Chapter

Floating Cage: A New Innovation of Seaweed Culture

Ma'ruf Kasim, Abdul Muis Balubi, Ahmad Mustafa, Rahman Nurdin, Rahmad Sofyan Patadjai and Wardha Jalil

Abstract

Eucheumatoid cultivation continues to expand with a variety of methods that can increase production. This chapter will discuss an innovation in seaweed cultivation of the genus *Eucheuma*, which is the prime marine commodity in the tropical regions of the world. Research conducted during 2015-2017 and 2019 in Southeast Sulawesi Province, Indonesia, provided an overview of the use of floating cage that showed very significant growth results. The research result showed that the growth rates of *Eucheuma denticulatum* and *Kappaphycus alvarezii* in floating cage seemed faster and resulted in better thallus morphology. Daily production of *E. denticulatum* and *K. alvarezii* that were cultivated in floating cage was higher than daily production of *E. denticulatum* and *K. alvarezii* cultivated on longline. Specific growth rate (SGR) of *E. denticulatum* and *K. alvarezii* cultivated by using floating cage method was also higher than *E. denticulatum* and *K. alvarezii* cultivated by using longline method. Moreover, the cultivation by using floating cages produces good growth rates with no effect of herbivore attacks.

Keywords: *Kappaphycus alvarezii*, *Eucheuma denticulatum*, floating cage, longline

1. Introduction

Seaweed cultivation is a good activity for improving the welfare of coastal communities. Several countries in Southeast Asia such as in the Philippines [1] cultivate seaweed with a fairly high production. *Kappaphycus alvarezii* is a type of macroalgae that is widely cultivated by the community. The morphological form of this species looks very bright and has many branches. This species has large primary thallus, and the color of the thallus is darker than that of thallus branches that look bright from the maintenance of vegetative branches [2]. Old branches of *Eucheuma denticulatum* that has been cultivated for more than 4 weeks are seen to spread. This distribution is thought to be a major factor causing this species to grow on coral reefs in Kaneohe Bay, Hawaii. Meanwhile, some of the most widely cultivated species are *K. alvarezii*, *Eucheuma striatum*, and *E. denticulatum* [2]. *E. denticulatum* has been widely cultivated in several countries such as the Philippines since 1971 [3–5]. The production of *Eucheuma* species continued to increase very rapidly in the initial cultivation process in 1971 with initial seedlings of less than 1000 Mt. of dry weight up to 100,000 Mt. of dry weight [3]. Two countries in Southeast Asia which intensively cultivate *E. cottonii* species are the Philippines and Indonesia. Specifically in Indonesia, until 1990, this seaweed production reached 6 Mt. per year of cultivation area [6]. Seaweed species of *Eucheuma* sp. is a group of lower plant known as seaweed and has a fairly rapid growth in nature [1]. Philippines is a country that has succeeded in developing a generative regeneration system, making the development of seaweed *Eucheuma* sp. quite fast [7]. Seedling growth tends to be rapid with changes in weights that continue to increase every week [8]. Meanwhile, Fiji Island has begun developing *K. alvarezii* aquaculture in their surrounding waters since 1970. Cultivation K. alvarezii are simple with poles and ropes and then develop to date using the longline method [9, 10]. Tuvalu has begun developing the cultivation of seaweed since 1977 [11], while Malaysia has developed cultivation since 1978 [4]. In Indonesia, the cultivation has begun to develop since 1985 [12, 13], while in Maldives, it has begun to develop in 1986 [14]. Furthermore, India and Tanzania have begun developing cultivation since 1989 [15–17], and several countries such as Vietnam, Brazil, and Venezuela have begun developing during the 1990s [18–20].

Cultivation of *K. alvarezii* developed quite well and provided a fairly good growth related to various physical chemical environmental factors that existed especially in the Yucatan region of Mexico [21]. Although well developed, growth of *K. alvarezii* species fluctuates seasonally especially in the northwestern coast of India [22]. The production value of the *K. alvarezii* species also depends on the cultivation method used. A closed method protecting *K. alvarezii* from various herbivorous attacks will be better than open methods. This happened in the waters of the south coast of Rio de Jeneiro, Brazil, illustrating that cultivation techniques with tubular netting are better than with the longline method [23].

Currently, various problems continue to afflict cultivation activities carried out by the community. One thing that really stands out from the various problems that exist is the low quality and low production of seaweed. There has been a decline in the quality of seaweed after 20 years of seaweed production in the Pacific region. Specifically in Indonesia, the low production of seaweed cultivation is caused by low quality of seeds, poor cultivation methods, intensity of attacks of pests and diseases, and marine environment that is impacted by global climate change [24]. Increase in population of herbivorous fish in the seaweed cultivation areas around the Mediterranean waters correlated with the species of epiphyte that existed. Current phenomenon that some unprotected cultivation sites provide food opportunities for herbivorous fish [25]. Recently, many studies have been done, but there are no appropriate actions and solutions to overcome the existing problems. Each stage of seaweed cultivation has its own specific problems. For this reason, it is very important to conduct a thorough and integrated research to approach every problem, starting from getting good quality seeds, good maintenance patterns, and biological, physical, chemical, and ecological factors related to seaweed resistance to the economic value of each production results that affect the selling value of seaweed.

2. Current problems in seaweed cultivation

The phenomenon of grazing by herbivorous fish is very common in all locations of seaweed cultivation (**Figure 1**). In India, especially in Krusadai Island, the production of seaweed farming of *Kappaphycus alvarezii* and *Eucheuma denticulatum* species has decreased around 10% of their growth due to attacks of herbivorous fish such as *Siganus javus* (rabbitfish), *Acanthurus* sp. (surgeonfish), *Cetoscarus* sp. (parrot fish), and sea urchin *Tripneustes* sp. [25]. Therefore, cultivation of *Kappaphycus alvarezii* in a cage can prevent seaweed from being attacked by herbivore. Cultivation with this protection system can be done with modifications in accordance with the topography of the area, and this has been done in several cultivation areas in the Philippines [26].

