Economic analysis of *Kappaphycus alvarezii* (Rhodophyta) cultivation using the horizontal net

[1]Ma'ruf Kasim, [1]Fitriani Saik, [1]LaOnu LaOla, [1]Nurdiana, [1]Ahmad Mansur, [1]Sarini Yusuf, [1]Abdul M. Balubi, [2]Wardha Jalil

[1] Faculty of fisheries and Marine Sciences, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia; [2] Faculty of Fisheries, Dayanu Iksanuddin University, Betoambari, Kota Baubau, Southeast Sulawesi, Indonesia. Corresponding author: M. Kasim, marufkasim@hotmail.com

Abstract. *Kappaphycus alvarezii* cultivation using the horizontal net has just begun in Indonesia recently. This study aims to clarify the economic aspect of the use of a horizontal net as a new cultivation method. The economic analysis includes the efficiency, effectiveness, productivity, and profit of *K. alvarezii* cultivation using a horizontal net. Survey and interviews were employed to collect research data. The use of the horizontal net is efficient, with an average value of 3.21 USD kg^{-1}. The average effectiveness value is 0.00032 kg USD^{-1}, which means it is good enough for all farmer groups' values. The use of the effective value for the horizontal net is indeed effective compared to the theoretical value of similar business units. The average productivity value is quite good, above 3.2, which indicates that the use of horizontal net results in a profitable level of productivity. The average profit value of 3.037 USD $year^{-1}$ is very good for community-scale seaweed cultivation businesses. The use of a horizontal net is the best solution to improve small-scale seaweed farming of the community.
Key Words: efficiency, effectiveness, productivity, profit, seaweed.

Introduction. *Kappaphycus alvarezii* is an economically important seaweed in tropical areas which commonly has a red color, and its wall cell contains a lot of polysaccharides that become the most carrageenan sources in the world. The carrageenan market is growing continually and needs tremendous raw material resources, at least in quality, price, and volume, for processing industry demands (Thirumaran and Anantharaman, 2009). Carrageenan of *K. alvarezii* is very important as a stabilizer, thickener, gel former, emulsifier, and so on. Thus, 80% of *K. alvarezii* production are utilized in food products, medicines, cosmetics, textiles, paints, toothpaste, and other industries (Winarno, 1990). Due to the huge demands of seaweed as an export commodity, improvement in seaweed cultivation is necessary, especially in Indonesia (Budiyanto, et al, 2019, Kasim et al, 2016, 2017a). However, the success of seaweed cultivation depends on factors that will affect the cultivation, which is an external factor regarding a suitable location for seaweed, factors regarding the local water environment characteristics, and internal factors regarding thallus origin and seed weight. *Eucheuma* production is growing fast in several countries, such as the Philippines. The low labor costs in the Philippines are driving the development of seaweed production in the country. The seaweed farming industry is dominated by small farmers who work very well at the regional level. Some things that support the growth of small-scale seaweed production are the hard work and the low working capital of the seaweed farmers (Blanchetti-Revelli, 1995). The success of the seaweed industry in a country like the Philippines can then be quickly applied in Indonesia. Economically important types of seaweed such as *K. alvarezii* and *E. denticulatum* have been introduced to tropical countries in the last 30 years. This condition is expected to spur the development of the world seaweed industry (Bindu & Levine, 2011). Several other countries, such as Tanzania, Malaysia, and Vietnam, began to advance the seaweed industry (Bixler & Porse, 2011). Industrial development continues to grow in line with the high demand for carrageenan as a raw material for various industries (FAO, 2014).

Kappaphycus cultivation becomes very commercial and has quite high economic value. This encouraged many people into seaweed cultivation. One hectare of seaweed cultivation will generate quite a lot of profit that ranges from 5-6 times the average income for working on agricultural land (Naylor, 1976). Considering the high potential of income that exists among seaweed farmers, some international institutions are starting to promote coastal community welfare development programs through seaweed cultivation. Hence the promotion of seaweed cultivation has been carried out in many tropical countries, including Indonesia, since the 1980s (Trono et al., 1980). Most coastal communities in Indonesia cultivate Kappaphycus. This is done because Kappaphycus cultivation requires small capital, low operating costs, large opportunities to do other jobs, flexible working hours. Another advantage is that Kappahycus cultivation can be harvested in a short time, which is about 30 - 45 days (Rimmer et al. 2021). Seaweed cultivation is an activity with low investment, simple technology, fast harvesting time, and a favorable price that provides a rapid return on investment. *Kappaphycus* sp. cultivation has improved the economy of coastal communities in several countries such as Indonesia, Tanzania, Vietnam, India, Pakistan, and the Philippines, Fiji (Arnold 2008; Bindu 2011; Kasim et al 2017b, Msuya 2006; My 2011; Namudu & Pickering 2006; Pettersson-Löfquist 1995; Sievanen et al. 2005; Zamroni & Yamao 2011). Most of the carrageenans that are cultivated are not used as food but as raw material for various industries so that it has sufficient economic value to improve the welfare of coastal communities (Beveridge et al., 2010; Espaldon et al., 2010; Gupta 2010).

