KORESPONDENSI MANUSKRIP

Judul : The Estimation of Environmental Carrying Capacity and Economic Value of Seaweed Cultivation in Kemojan Island

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in Kemojan Island
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Author(s): Dian Wijayanto, Azis Nur Bambang, Ristiawan A. Nugroho, Faik Kurohman, Oktavianto E. Jati
Keywords: : BOD5, Eucheuma cottonni, tropic saprobic indexes, Kemojan island
Abstract: Eucheuma cottonni cultivation has been a major source of income among local residents of Kemojan Island. Expansion of seaweed cultivation area in Kemojan Island waters needs to be anticipated by analyzing the carrying capacity of the aquatic environment. This study estimated the aquatic environment carrying capacity for seaweed cultivation in Kemojan Island and its economic value. The environmental carrying capacity measured by calculating the BOD5 and tropic saprobic index (TSI) in 5 observation stations. The measurement resulted in TSI values that ranged between 2.43 to 7.43 (slightly polluted to unpolluted categories), and BOD5 values between 2.6 to 5.4 ppm (below the sea waters pollution threshold). The total estimated area which capacity that can be developed for E. cottonni cultivation was approximately 86.2 ha (sea waters) with a potential production of 7,392 tons (wet weight) per year and economic value reaching IDR 11.09 billion.

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The Estimation of Environmental Carrying Capacity and Economic Value of Seaweed Cultivation in Kemojan Island

Dian Wijayanto, Azis Nur Bambang, Ristiawan A. Nugroho, Faik Kurohman, Oktavianto E. Jati

(Faculty of Fisheries and Marine Sciences, Universitas Diponegoro, Indonesia)

Abstract: *Eucheuma cottonni* cultivation has been a major source of income among local residents of Kemojan Island. Expansion of seaweed cultivation area in Kemojan Island waters needs to be anticipated by analyzing the carrying capacity of the aquatic environment. Studies on the environmental carrying capacity of seaweed (*E. cottonni*) cultivation on Kemojan Island have never been conducted. This study aims to estimate the carrying capacity of the aquatic environment on Kemojan Island for seaweed cultivation.We have combined BOD_5, TSI (tropic saprobic index) and regression to estimate the carrying capacity of the coastal environment for seaweed cultivation. There were 5 observation stations in this study. The measurement resulted in TSI values that ranged between 2.43 to 7.43 (slightly polluted to unpolluted categories), and BOD_5 values between 2.6 to 5.4 ppm (below the sea waters pollution threshold). The total estimated area which capacity that can be developed for E. *cottonni* cultivation was approximately 86.2 ha (sea waters) with a potential production of 7,392 tons (wet weight) per year and economic value reaching IDR 11.09 billion.

Keywords : BOD_5, *Eucheuma cottonni*, tropic saprobic indexes, Kemojan island

克莫詹岛海藻养殖环境承载力及经济价值估算

Dian Wijayanto, Azis Nur Bambang, Ristiawan A. Nugroho, Faik Kurohman, Oktavianto E. Jati

(Faculty of Fisheries and Marine Sciences, Universitas Diponegoro, Indonesia)

(Abstract in Chinese): *Eucheuma cottoni* 种植一直是 Kemojan 岛当地居民的主要收入来源。需要通过分析水生环境的承载能力来预测 Kemojan 岛水域海藻养殖面积的扩大。本研究估算了克莫扬岛海藻养殖的水生环境承载能力及其经济价值。通过计算 5 个观测站的 BOD5 和热带腐烂指数（TSI）测得的环境承载能力。测量得出的 TSI 值介于 2.43 至 7.43 之间（轻度污染至未受污染类别，BOD_5 值介于 2.6 至 5.4 ppm 之间（低于海水污染阈值. E.*cottonni* 可开发容量的总估计面积约为 86.2 公顷（海水），年潜在产量为 7,392 吨（湿重，经济价值达到 11.09 亿印尼盾.

(Keywords in Chinese)：BOD5, *Eucheumacottonni*, 热带腐殖质指数, Kemojan island

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Introduction

Kemojan Island is a part of Karimunjawa Islands. The Karimunjawa Islands is one of protected marine area in Indonesia (111,625 ha) and is also a popular marine tourism destination for domestic and international tourists (Baskara et al 2017, BTNKJ 2019, Kennedy et al 2020). The Indonesian government has regulated zonation of waters in Karimunjawa Islands; core zone, marine protection zone, marine tourism zone, traditional capture fisheries zone, and

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About the author: Dian Wijayanto*, Azis Nur Bambang, Ristiawan A. Nugroho, Faik Kurohman, Oktavianto E. Jati, Faculty of Fisheries and Marine Sciences, Universitas Diponegoro, Semarang, Indonesia.
†Corresponding Author’s name, E-mail:dianwijayanto@gmail.com

marine cultivation zone (BTNKJ 2019). The welfare of the community should be should be taken into consideration to gain their supports towards the conservation program.