Figure 1.
*Grazing activity of herbivorous fish (*Siganus *sp.) on* Kappaphycus alvarezii*.*

The use of cage for *K. alvarezii* cultivation can be carried out in areas that have high intensity of herbivorous fish attack. However, the durability of the tools to support cultivation needs to be considered. *K. alvarezii* cultivation activity together with oysters and snapper cultivation activities is an alternative cultivation with a good confinement system [27]. Seaweed *Gracilaria gracilis* can be cultivated in a closed container to avoid various attacks by herbivore such as isopods. These animals are seen to not exist in closed cultivation conditions, thus preventing these animals from entering to eat seaweed. Herbivorous fish are not detected when this type of seaweed is treated with freshwater in an enlargement tank, which does not cause damage [28].

3. New innovation method in seaweed cultivation

Floating cage is a technological design that functions as a seaweed cultivation tool. This cultivation tool can protect seaweed from pests while reducing the potential for ice–ice disease [16, 29, 30]. Various sizes and shapes were developed as tools that can be used for seaweed cultivation. The basic materials of floating cages include PVC pipes, nets equipped with buoys as markers, and weights attached to the raft to facilitate the laying of the raft in the desired area. The shape of the tool is designed like a rectangular box with varied sizes. The surface of the raft is left

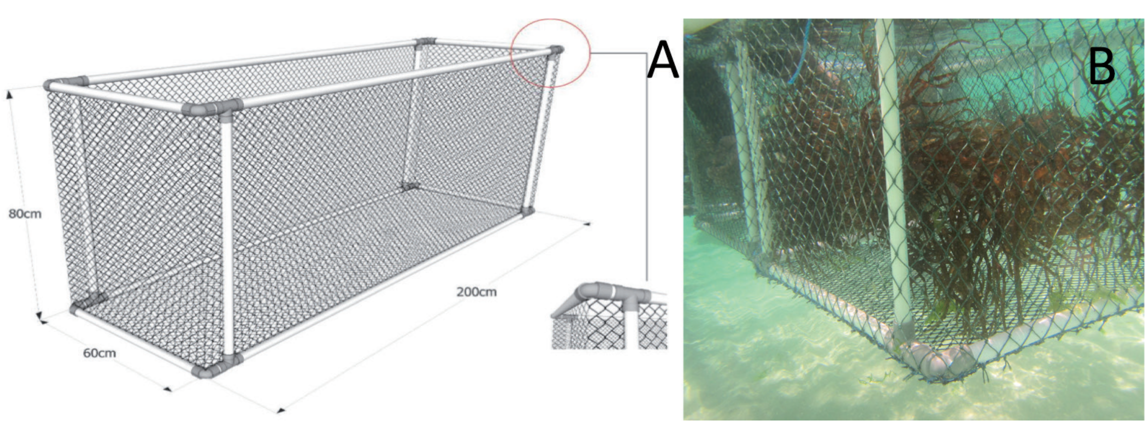

Figure 2.
Illustration of floating cage that was used during research (a). Thallus of K. alvarezii *inside the floating cage (B).*

open, while the bottom and all sides are covered using a multifilament net with a mesh size of 1 cm [31]. The process of seaweed cultivation in floating cages is done by spreading seaweed directly in floating cage without binding. In the harvesting process, floating cage can be directly drawn to the shallower parts of the coast so that the harvesting process can be more easily done (**Figure 2**).

4. Growth of thalli of *Kappaphycus alvarezii* in floating cage

The growth of thalli of *Kappaphycus alvarezii* cultivated in Lakeba Beach, Southeast Sulawesi Province, Indonesia, was different from *E. denticulatum* which was maintained by a floating net (**Figure 2**) and longline (**Figure 3**). This difference occurred during 20, 30, and 40 days of the maintenance period. More differences were caused by the shape and number of thalli that grew and the presence of disruption from pests. This was because the thalli maintained by the longline method looked new and sporadic, and the tip of each thallus appeared to be blunt. This indicated the presence of pests that ate seaweed. Meanwhile, those maintained with

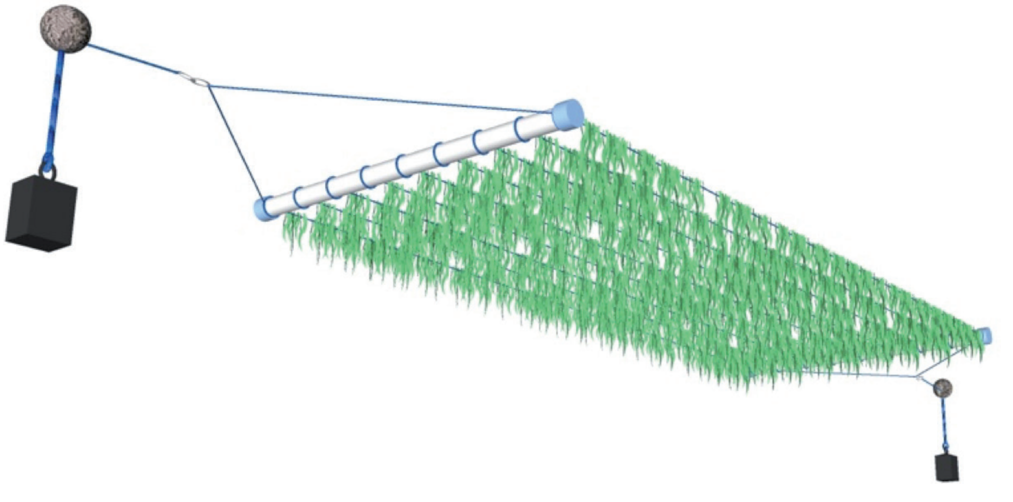

Figure 3.
Illustration of seaweed cultivated on longline.

