaetomorpha* sp., which is covered on *E. denticulatum* at longline, seen very high during end of August and beginning of September, was 3.68 and 2.89 g, respectively. In floating cage, *Chaetomorpha* sp. growth did not exceed an average of 0.5 g (Figure 7).

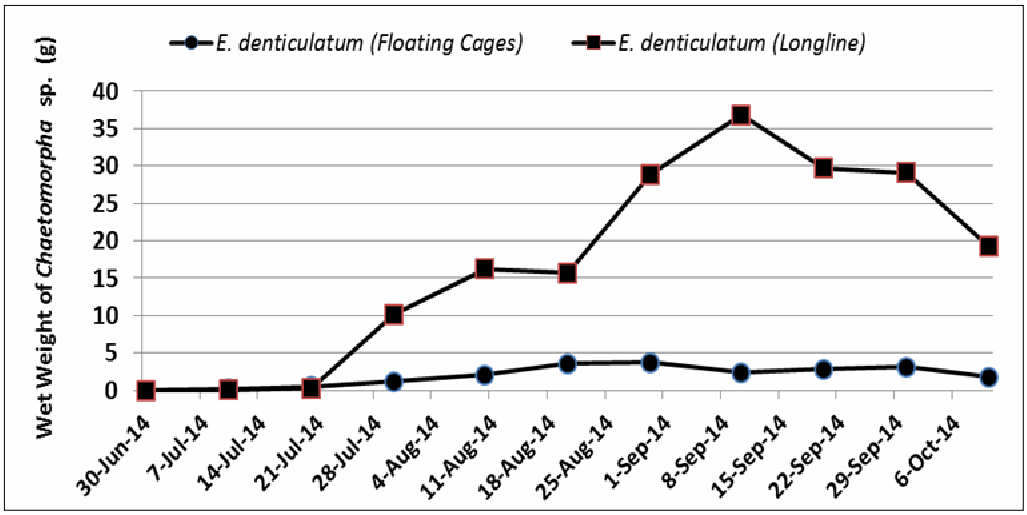

Figure 7. Growth of *Chaetomorpha* sp. during cultivation period on longline and inside the floating cages.

Environmental parameters. During the study, temperature at morning was 25-27°C and in the afternoon ranged between 27-32°C. The highest current velocity seen in July and August reached 0.163 and 0.167 m sec^{-1}, respectively, however, in general, the current velocity range was from 0.01 to 0.167 m sec^{-1}. Salinity ranged between 30-32 ‰. Nitrate concentration was highest in mid-June (0.838 mg L^{-1}) and low in the middle of October (0.0136 mg L^{-1}). Phosphate concentration was low in April (0.0017 mg L^{-1}) and high in middle-August for 0.0099 mg L^{-1} (Table 1)

Table 1

Physical and chemical parameters during cultivation periods

Dates	Temperature (ºC)		Current velocity	Salinity	Nitrate	Phosphate
	AM	PM	(m sec^{-1})	(‰)	(mg L^{-1})	(mg L^{-1})
15-Apr-14	26	29	0.067	32	0.0172	0.0074
30-Apr-14	26	29	0.067	31	0.0167	0.0017
15-May-14	27	30	0.017	32	0.0134	0.0079
30-May-14	26	28	0.035	32	0.0474	0.0061
15-Jun-14	25	27	0.171	30	0.0838	0.0057
30-Jun-14	27	29	0.177	31	0.0564	0.0086
15-Jul-14	26	30	0.163	32	0.0345	0.0084
30-Jul-14	27	31	0.051	32	0.0350	0.0051
15-Aug-14	26	30	0.135	31	0.0342	0.0085
30-Aug-14	27	31	0.167	30	0.0396	0.0079
15-Sep-14	26	32	0.087	31	0.0275	0.0099
30-Sep-14	27	31	0.067	32	0.0241	0.0087
10-Oct-14	26	30	0.017	31	0.0136	0.0052
30-Oct-14	27	31	0.031	31	0.0291	0.0079
15-Nov-14	25	29	0.067	30	0.0474	0.0060

Presently there are very few studies which are comparing the growth of *Eucheuma* sp. with different cultivation methods. In our study, the growth *E. denticulatum* cultivated by cages and longline seem less different in April-July for 40-50 days when there were no herbivorous fish. However, *E. denticulatum* cultivated by longline has a relatively low

growth compared with the floating cage. From our field observation during August, current was starting to fast and affected seaweeds at near surface. Most seaweed was shaking by current and several were broken and some other thallus were grazed by herbivorous fish.