*Kappaphycu*s products are diverse, such as copra, tea, and coffee, which have a relatively stable marketing model. Seaweed commodities have prices that are sometimes unpredictable and are not determined by seaweed farmers (Tinne et al., 2006). Seaweed traders, including collectors and seaweed farmers, cannot determine with certainty the price of seaweed. The price information comes from ongoing international market fluctuations. Changes in prices in the current year cannot be guaranteed to be stable because the need for carrageenan and environmental conditions and seasons also determine the price in international markets (Barta, 2008). Despite the fluctuating production and prices, seaweed is one of the important commodities that provide economic value to coastal communities. In Indonesia, most of the coastal communities do seaweed cultivation (Budiyanto et al 2019, Kasim et. al 2018). Seaweed cultivation is one source of income for the daily life of coastal communities. Most coastal water conditions in Indonesia, especially its water quality and topography, are very potential for seaweed cultivation (Kasim et al 2016). Moreover, a cultivation system that is conducted with a horizontal net method can reach the desired production (Kasim et al. 2018). To know the profit of seaweed cultivation using a horizontal net method requires research related to the efficiency, effectiveness, and productivity of *K. alvarezii*. This research aims to understand the efficiency and effectiveness of *K. alvarezii* cultivation using a horizontal net method at seaweed cultivation areas in Southeast Sulawesi, Indonesia.

Material and Method. The research was conducted at seaweed cultivation areas in Southeast Sulawesi, Indonesia. The research location is at coordinate point of 05^0 29'16,2" S and 122^0 33'47,0" E, located on 05^0 29'18,8" S and 122^0 33'48,9" E. Population in this research was representatives of the seaweed farmers who used a Horizontal net method. A horizontal net is a tool for seaweed cultivation (Figure 1). This tool is rectangular, with the outer wall encased by a net. The mesh size of the net is 1 cm, so that fish do not have access to eat seaweed. A horizontal net is a tool that can protect seaweed from fish and turtle pests (Kasim, et al. 2020, 2021). The farmers who used a horizontal net method in cultivating the seaweed were grouped into three groups. Each group consisted of 10 farmers, while the total of farmers that used horizontal net was 30 farmers. The sample of this research was the farmers who used the horizontal method in the seaweed cultivation areas and met the criteria for observation, which was farmers who had a horizontal net with an initial *K. alvarezii* seed weight of 25 kg – 85 kg. Each farmer group has a different cultivation location. However, they are in the cultivation area at the study site. Each group has the same number of horizontal net units.

Figure 1. Horizontal Net horizontal net used in this study (Kasim, 2020).

According to LaOla (2012), the formula that can be used to identify profits on business is as follows:

1. To calculate efficiency:
   Ef = TC/Q
   Whereas:
   Ef = Efficiency
   TC = Total Cost (USD)
   Q = Production Quantity (Kg)
2. To calculate effectiveness:
   Ev = Q/TC
   Whereas:
   Ev = Effectiveness
   Q = Production Quantity (Kg)
   TC = Total Cost (USD)
3. To calculate productivity:
   Pr = TR/TC
   Whereas:
   Pr = Productivity
   TR = Total Revenue (USD)
   TC = Total Cost (USD)
4. To calculate profit:
   π = TR – TC
   Whereas:
   π = Profit
   TR = Total Revenue (USD)
   TC = Total Cost (USD)

Results and Discussion. The results showed that the total average cost for the three groups of farmers was 14.539 USD year^{-1}. The highest amount was discovered in farmer group 3 with a value of 18.311 USD year^{-1}. This value was obtained from the value of dried seaweed production at an average of 6,288 kg year^{-1}. The highest value was discovered in farmer group 3, with a value of 6,846 kg year^{-1} (Table 1).