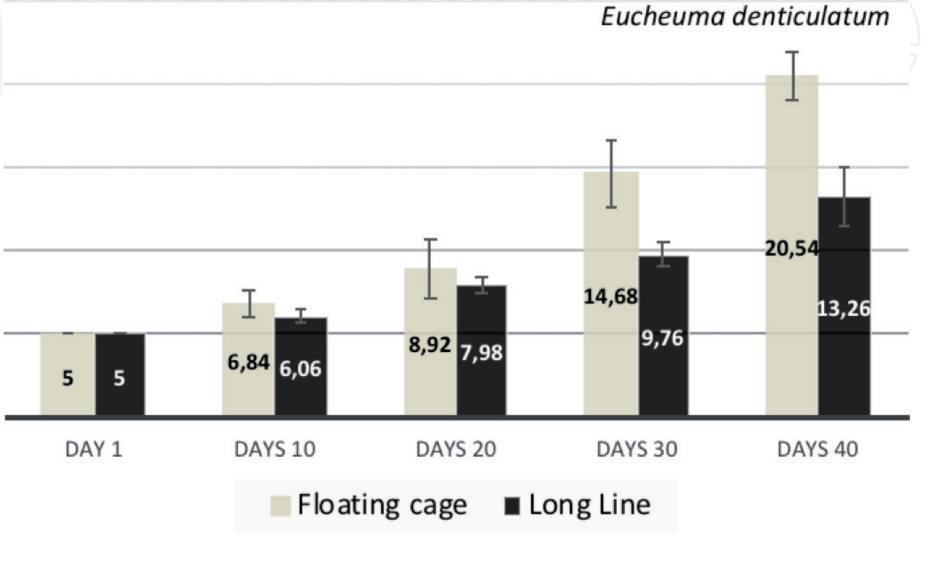

Figure 4.
Total growth of seaweed Eucheuma denticulatum *cultivated with floating cage and longline at initial weight of 5 kg.*

floating net rafts appeared to have lush thallus with tapered thallus tip. The results show that seaweed production cultivated by floating cage looked much better than that cultivated by longline. Growths of *E. denticulatum* that was cultivated using floating cage and longline looked different. The growth of cultivation over 40 days developed from an initial weight of 5–20.54 and 13.26 kg by using floating cage and longline, respectively (**Figure 4**).

The growth trials of *K. alvarezii* also showed different results for initial weights of 5 kg. In the process of cultivation for 40 days, the growth of this species increased to 19.2 and 12.7 for cultivation using floating cage and longline, respectively (**Figure 5**).

The results of the growth of new thallus with initial weight of 100 g showed the difference in the floating cage and on longline. From the results of the cultivation for 40 days, it was seen that the change in the weight of *E. denticulatum* on the longline was only around 432 g, while the change in weight in floating cage could reach an average of 1028 g. This result was very significant where changes in seaweed weights can reach 10 times for adequate seedlings (**Figure 6**).

There was also a difference between cultivations of *K. alvarezii* seeds in floating cage and on longline. With an initial 100 g wet weight, the change in wet

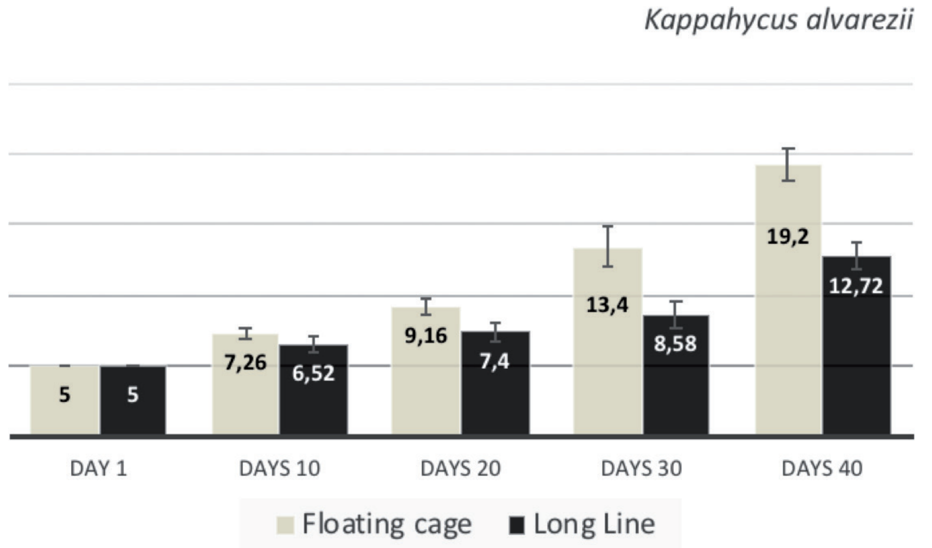

Figure 5.
Total growth of seaweed K. alvarezii *which was cultivated with floating cage and longline at an initial weight of 5 kg.*

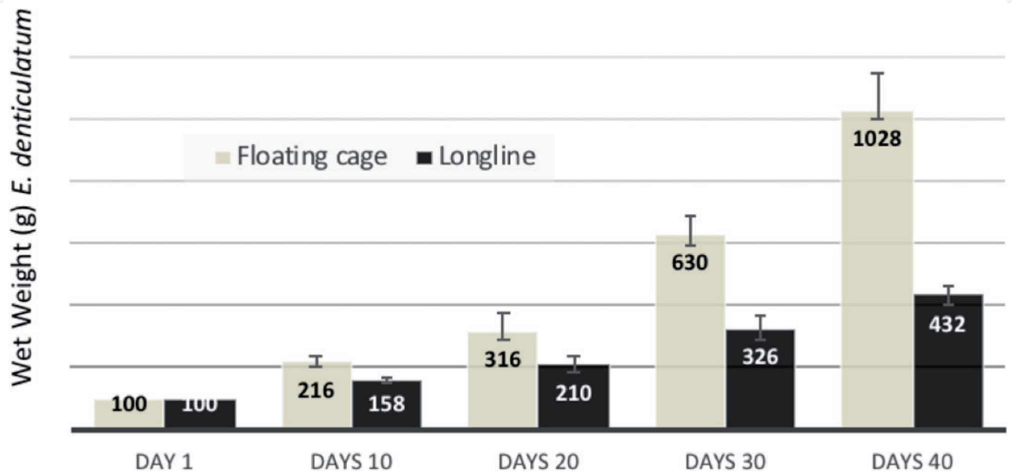

Figure 6.
Differences in growth of E. denticulatum *cultivated by floating cage and longline with initial weights of 100 g.*