The seaweed cultivation has developed as one of the main occupations among local community in Kemojan Island. Wijayanto et al (2020a) proved that seaweed farmers can fulfil their family needs by cultivating seaweed using at least 19 rope units with an average rope length of 129 m. Seaweed cultivation is considered low-risk farming with guaranteed yield which has attracted fishermen to switch professions as seaweed farmers (Wijayanto et al 2020a, Kennedy et al 2020). Various aspects of seaweed cultivation on Kemojan Island needs to be measured, including the carrying capacity of the aquatic environment. This study estimated the aquatic environment carrying capacity and economic value of seaweed (E. *cottonni*) cultivation in Kemojan Island.

1 Materials and Methods

1.1 Location and Time of Research

This study was conducted in the Kemojan Island waters (northwest coast), particularly at the marine cultivation zone in the Karimunjawa waters conservation area (BTNKJ 2019). Observations were administered in 5 observation stations (see Figure 1) from September to October 2020. Measurements were carried out during high tides. Rizki et al (2021) stated that sea currents on the northwest coast of Kemojan Island flow from northeast to southwest during high tide and from the southwest to the northeast during low tide.

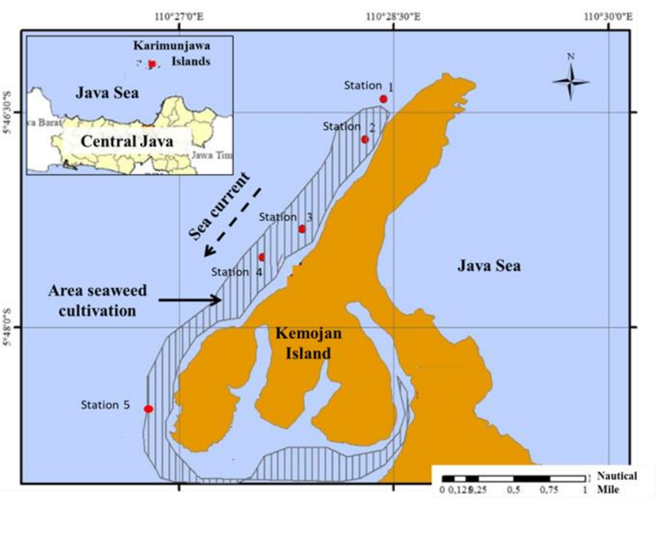


Fig.1 Research Location

1.2 Measurement of BOD_5

BOD_5 was measured by performing titration based on SNI (Indonesian national standard) number 6989.72:2009

1.3 Plankton and Saprobity Analysis

Samples of plankton were obtained through filtration of 100 liters of water samples collected from the site. Furthermore, the water sample was filtered through a plankton net. The filtered water was then put into a sample bottle and added with 4% formalin solution. The formulas used in the analysis of plankton uniformity and diversity referred to (APHA 1989, Tjahjono et al 2018, Hidayat et al 2018, Ujianti et al 2019):

$$N = (T/L).(P/p).(V/v).(1/w) \quad (1)$$

$$H' = - \sum Pi \ln Pi \quad (2)$$

$$Pi = Ni/N \quad (3)$$

$$E = H'/Hmax \quad (4)$$

N is the number of plankton per liter. T is the area of the cover glass (mm^2). L is the field of view on microscope (mm^2). P is the amount of plankton filtered. The notation p is the number of fields of view observed. V is the volume of the filtered plankton sample (ml). The notation v is the volume of the plankton sample under the cover glass (ml). While w is the volume of filtered plankton samples (liters). H' is the index of plankton diversity. Ni is the number of individuals of the plankton species (type i). N is the total number of individuals. E is the uniformity index. H'max is obtained from ln S, where S is the number of species found. Analysis of the saprobity water was carried out using the following formula (Nuriasih et al 2018, Tjahjono et al 2018, Hidayat et al 2018):

$$SI = \frac{1(nC) + 3(nD) + 1(nB) - 3(nA)}{1(nA) + 1(nB) + 1(nC) + 1(nD)} \quad (5)$$

$$TSI = \frac{1(nC) + 3(nD) + 1(nB) - 3(nA)}{1(nA) + 1(nB) + 1(nC) + 1(nD)} \, x \, \frac{nA + nB + nC + nD + nE}{nA + nB + nC + nD} \quad (6)$$