Table 1.

Total cost per year of seaweed cultivation using horizontal net

Farmers	*Dry Production* (Total Kg Year^{-1})	*Total Cost* (USD Year^{-1})
Farmers group 1	5.760	11.111
Farmers group 2	6.258	14.197
Farmers group 3	6.846	18.311
Average	6.288	14.539

The total annual income obtained by the three groups of farmers who used horizontal net method was 4.491 USD year^{-1} on average. The highest revenue was found in farmer group 3, with a value of 4.890 USD year^{-1}. This value was based on the average total cost for the three groups of 1.454 USD year^{-1}. The highest cost value was in the farmer group 3 with 1.831 USD year^{-1}. The average profit value for the three groups was 3.037 USD year^{-1} (Table 2). Seaweed cultivation generates a different production in each location. Different amounts of the harvest will give different sales results. However, the price per kg of dried seaweed is the same in all locations.

Table 2.

Productivity value of seaweed cultivation using horizontal net

Farmers	*Revenue* (USD Year^{-1})	*Total Cost* (USD Year^{-1})	*Profit* (USD Year^{-1})
Farmers group 1	4.114	1.111	3.003
Farmers group 2	4.470	1.420	3.050
Farmers group 3	4.890	1.831	3.059
Average	4.491	1.454	3.037

Efficiency Analysis. The highest efficiency value was seen in farmer group 3, with a value of 3,745 USD kg^{-1}. This value was not too different from the values in other farmer groups. However, it appeared that the average efficiency value of all groups of farmers was 3,207 USD kg^{-1}. The efficiency analysis of seaweed cultivation using the horizontal net method in the study site can be seen in Figure 2.

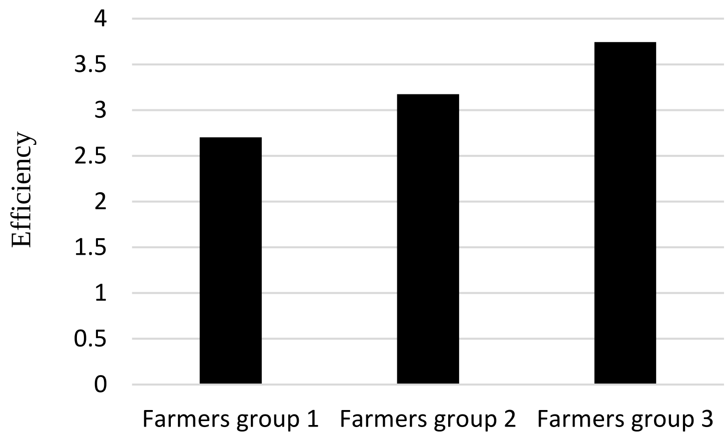

Figure 2. Efficiency value of all farmers groups in study sites.

The farming business can be said to be effective if farmers or producers can allocate resources properly. It is efficient if the resource utilization produces output that exceeds the input. The definition of efficiency is relative. Efficiency can be defined as the smallest input that generates production as maximum as possible (Soekartawi 2001). Efficiency analysis is needed to help farmers allocate factors of production to avoid waste. Efficiency in the use of inputs is very important and very influential on production results and profits. Rational farmers will be principled about how the production process can achieve the highest level of economic efficiency. The highest economic efficiency from the use of production factors is achieved if the comparison of the value of marginal products with the prices of each factor of production is equal to one (Nurmala et al 2015).

Based on data of results, seaweed farmers used the horizontal nets method in study sites efficiently. It can be seen that the total cost from farmer group 1 was 1111 USD, while their dry production per year was around 5.760 kg in 10 units of horizontal nets. As for farmer group 2, the total cost was 1.427 USD and the dry production per year was 6,258 kg in 10 units of horizontal nets. Meanwhile, the total cost of farmer group 3 was the biggest, which was 1.831USD, and the dry production per year was around 6.846 kg in 10 units of horizontal nets. According to the data, in order to obtain the efficiency value, the total cost is divided with total production (kg) per year, so the efficiency value in farmer group 1 was 2.701 USD kg^{-1}, in farmer group 2 was 3.176 USD kg^{-1}, and in farmer group 3 was 3.745 USD kg^{-1}. It shows that the most efficient seaweed cultivation business was performed by farmer group 1 because out of those three farmer groups, farmer group 1 spent the least cost, which was 1.111 USD year^{-1}. It is according to LaOla (2012) that a business is efficient if the total cost generated is small. In the marketing of efficiency of seaweed cultivation (*Eucheuma cottonii*) in Sumenep District, East Java, Indonesia, it was found that the marketing functions of seaweeds performed by each marketing institution were the exchange functions consisting of sales and purchases, as well as physical functions consisting of drying, storage, packaging, and transportation. The marketing margin and profit of each marketing institution in each marketing channel were the marketing channel I, the total marketing margin was 0.75 USD kg^{-1}, and the total profit was 0.75 USD kg^{-1}. Meanwhile, the total marketing margin of marketing channel II was 0.43USD kg^{-1} , and the total profit was 0.42 USD kg^{-1}. Furthermore, the percentage of the efficiency level was <50%, meaning that it was efficient. The efficiency value of marketing channel I was 2.08%, while the efficiency value of marketing channel II was 0.83% (Doni, 2017).