The average growth rate of thallus of *E. denticulatum* in August seen to decrease drastically when herbivores fish are found abundantly around the cultivation area. Hurtado-Ponce (1992) found that the production of the cultured *Eucheuma* sp. in Igang Guimaras Philipines during February and March were 862 and 575 g m^{-1} $line^{-1}$. The growth rate of *Eucheuma* sp. seen to increase during April and May to become 1877 and 2237 g m^{-1} $line^{-1}$. The increase of growth rate is good in general, because *Eucheuma* sp. is kept in floating cages that protect it against herbivorous fish. Growth of Euchematoids in April and May is a good season for *Eucheuma* sp. In Bongao, Southern Philippines, *Eucheuma* sp. growth rate can reach 300% of the biomass after cultivated for 4-7 weeks (Villanueva et al 2011). In Vietnam, growth rate of *Eucheuma* sp. cultivated by longline method at a depth of 0.5 to 1 m seems good during January-August, with daily growth average of 6.14 to 6.26% day^{-1}. However, the growth rate was increased in May-June in the range 9.14-10.8% day^{-1} respectively (Ohno et al 1994). In Ubatuba Bay, Sao Paulo, Brazil, *Eucheuma* sp. cultured with monoline method grew well at water surface and at a depth of 0.5 m. Mean growth rate ranged from 5.2 to 7.2% day^{-1} for the cultivation period of 28 days. However, growth is seen to decline during the cultivation for 59 days and seems highest growth rate during 44 days (Hayashi et al 2007). In Madagascar, the highest growth rate of *E. denticulatum* was recorded in April and February. While in March decreased growth rate was caused by herbivorous and ice-ice diseases. Specific growth rate recorded at each planting season was 2.2% day^{-1} (Mollion & Braud 1993). In Yucatan State, Mexico, the growth rate of *Eucheuma isiforme* increased during the 25-day cultivation of 2.21% day^{-1}. Growth rate decreased after 50 days because of the presence of pests and ice-ice (Perez-Enriquez 1996). At Vizhinjam village, Kerala, India, growth and production of *Eucheuma* sp. in shallow waters seem high at 45-60 days of cultivation with the production of 24 and 36 kg respectively, occurred in March and May (Bindu 2011).

During our study, environmental factors also played an important role for the growth of *E. denticulatum*. For the good growth of *E. denticulatum* in June and July, the temperature ranges from 26-29°C, salinity ranges from 30-31 ‰ with a strong enough current velocity compared to other months (0.163 to 0.177 m sec^{-1}). Nitrate concentration ranging from 0.564 to 0.0838 mg L^{-1} and phosphate ranges from 0.0084 to 0.0086 mg L^{-1}. *Eucheuma* sp. growth in Vietnam is also related to environmental conditions. In May *Eucheuma* sp. growth of related with a range of 27.2 to 30°C temperature. Salinity ranged from 31.4 to 34 ‰ (Ohno et al 1996). In the Philippines, a good temperature for growth of *Eucheuma* sp. is 28-30°C and salinity ranges from 33-35 ‰ (Dawes et al 1994).

Conclusions. Differences in cultivation methods will provide differences in growth rate. Longline method is the open method which provides an opportunity for herbivorous fish to graze *E. denticulatum*. Average growth rate of *E. denticulatum* cultivated in floating cage was higher compared to longline technique and the growth rate of *E. denticulatum* cultivated in floating cage and longline seems very different in August when many herbivorous fish are present around the cultivation area. It is concluded that the cultivation by using floating cages proved to be better in growth rates with no effect of herbivorous attacks.

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