weight of *K. alvarezii* by the longline method could reach 488 g, while with floating cage, it could reach an average of 758 g. This difference in growth was greatly influenced by several factors, including pests that were very intensely attacking seaweed, current pressure that could occasionally wash seaweed from its bonds, and seaweed *Chaetomorpha* sp. that developed quite high in all cultivation locations (**Figure 7**).

The difference in growth and weight of thallus in each month shows the difference between cultivation with floating cage and longline. On the growth chart, it can be seen that changes in seaweed weights had begun since the cultivation period for 10 days and the first 20 days. Furthermore, the changes were seen to be greater on the 30th and 40th days. This proves that maintenance with longline guarantees that seaweed can continue to grow well without any interference from pests and diseases that can reduce seaweed production. Another reason for the difference is that the longline cultivation method is prone to current shocks that can break the seaweed so that it will be washed away by the current.

Specific growth rates of *E. denticulatum* species differed in longline and floating cage cultivation methods. The average SGR of *E. denticulatum* was around 4.3%/day for the use of longline method, while for the use a floating cage, the SGR averaged

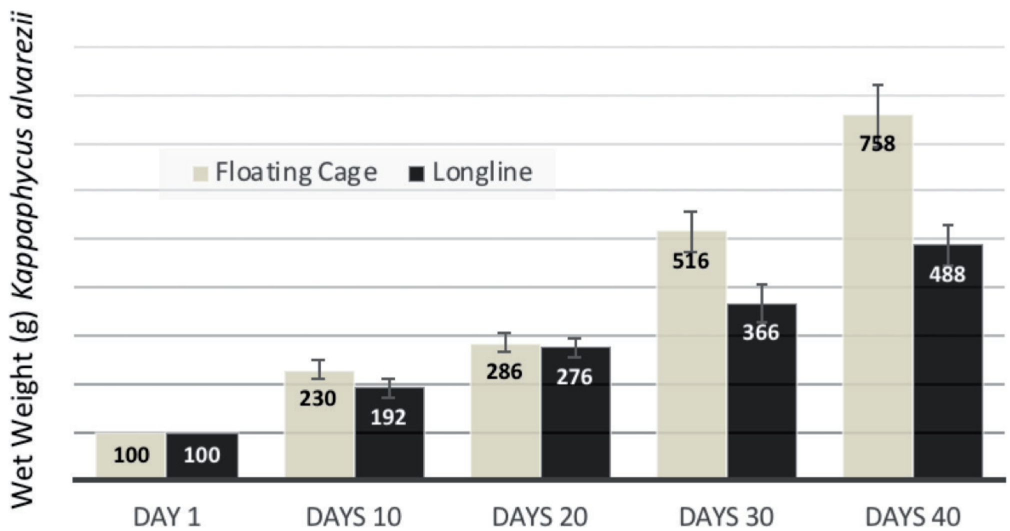

Figure 7.
Differences in growth of K. alvarezii *maintained by floating cage and longline with initial weights of 100 g.*

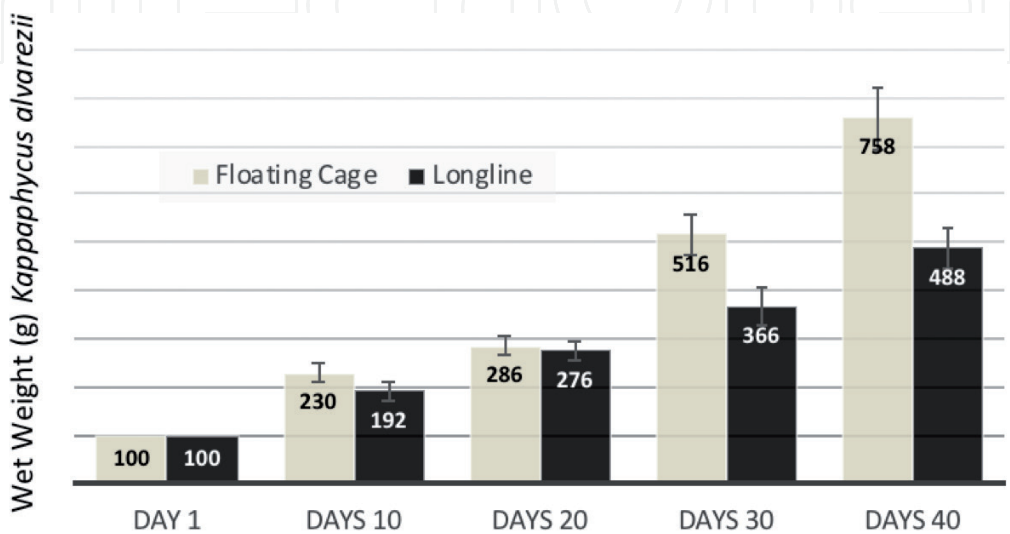

Figure 8.
Specific growth rate of E. denticulatum *cultivated with longline and floating cage.*

6.4%/day. SGR difference looked even each month. During the 6-month cultivation period (April–September) with a 35-day planting period, it was seen that the difference between floating cage and longline was around 3% (**Figure 8**).