Effectiveness Analysis. The best effectiveness value was seen in farmer group 3 with a value of 0.00027 kg USD^{-1}. The effectiveness value between farmer group 3 and other farmer groups did not look too different. The average effectiveness value of all groups of farmers was 0.00032 kg USD^{-1}. Effectiveness analysis of seaweed cultivation using the horizontal net method in the study site can be seen in Figure 3.

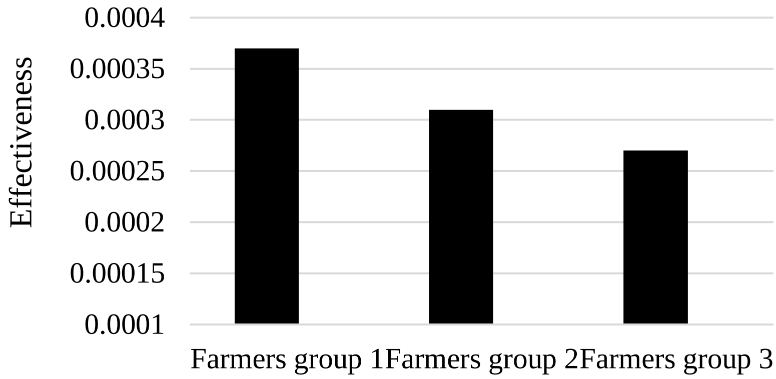

Figure 3. Effectiveness value of all farmer groups in study sites.

Effectiveness is resources, facilities, and infrastructure utilization in a certain amount which is consciously determined before generating certain products or services. Effectiveness shows success; it shows whether the targeted goals are achieved. If the results reach close to the goals, then the effectiveness is higher (Suparman, 2012). Table 6 shows that seaweed cultivation using horizontal nets in study sites was effective. It was considered effective because, in Table 6, the total cost from farmer group 1 was 1111 USD while the production result per year was around 5.760 kg. Meanwhile, farmer group 2 had a total cost of 1420 USD and the production result per year was 6.258 kg. Farmer group 3 had the highest total cost of 1831 USD, and their production result per year was around 6,846 kg. The total production (kg) per year was divided by the total cost to obtain effectiveness value, so the effectiveness value of farmer group 1 was 0.00037 kg year^{-1}, the effectiveness value of farmer group 2 was 0.00031 kg year^{-1}, and the effectiveness value of farmer group 3 was 0.00027 kg year^{-1}. Differences are caused by differences in production quantity obtained by each group. The most effective seaweed cultivation was performed by farmer group 3 who produced 6.846 kg year^{-1}. It is according to LaOla (2012) that a business is effective if the production quantity obtained is higher.

Productivity Analysis. The best productivity value was seen in farmer group 3, with a value of 2.67. The productivity value between farmer group 3 and other groups of farmers did not look too different. The average productivity value of all groups of farmers was 3.17. Productivity analysis of seaweed cultivation using the horizontal net method in the study site can be seen in Figure 4.

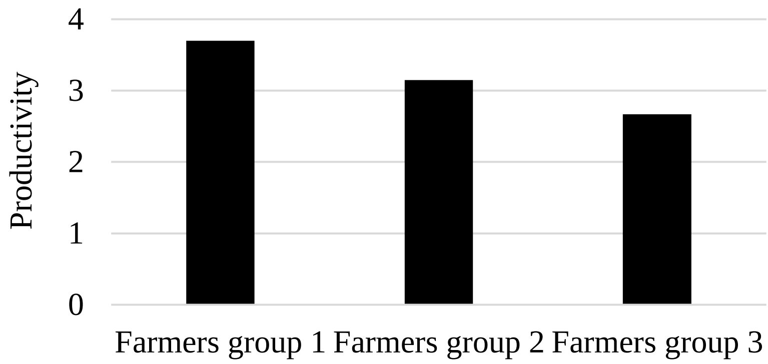

Figure 4. Productivity value of all farmer groups in study sites.