The notation n is the number of individual organisms in each saprobity group. The notation nA is the number of individual organisms as part of the polysaprobic group. The notation nB is the number of individual organisms as part of the mesosaprobic group. The notation nC is the number of individual organisms as part of the mesosaprobic group. The notation nD is the number of individual organisms as part of the oligosaprobic group. The notation nE is the number of individual constituents other than groups A, B, C, and D.

2 Result

2.1 Plankton Analysis

The results of uniformity and diversity analysis of phytoplankton and zooplankton are presented in Tables 1 and 2. In general, the level of plankton diversity index ranges from 1.53 to 2.22 for phytoplankton and 0.65 to 1.48 for zooplankton. The marine biota community is considered unstable if the diversity value is less than 1, moderate if the diversity value is between 1 and 3, and stable if the diversity value is more than 3 (Hidayat 2018, Ujianti et al 2019).

Table 1 Plankton composition on site
Tab.1

No.	*Species*	*Station 1*	*Station 2*	*Station 3*	*Station 4*	*Station 5*
1	*Ərataulina sp*			178		
2	*Ceratium* sp.	14				
3	*Chaetoceros* sp.	50				
4	*Climacosphenia* sp.		14			
5	*Coscinodiscus* sp.	28	7	35	69	28
6	*Cyclotella* sp				4	
7	*Dictyocha* sp.	7				
8	*Diploneis* sp.				4	7
9	*Ditylum* sp.				7	
10	*Eucampia* sp.	7				23
11	*Fragilaria* sp			66	35	
12	*Glenodinium* sp.			7		
13	*Guinardia* sp.	40				
14	*Gymnodinium* sp.	7	107			
15	*Gyrosigma* sp.					7
16	*Hemiaulus* sp.				16	
17	*Leptocylindrus* sp.		50	30	54	
18	*Melosira* sp.				7	
19	*Navicula* sp.			7		
20	*Nitzschia* sp.	21		42	21	28
21	*Oscilatoria* sp	85	142	395	192	285
22	*Phyrophacus* sp.		16			
23	*Pleurosygma* sp.				45	16
24	*Protoperidinium* sp.			180	152	59
25	*Rhizosolenia* sp.	64	26	14	54	178
26	*Thalassionema* sp.				16	
27	*Thallasiosira* sp	78				
28	*Thallasiothrix* sp.	57				
	Zooplankton					
1	*Brachyscelus* sp.					21
2	*Calanus* sp.	45	5		19	43
3	*Euterpina* sp.				12	
4	*Favella* sp.	14	5	7		
5	*Limacina* sp.	7		7		50
6	*Nauplius*	164	79	129	171	167
7	*Oithona* sp.	21	7	17	43	236
8	*Tintinnopsis* sp.			14	10	57

Table 2 Analysis of uniformity and diversity of phytoplankton
Tab.2

Station	*Number of Species*	*Diversiy Index*	*Uniformity Index*	*Abundance (Cell per liter)*
1	14	2.12	0.80	683
2	9	1.54	0.70	636
3	10	1.69	0.73	959
4	7	1.53	0.79	364
5	12	2.22	0.89	462

Table 3 Analysis of uniformity and diversity of zooplankton
Tab.3

Station	*Number Of Species*	*Diversiy Index*	*Uniformity Index*	*Abundance (Cell per liter)*
1	5	1.03	0.64	255
2	6	1.48	0.83	574
3	4	1.11	0.62	188
4	4	0.65	0.47	95
5	5	1.06	0.65	252

The uniformity levels of the five stations range from 0.70 to 0.89 for phytoplankton and 0.47 to 83 for zooplankton. For zooplankton, only station 4 show low uniformity, while other stations have high uniformity. According to Ujianti et al (2019), a uniformity index close to 1 indicates an even distribution between species, while a uniformity value close to 0 indicates low species uniformity. The results of the saprobity analysis are shown in Table 3. In general, the TSI value ranges from 2.43 to 7.43 which is between light pollution to not polluted categories.