The result of specific growth rates of seaweed *K. alvarezii* cultivated with longline was 4.1% per day, appearing to be lower on average than the specific growth rate of seaweed maintained with floating cage, which could reach 5.8%/day (**Figure 9**). The specific growth rate of *K. alvarezii* is an illustration of the daily growth rate of seaweed compared to the total growth in one harvest period. This

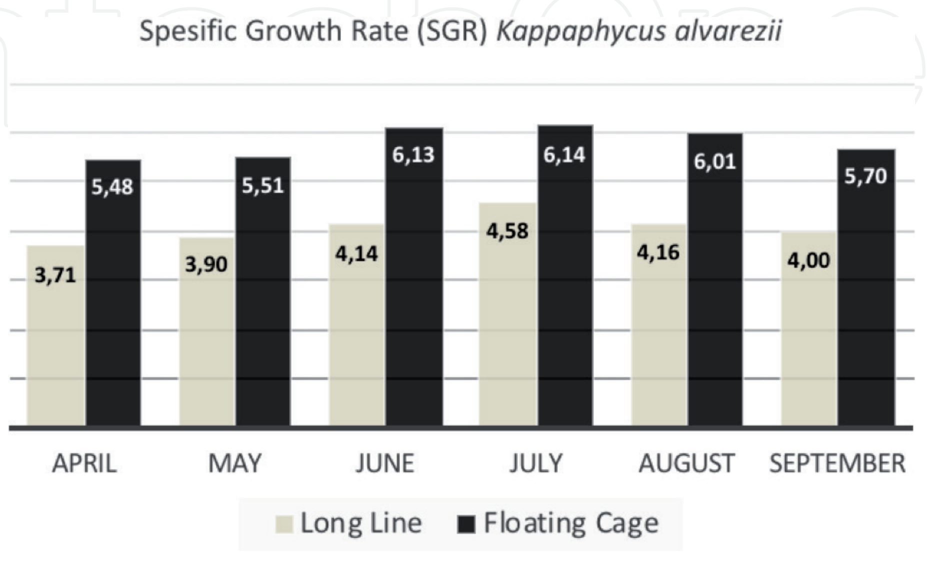

Figure 9.
Specific growth rate of K. alvarezii *that was cultivated by longline and floating cage.*

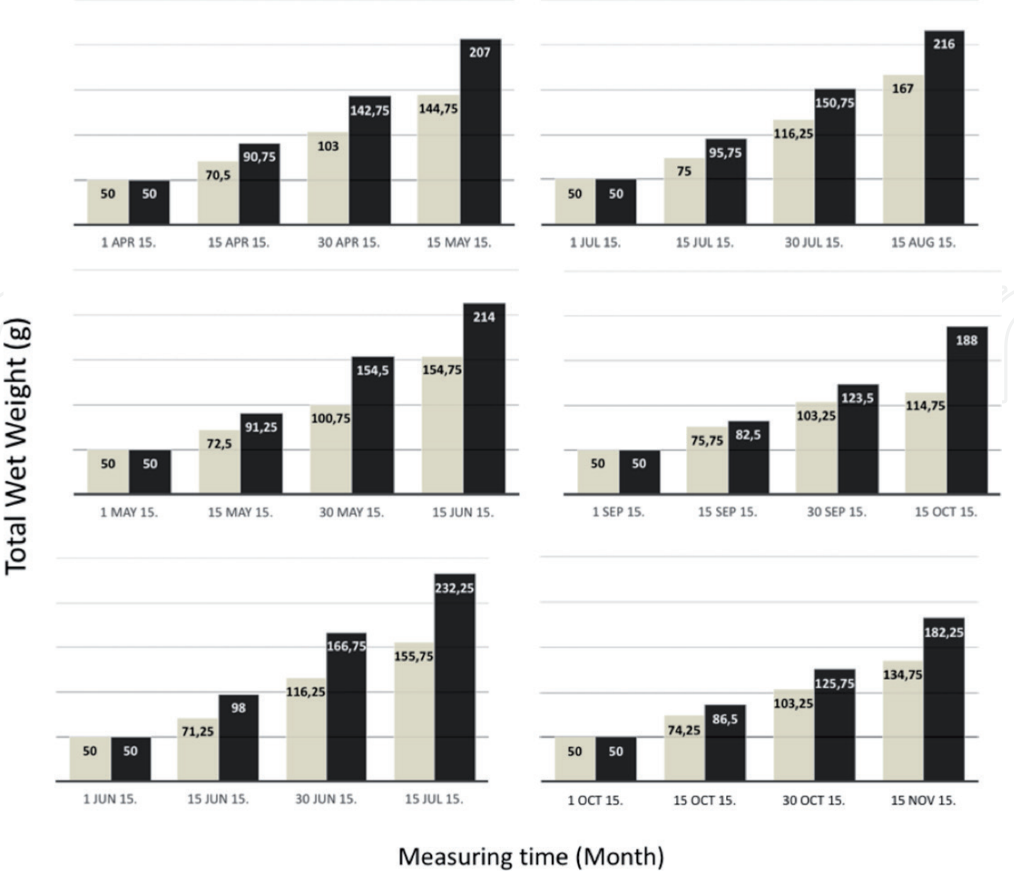

Figure 10.
Growth of thalli of E. denticulatum *cultivated with longline and floating net rafts [29, 30].*

means that the daily growth rate of seaweed maintained by longline is much lower than the daily growth rate of seaweed maintained by floating cages.

The growth of new thallus per month during the research from May to November showed that there were variations in growth each month that were quite different between the two methods. However, these variations did not provide a significant difference in thallus growth each month in the floating cage. The growth from May to July was seen to be different from the growth from September to November (**Figure 10**). The total growth using floating cage method was much higher than the growth using the longline method, especially in August to November. This can be expected from the presence of herbivorous fish that often attack seaweed in the months of August to November. The longline method is an open method that provides opportunities for herbivorous fish to eat seaweed, while floating cage is a closed method that protects seaweed from various attacks of pests, especially herbivorous fish.