The results of a study on the analysis of the benefits of seaweed cultivation in the city of Tual, Southeast Maluku, Indonesia, found that the average profit obtained by farmers was 1.081 USD for a group of small farmers and 2138USD for a group of big farmers. The results of the analysis of the ratio of income indicated a very efficient value of 3.3 for smallholder groups and 3.4 for the large group of farmers. The break-even point will be obtained by small businesses when the price per kg of seaweed is in the range of 0.28 USD with an average production of 1.163 kg of dried seaweed. The break-even point for the group of big farmers will occur when the price per kg of seaweed is in the range of 0.27 USD with an average production of 2.275 Kg. The average return on investment is 326% for small farmers and 342% for large farmers (Tawakal et al 2019)

In seaweed production conducted in the Philippines, the value of productivity is seen from various aspects, including agricultural techniques, diseases, and the effects of typhoons on seaweed production (Hurtado 2013). Another study conducted in 20 cities in Palawan discovered a production of 138.950m.t. seaweed in 2000. They also mentioned that the highest productivity of seaweed cultivation in Green Island was strongly determined by seasonal planting (Mundo et al 2002). Research that analyzed the value of profits in Green Island, Palawan, Philippines, found that the value of profits from seaweed farmers was highly dependent on many factors, including the season and the production process. This value will increase or decrease in certain seasons. However, in August–December, the community could not plant because of environmental problems. Profit value is very slow due to the lack of capital owned by farmers (Alin et al 2015).

Profit Analysis. The highest profit value was seen in the farmer group 3 with a value of 3.059 USD year^{-1}. The profit value of each group of farmers in the research location was not too different. The average value of the profit obtained by all groups of farmers was equal to 3.037 USD year^{-1}. Profit analysis of seaweed cultivation using the horizontal net method in study site can be seen in Figure 5.