Table 4 Saprobity analysis
Tab.4

Station	*SI*	*TSI*
1	1.00	4.09
2	1.00	3.33
3	1.00	7.43
4	1.00	4.36
5	1.00	2.43

2.2 BOD_5 Analysis

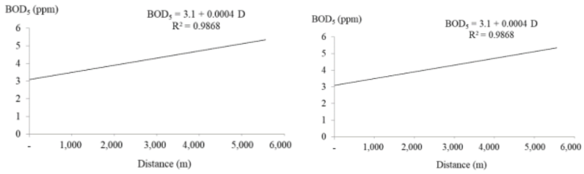
The results of the BOD_5 analysis shown in Table 4 presents that in general, the BOD_5 value ranges from 2.6 to 5.4 ppm (below 10 ppm) under the pollution threshold (Decree of the Minister of the Environment No. 51/2014). The results of this study conform with Yuliana et al (2020) and Rizki et al (2021). Yuliana et al (2020) conducted a study in Menjangan Island waters located approximately 10 km away from station 5 of this study. Whereas, Rizki et al (2021) conducted their study in Kemojan Island waters.

Table 5 BOD_5 (ppm) Analysis
Tab.5

Station	*BOD_5*
1	3.2
2	2.7
3	3.7
4	2.6
5	5.4

2.3 Environmental Carrying Capacity and Economic Analysis

The regression analysis of BOD_5 to the length of the cultivated area (distance), and TSI to the length of the cultivated area (distance) can be seen in Figure 2. The length of the cultivated area and the TSI, was found to share negative correlation, indicating that more intensive cultivation activities tends to decrease TSI, while smaller TSI value reflects higher pollution level. On the other hand, a positive relationship was found between the length area of cultivation and BOD_5, implying that more intensive cultivation activities increase BOD_5 (indicating increasingly polluted area).



Note: distance was calculated from station 1 (zero meter point)
Fig.2 The relationship between BOD5 and TSI with Length of Cultivation Area

The estimated production capacity and economic potential are shown in Table 5. We developed 2 scenarios using the BOD_5 and TSI approaches. According to the Decree of the Minister of the Environment No. 51/2014, the BOD_5 threshold for marine tourism is 10 ppm. Meanwhile, based on TSI reference, a value of 1.5 is classified as low waters (Nuriasih et al 2018). There is a potential for expansion of cultivation area from the current area in the capacity scenarios. The increase in area can be obtained by expanding the cultivation area towards the sea (not towards the land).

Table 6 Estimated Maximum Capacity and Economic Potential
Tab.6

	Estimation of Existing Condition	*Scenario 1 (BOD = 10 ppm)*	*Scenario 2 (TSI = 1.5)*
Total area (m^2)	4,630,000	8,625,000	4,736,363
Maximum accumulative rope length (m)	1,322,857	2,464,286	1,353,247
Production potential (kg in wet/year)	3,968,571	7,392,857	4,059,740
Economic value production potential (IDR/year)	5,952,857,143	11,089,285,714	6,089,609,689

2 Discussions

Marine protected areas or MPAs (including Karimunjawa Islands) are determined to counter global marine environmental degradation and support local fishing businesses and create job opportunities through ecotourism at the same time. Several studies have conformed the important role of MPAs in protecting coral reef ecosystems, seagrass beds and fishery resources. The impact of MPAs will be more significant in the long term (Chirico et al 2017, Sala & Giakoumi 2018).

Seaweed cultivation activities in Kemojan Island have been known to bring positive impacts on the improvement of local community's welfare Seen from economic perspective, the development of tourism activities in Karimunjawa Islands brings both positive and negative impacts on poverty alleviation. Tourism development opens up employment opportunities as tourism workers, such as hotel employees, restaurant employees and tour boat rental service providers. Large-scale hotels are mostly owned by immigrants (not local community). On the other side, land conversion reduces the income of local farmers (Setiawan et al 2017). Therefore, seaweed cultivation needs to be developed as an alternative livelihood for the community in Karimunjawa Islands. Seaweed cultivation in Indonesia is mostly done traditionally using limited amount of capital. It is time for the Indonesian government to encourage the development of intensive seaweed cultivation in offshore waters, especially for industrial purposes (Wijayanto et al 2020a)

Wijayanto et al (2021) also stated that for optimal profits, the cultivation of E. *cottonni* should employ a 40-day cultivation pattern per cycle. Meanwhile, the optimal distance between the ropes for the growth of E. *cottonni* and its revenue cost (RC) ratio is 25 cm (Wijayanto et al 2020b). However, seaweed cultivation activities might negatively affect the aquatic environment, where Kemojan Island is a part of Karimunjawa waters conservation area. Water quality is an important factor that determines the sustainability of coral reefs and other aquatic biota in Karimunjawa Islands conservation area (Yuliana et al 2020). As stated by Sulardiono et al (2018), anthropogenic activities in the form of tourism and marine cultivation (in cage) leave organic waste in Menjangan Island waters (Karimunjawa Islands), increasing the eutrophication process which in turn decreases the water quality from the oligotrophic to mesotrophic category. Kennedy et al (2020) also highlighted that water pollution, tourism activities and marine aquaculture are indeed a northern threat to the health of coral reefs in Karimunjawa Islands.