The growth of the new thallus from May to November showed that there were variations in growth each month. However, these variations did not provide a significant difference for thallus growth each month in floating cage. Observation during May to July, growth was seen to be different from September to November (**Figure 11**).

However, if we look at the difference of growth in the floating cage method and the longline method for each different month, it appeared that the two methods had significantly different growths. The total growth in floating cage was much higher than the growth in the longline, especially in August to November. This can be expected from the presence of herbivorous fish that often attack seaweed in the months of August to November. It is important to be noted that longline method is an open method that provides opportunities for herbivorous fish to eat seaweed,

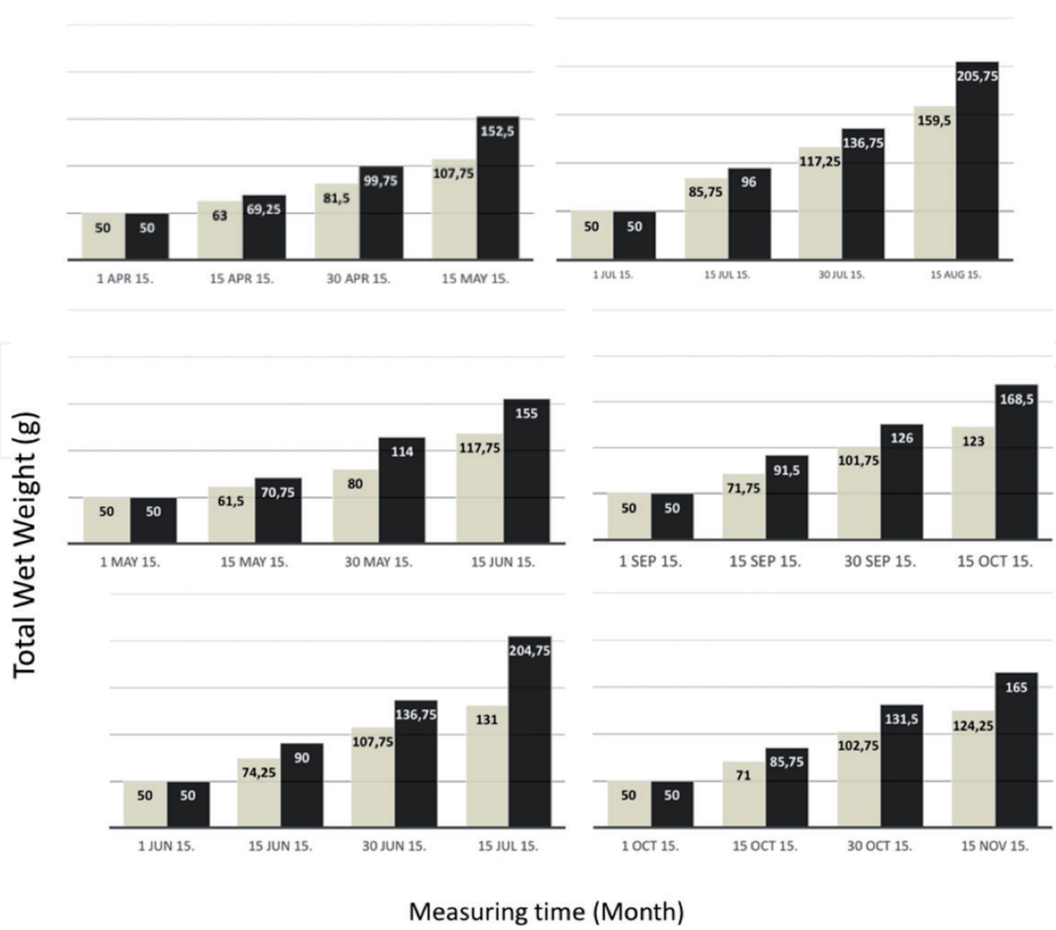

Figure 11.
Growth of the thalli of K. alvarezii *cultivated with longline and floating net rafts [29, 30].*

while the floating cage method is a closed method that protects seaweed from various attacks of pests, especially herbivorous fish (**Figures 10** and **11**).

The growth rate of *K. alvarezii* which was cultivated by floating cage was different from the growth of the same species in the longline. From the results of research conducted, the growth of *K. alvarezii* on longline was slower than the growth of the species in floating cage for 40 days. On the growth chart, the trend is seen to be rising and different between the two methods. The more visible difference was the growth in 40 days during the cultivation process. Production of *E. denticulatum* and *K. alvarezii* seemed to be slow with the longline method. Some of the indications seen at the cultivation site were that the use of the longline method in the harsh conditions of the waves experienced a hard shock and caused the fracture of the thallus of *K. alvarezii* and *E. denticulatum*. Broken thallus will reduce the weight achieved in 40 days of cultivation. The use of floating cage can avoid the drift of the thallus if it is broken and causes seaweed to remain in the cultivation area. Another situation was the extent that was still in the area of cultivation attacked by herbivorous fish. The most recent indication was that the average growth rates of the thallus of *K. alvarezii* and *E. denticulatum* in August were seen to decrease dramatically when fish herbivores were found to be abundant around the cultivation area. Production of *K. alvarezii* cultivated in Igang, Guimaras, Philippines, during February and March was 862 and 575 g/m/line. The growth rate of *K. alvarezii* was seen to increase during April and May with 1877 and 2237 g/m/line [26].