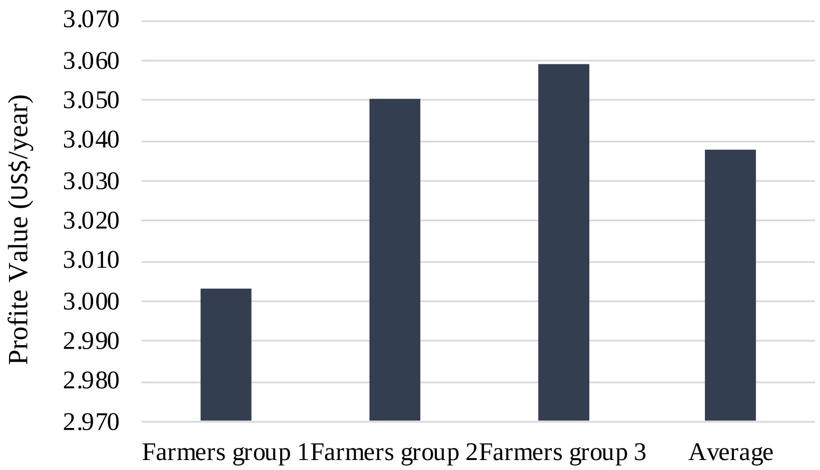

Figure 5. Profit value data of seaweed cultivation using horizontal net

A low seaweed cultivation productivity refers to limited production, which later affects the income of seaweed farmers. According to Kadi (2005), natural production decrease is usually caused by improper harvest timing or seasonal deviation that negatively affects the seaweed growth as the impact of inappropriate hydrology factor. Growth and life sustainability are also supported by substrate stability as a place to grow, which is affected by daily human activity on the surface of the substrate of "reef flats" in reef areas that can cause pressure towards the presence and diversity of seaweed. Based on the results, it suggested that seaweed farmers who used the horizontal net method in study sites were productive. Results show that the productivity value of farmer group 1 had a total cost of revenue of 4.114 USD while the total cost per year was 1.111 USD, so the productivity value was 3.70. The total cost of revenue of farmer group 2 was 4.489 USD year^{-1}, and the total cost was 1.427 USD, so the productivity value was 3.15. The total cost of revenue of farmer group 3 was 4.890 USD, while their total cost was the biggest, 1831 USD, and productivity value was 2.67. This suggested that the most productive seaweed cultivation was from farmer group 3 because they had the biggest total revenue of 4.890 USD per year (Saik 2016). It is according to LaOla (2012) that a business is productive when the total revenue is higher than the total cost of expense. Profit or benefit is calculated as total revenue minus the total cost of expense: π=TR-TC. The profit on seaweed cultivation using the horizontal nets method was analyzed. The result shows that seaweed farmers who used the horizontal nets method in study sites generated profit. That was because every farmer group used different initial seed weight, so that farmer group 3 had more seed than any other farmer group, whereas the initial seed weight was 810 kg in 10 units of horizontal nets, and within one year, they had been producing six times so the dry production obtained in one year was 6.846 kg, and the total revenue was bigger than the total cost of production per year in 10 units of horizontal nets. Meanwhile, the initial seed used by farmer group 2 was 490 kg in 10 units of horizontal nets and had been producing six times within one year, so the dry production obtained was 6.258 kg with total revenue of 4.489 USD. The initial seed of farmer group 1 was 210 kg in 10 units of horizontal nets and had been producing six times within one year, so the dry production obtained was 5.760 kg with total revenue of 4.114 USD $year^{-1}$. Therefore, the average profit from each farmer group that cultivated seaweed using the horizontal nets method at study sites was 3.037 USD $year^{-1}$. Seaweed cultivation business will be profitable or worthy if the revenue is bigger than the cost for seaweed cultivation business operational. Meanwhile, if the revenue is smaller than the total cost, then the seaweed cultivation business is non-profitable or unworthy.

Conclusions. The horizontal cultivation business is a small business that has better efficiency and effectiveness compared to similar businesses. The cultivation of Kappaphycus alvarezii using a horizontal net has good economic opportunities. The average efficiency value of about 3.207 is good. The average tool effectiveness value of 0.00032 kg USD^{-1} is good, and the average productivity value of 3.17 is good. Thus, the average profit value of all *Kapapphycus* farmers is 3,037 USD $year^{-1}$. The use of horizontal net cultivation methods provides a good productivity value so that farmers can have a good profit value to support their lives.

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Conflict of interest. The authors declare no conflict of interest.

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Authors:
Ma'ruf Kasim, Halu Oleo University, Faculty of Fishery and Marine Sciences, Indonesia, Southeast Sulawesi, 93231, Kendari, Andounohu, Kampus Bumi Tridarma UHO, e-mail: marufkasim@uho.ac.id
Fitriani Saik, Alumni Halu Oleo University, Faculty of Fishery and Marine Sciences, Indonesia, Southeast Sulawesi, 93231, Kendari, Andounohu, Kampus Bumi Tridarma UHO, e-mail: firianisaikfpik2020@gmail.com
LaOnu LaOla, Halu Oleo University, Faculty of Fishery and Marine Sciences, Indonesia, Southeast Sulawesi, 93231, Kendari, Andounohu, Kampus Bumi Tridarma UHO, e-mail: onu.laola@yahoo.co.id
Nurdiana, Halu Oleo University, Faculty of Fishery and Marine Sciences, Indonesia, Southeast Sulawesi, 93231, Kendari, Andounohu, Kampus Bumi Tridarma UHO, e-mail: nurdiana@uho.ac.id.m
Ahmad Mansur, Halu Oleo University, Faculty of Fishery and Marine Sciences, Indonesia, Southeast Sulawesi, 93231, Kendari, Andounohu, Kampus Bumi Tridarma UHO, e-mail: ahmadmansur@uho.ac.id
Sarini Yusuf, Halu Oleo University, Faculty of Fishery and Marine Sciences, Indonesia, Southeast Sulawesi, 93231, Kendari, Andounohu, Kampus Bumi Tridarma UHO, e-mail: sarini_yusuf@ymail.com
Abdul Muis Balubi, Halu Oleo University, Faculty of Fishery and Marine Sciences, Indonesia, Southeast Sulawesi, 93231, Kendari, Andounohu, Kampus Bumi Tridarma UHO, e-mail: ilmibahrain02@gmail.com
Wardha Jalil, Faculty of Fisheries, Dayanu Iksanuddin University, Kampus UNIDAYAN, Betoambari, Kota Baubau. Southeast Sulawesi, 93231, Indonesia. e-mail: wardha.jalil@yahoo.co.id

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