Plankton population can be an indicator of water pollution. Phytoplankton holds a very important role in aquatic ecosystems and in the food chain. of the population of phytoplankton relates to the productivity of the waters. Greater amount of phytoplankton population indicates more fertile waters (Aryawati et al 2017). Some researchers have conducted plankton analysis to measure water saprobity as an indicator of pollution, including Nuriasih et al (2018), Tjahjono et al (2018), and Hidayat et al (2018). Lower TSI value has also been known as an indicator of increasingly polluted waters.

Intensive seaweed cultivation in Kemojan Island can potentially bring biological waste, including dead seaweed. This condition then increases the demand for oxygen in bacteria decomposition of organic waste. As a result, the competition for oxygen among biotas in these waters becomes tighter. Therefore, seaweed cultivation in Kemojan Island needs to be well-regulated. Environmental carrying capacity should be set as a guide in the management of seaweed cultivation. Oxygen in the aquatic environment is produced through the process of photosynthesis, both by phytoplankton and aquatic plants. Oxygen is used in the respiration process of marine biota including plants, animals, and bacteria as well as in the decomposition of organic matter described by BOD (Aryawati et al 2017, Nuriasih et al 2018).

BOD is an indicator of the need for oxygen to decompose biological waste materials in the water by microorganisms. High BOD disrupts the oxygen balance in the waters. If the oxygen in the waters runs out, fish and aquatic plants might die. The excessive increase in organic matter in the waters can lead to the enrichment of inorganic matter and the growth of phytoplankton. Furthermore, phytoplankton blooms cause depletion of dissolved oxygen (DO) and death of aquatic biota (Sulardiono 2018, Prambudy et al 2019). The distribution of BOD in the waters of Kemojan Island is influenced by tides (Riski et al 2021). BOD indicates the presence of organic matter in the waters, in which greater BOD reflects that the waters is increasingly polluted with organic matter (Sulardiono 2018). The Indonesian government has set a BOD_5 limit of 10 ppm for marine tourism and 20 ppm for marine life (Decree of the Minister of the Environment No 51/2014).

The complexity of seaweed cultivation problems in Karimunjawa Islands demands a comprehensive approach regarding the protection of protected biota in conservation areas, environmental carrying capacity and socio-economic interests of the local community. The development of seaweed cultivation in Kemojan Island should go hand in hand with the marine conservation. Too large seaweed cultivation in coastal areas bring changes in coastal ecosystems, including the presence of seagrass beds. There is also a potential conflict of interest between seaweed farmers and sea turtle protection because sea turtles can be the pests of seaweed cultivation. These problems challenge the managers of the Karimunjawa Islands region to find the balance among tourism development, conservation (coral reefs and mangroves), coastal cultivation, marine aquaculture, and coastal fisheries. Wibawa et al (2021) argued that the gaps in the policies set by government agencies in the Karimunjawa Islands still occur. Involving academics, businessmen, government and (local) communities (ABGC approach) is important to prevent policy overlap (Baskara et al 2017). Community involvement is also an important factor in the development and management of marine resources in Karimunjawa Islands, including in Kemojan Island (Kennedy et al 2020).

3 Conclusion

The TSI values of 5 observation stations ranged between 2.43 to 7.43 (light pollution category), and BOD_5 values between 2.6 to 5.4 ppm (below the marine pollution threshold). It is estimated that the available land capacity for E. *cottonni* cultivation is 86.2 ha with a potential production of 7,392.9 tons (in wet) per year or equal to IDR 11.09 billion (scenario 1). This study proved that the combination of TSI, BOD_5 and linear regression can be used to estimate the carrying capacity of the aquatic environment for seaweed cultivation. Further research can be done by increasing the water quality variable and using a non-linear regression model to estimate the carrying capacity of the aquatic environment.

4 Acknowledgement

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