The increase in growth of this type is quite significant because *K. alvarezii* is kept in bamboo cages that block access of pest fish to attack *K. alvarezii*. The condition of seaweed in this area during the months of April and May looks very good. The time period of April to May is a good growing season. Some thalli are seen growing well and in good morphological form. While in Bongao, Southern Philippines, the growth rate of *K. alvarezii* can actually reach 300% of the average initial weight after being cultivated for 4–7 weeks [32], in Vietnam, the growth rate of *K. alvarezii* cultivated by the longline method with different depths, especially at a depth of 0.5–1 m, appeared to be increasing and in good condition during the time period of January–August, with a range daily growth of 6.14–6.26% on day 1. However, the growth rate increased in the time period of May–June in the range of 9.14–10.8% each day [33]. In Ubatuba Bay, Sao Paulo, Brazil, *K. alvarezii* was bred with the monoline method and grew well on the surface of the water and at a depth of 0.5 m [35]. The average growth of this species with a cultivation time of around 28 days was in the range of 5.2–7.2% day 1. However, growth was seen to decrease during cultivation for 59 days. Highest productivity was on day 44 during cultivation [34].

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 fish and ice–ice disease [36]. Specific growth rate recorded at each planting season was 2.2% day 1 [32]. In Yucatan State, Mexico, the growth rate of *Eucheuma isiforme* increased during the 25-day cultivation of 2.21% day 1. The growth rate highly decreased in cultivation period after 50 days since the presence of pests and ice–ice disease [33, 37]. At Vizhinjam village, Kerala, India, the growth and production of *K. alvarezii* in shallow waters seemed high at 45–60 days of cultivation with the production of 24 and 36 kg, respectively, in March and May [34].

5. Thallus health condition in a floating cage

Thallus health can be seen from the morphological form of the thallus. The healthy shape of the thallus morphology looks cleaner. Healthy thallus has tapered tip, and there are many new thalli starting to emerge. Thallus of seaweed

Figure 12.
Thallus of K. alvarezii *cultivated by floating cage.*

maintained by the floating cage looked cleaner than that maintained by longline (**Figure 12**). At the time of a fairly high pest attack, seaweed thallus looked white and would eventually die. Seaweed thallus which was attacked by pests had many wounds and bleached and the thallus was cut off. The intensity of this pest attack was seen at all times, especially during the attack of *Siganus* sp., which usually happens in August–November every year. However, this pest is not the only one that often attacks seaweed. Some farmers reported that their seaweed was attacked by sea turtles. This is because sea turtle is a herbivore that likes to eat seaweed.

Besides fish pests, it was also reported that a number of thalli that died or were sick were mainly caused by ice–ice disease which often attacks seaweed. In general, longline cultivation provides opportunities for seaweed to be affected by changes in temperature and salinity at certain times, especially in the rainy and dry seasons. During summer, a lot of seaweed is affected by surface heat so that it becomes stressed and eventually bleaches. When the rainy season occurs, some seaweed will be affected by changes in surface salinity, which drops suddenly due to rainwater, because seaweed is very close to the surface of the water. Different things can be seen with the use of the floating cage. Seaweed in this tool looks fresher and healthier because it will be able to avoid herbivorous pests. Besides that, seaweed will also be able to avoid changes in temperature and surface salinity during rainy season or dry season. Seaweed in floating cage will be submerged at depths above 10 cm below sea level. Thallus of seaweed maintained by floating cage looks clean, and the tip of the thallus is tapered, and there are no bites of data pests nor is there ice–ice disease [38]. Seaweed in floating cages has many thalli that continue to grow. Thallus morphologies of *E. denticulatum* and *K. alvarezii* that were cultured with longline and floating cage looked different in August and September. In August, the intensity of herbivore attack was seen to be high enough so *E. denticulatum* and *K. alvarezii* were highly consumed by herbivorous fish (**Figure 1**). In September, it could be seen that epiphytic *Chaetomorpha* sp. wrapped *E. denticulatum* and *K. alvarezii* until they could not be seen. Morphologies of *E. denticulatum* and *K. alvarezii* that were in floating cage looked intact, and there was no sign of being consumed by fish. Growth of *Chaetomorpha* sp. on each thallus of *K. alvarezii* (weight

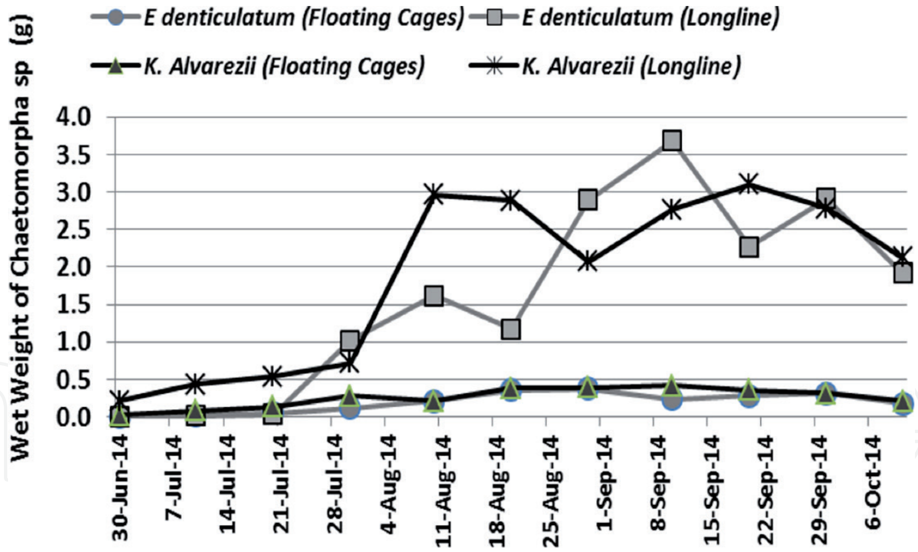

Figure 13.
Growth of Chaetomorpha *sp. during cultivation periods on longline and inside the floating cages.*

100 g) that was cultured by longline was seen to rise at the beginning of August and at the end of September with 2.9, and 2.78 g, respectively. Meanwhile, growth of *Chaetomorpha* sp., which covered *E. denticulatum* also at longline, was seen to be very high at the end of August and at beginning of September with 3.68 and 2.89 g, respectively. Different phenomena were seen in floating cage where *Chaetomorpha* sp. growth did not exceed an average of 0.5 g (**Figure 13**).

6. Floating cage development recommendations

The results showed that floating cage had a significant effect on increasing seaweed production. Seaweed is completely protected from pests and ice–ice disease. Increased seaweed production will provide increased harvest income from seaweed cultivation. Floating cage is a very simple innovation tool that has a series of seaweed cultivation tools from PVC paralon and nets. This tool is very environmentally friendly if compared with the current seaweed method. At present, the longline method has various serious problems. The problem is, in certain areas, pests and epiphyte attachments occur as well as the use of used plastic bottles. The use of used plastic bottles is an act that is not environmentally friendly. Used plastic bottles used as buoys are seen to pollute the ocean and have a wider impact on organisms around the cultivation area (**Figure 14**).

The survey results explain that in 1 Ha longline cultivation area will require at least 200 used plastic bottles. Plastic bottles are used as buoys in seaweed cultivation. Used plastic bottles are taken from bottle wastes in the community environment. The use of used plastic bottles can be used only in 1 year of use; after 1 year usually these plastic bottles will leak and be thrown into the sea. Many serious problems occur among farmers. At present it is very important to develop an alternative seaweed cultivation that is environmentally friendly and has high productivity.

Floating cage that uses multifilament nets and PVC pipe does not cause environmental damage (**Figure 14**). PVC pipe is used as a float and also as a main pole to hold the net. PVC pipe series will last long enough in the waters. The use of PVC pipe and nets with good care will provide a long usage period. Arrangement of floating cage in the sea will look neatly arranged. The prospect of using floating cage has a very good future with various benefits. We got the advantage of using floating cage by interviewing farmers who use this tool in several seaweed

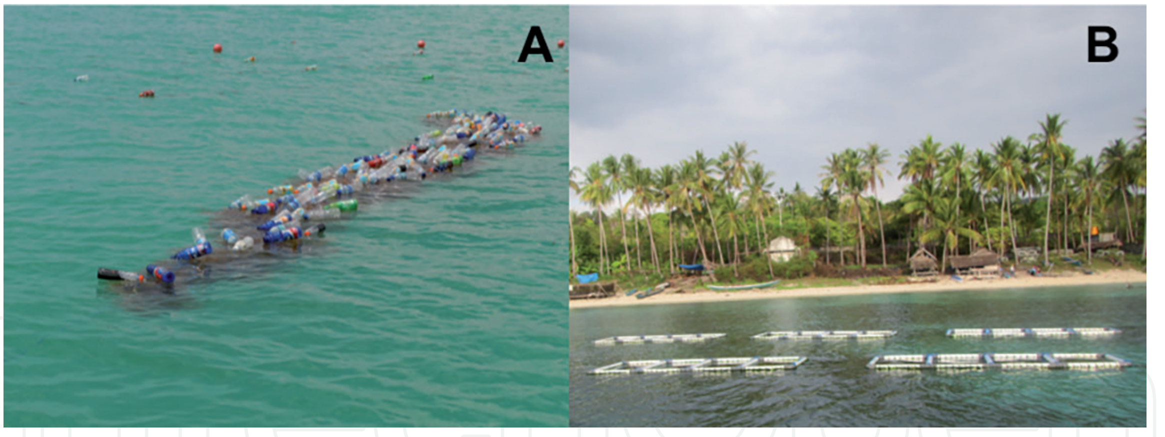

Figure 14.
Longline cultivation using used plastic bottles (A) and clean and beautiful floating cage arrangement (B).

cultivation locations in Southeast Sulawesi, Indonesia. The results of our interviews are formulated in order of priority of the benefits obtained by the community in using floating cage tools. These advantages include:

- *Easy to assemble*. This tool is made of a PVC pipe with a size of 3 mm which can be designed rectangular with an appropriate connection. PVC pipes are cut according to the desired size and connected with the appropriate connections (**Figure 1**).

- *Durable*. This tool is proven to be resistant at sea and will never rust. The durability of the tool with good care can reach 20–25 years of use.

- *Easy to maintain*. This tool has a very simple form and will be easily cleaned and maintained to extend its durability. Optimal results can be provided, it takes one reserve outer net as a replacement net each time the cultivation.

- *Float and balanced*. The shape of this tool is simple and floats on the surface of the water. This tool can be placed in all marine topography.

- *Full protection*. This tool is effective in protecting seaweed. The outer net as a protective device is very effective in avoiding herbivorous attacks that often graze seaweed.

- *Clean seaweed*. Seaweed will be cleaned from various dirt that are attached to the sea, including epiphyte, with a note that farmers must also often do the cleaning on the outer wall and in the net.

- *Volume of large seaweed*. The number of cultivated seaweed seeds is large with an initial weight capacity of 40–80 kg wet. After 30 days, it can reach 160–320 kg of wet confinement.

- The location of cultivation is narrow and orderly. The design of this tool does not require a large cultivation location. With just a small and regular area, the farmer can arrange the floating cage placement.

The many advantages of using floating cage tools illustrated very clearly that the future use of floating cage methods will be very good. Although currently the use of floating cage is still limited to certain locations, however, this development will continue to occur along with the desire to use prospective tools with excellent economic and ecological benefits. Cultivation communities will be able to choose to use tools that are economically and ecologically beneficial. The ecological advantage is in favor of the sustainability of other marine resources.

7. Conclusion

Innovation of cultivation methods using floating cage gives good results to support the growth of *Kappaphycus alvarezii* and *Eucheuma denticulatum*. The growth of *K. alvarezii* looks quite good with a specific growth rate up to 6.4%/day using floating cage method. However, *K. alvarezii* only has 4.2% growth/day using the longline method. The floating cage method can truly protect seaweed from herbivorous fish. Thus, the growth of seaweeds *K. alvarezii* and *E. denticulatum* is better because they are not attacked by fish.

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