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The sustainability of the diversity of marine macrofauna associated with seagrass through ecotourism in The Mandalika Exclusive Economic Zone Lombok Island, Indonesia

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Abstract. Ecotourism activities play an essential role in protecting and managing natural habitats and the species found in the habitat and creating economic benefits for the surrounding community. However, some parties state that ecotourism has a negative effect on the environment if it does not correctly follow the area's rules and the ecotourism activities are not monitored and appropriately assessed. The objective of this study were : (i) to evaluate the diversity of seagrass and associated macrofauna at the Kuta ecotourism site in the Mandalika area of Lombok Island Indonesia and (ii) to know the response of the surrounding community and stakeholders in terms of the role of ecotourism in supporting the sustainability of the seagrass ecosystem in its function as an important factor in maintaining the diversity of marine macrofauna in the area. Data collection methods related to seagrass diversity and associated biota (Bivalves and Echinoderms) were carried out using the line transect method and the quadrat method. Meanwhile, the perception and response data of the community was obtained through observation and interviews. Data analysis was carried out in a qualitative descriptive manner. The results showed that there were 8 species of seagrass found. Seagrass species *Syringodium isoetifolium* and *Cymodocea rotundata* have the highest density of about 18.48 ind/m², and *Enhalus acoroides* has the highest area of coverage, which is around 16.41 ind/m². The highest macrofauna diversity was fish (10 families with 16 species) followed by Echinoderms (7 families with 9 species), and Bivalves (5 families with 7 species). Respondents in the fishermen category showed their understanding that ecotourism in their area plays an important role in supporting the sustainability of seagrass ecosystems, and this condition affects maintaining the diversity of associated marine macrofauna. This is supported by the findings that there has been a transition in the use of marine biota fishing gear, namely from the use of tools/methods that are not environmentally friendly to the use of tools/methods that are environmentally friendly. The most encouraging thing is that the use of bombs has completely stopped after ecotourism started in their area. Thus, it can be concluded that the existence of ecotourism in the Mandalika has had a positive influence on the behavior of fishing communities, especially in maintaining the seagrass ecosystem which is important in supporting the sustainability of marine macrofauna biodiversity in the Mandalika, South Coast of Lombok, Indonesia.

Keywords: Diversity; Seagrass Ecosystem; Ecotourism.

1. Introduction

The existence of seagrass in the marine environment has an essential function, especially as a habitat for marine fauna, coastal protection, sediment stabilization, circulation of CO₂ and O₂ gases [1].



However, the threat to the sustainability of seagrass existence globally and regionally is still on going [2]. At the global level, the source of the danger to seagrass sustainability is climate change [3], such as rising temperatures, increasing rainfall intensity, and infrastructure development [4]. Meanwhile, at the regional level caused by anthropogenic activities using trawls, boat propellers, and anchors [5,6]. In addition, species invasion can be a threat to seagrass survival [2]. However, seagrass has a high recovery rate for sustainability after getting pressure from the environment [7].

Seagrass in the marine environment is a resource that can control the active movement of fauna between adjacent habitats and influences nutrient flow, trophic structure, fishery production, and species diversity [8]. The composition of the fauna community associated with seagrass has variations between locations of seagrass beds from a spatial scale [9]. In addition, seagrass provides a suitable habitat for the growth and development of communities of Bivalves, Echinoderms, Molluscs, Crustaceans, and Cephalopods [10]. One indicator of the preservation of seagrass ecosystems is the high number of species and fauna populations associated with seagrass. On the other hand, if the seagrass condition is not sustainable, the faunal abundance is relatively low [11].

The species richness of seagrass on the southern coast of Lombok Island is around eight species [12]. Seagrass sustainability parameters are reflected in the richness of fish and fauna species associated with seagrass [12]. In various regions, the presence of seagrass has become a solution for the sustainability of the livelihoods of local communities, especially small fishermen [13]. Another use is as an ecotourism object, mainly because of the beauty of marine fauna associated with seagrass such as echinoderms that tourists can enjoy [14].

Ecotourism is a form of tourism that is very closely related to the principles of environmental conservation. In developing an ecotourism strategy, sustainable ecosystem management is used. Thus ecotourism is very feasible to be a way to preserve ecosystems. Directly and indirectly, ecotourism activities also play an essential role in protecting and managing natural habitats and the species found in them and creating economic benefits for the surrounding community. However, some parties state that ecotourism can damage the environment if it does not correctly follow the area's rules and is not monitored and appropriately assessed [15].

Therefore, the research aims to know the condition of macrofauna diversity associated with seagrass and the response of the surrounding community after the south coast area was developed into an ecotourism area.

2. Materials and Methods

2.1 Time and Location of Research

The research was carried out in April – August 2021 in the Exclusive Economic Zone of Mandalika, Central Lombok Regency (Figure 1), with a geographical position of 8°53'36.5"S 116°16'50.8"E. The tourist area is established through Government Regulation Number 52 of the year 2014 under Exclusive Economic Zone Mandalika. This regulation is by Law Number 39 of the year 2009 concerning Exclusive Economic Zone. The development of the Mandalika is focused on the main activities in the tourism zone by Article 4 of Government Regulation Number 52 of the year 2014 [16].

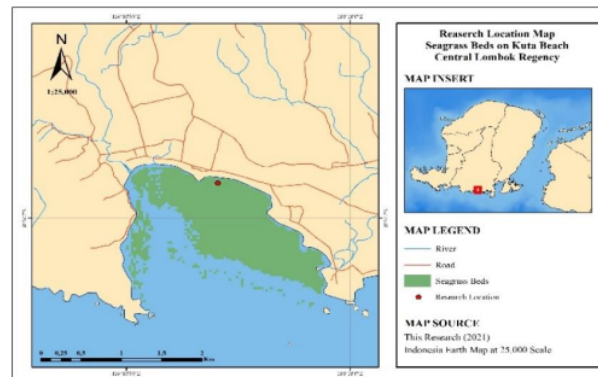


Figure 1. Research location map.

2.2 Data collection

Sources of research data are ecological data (seagrass and macrofauna), and social data (respondents' perceptions regarding the presence of seagrass in the Mandalika and changes in the use of fishing gear before and after the implementation of ecotourism).

2.2.1 Ecological data

Seagrass ecology data collection. Ecological data variables were seagrass species, density, and seagrass cover. While the macrofauna data variables are the type of species, the number of individuals per species, and the percentage of species. The method for collecting data on seagrass and macrofauna (Bivalves and Echinoderms) used transect and quadrat methods, while macrofauna fish used data from fishermen's catches [17]. Identification of seagrass species using a seagrass watch and fauna data were identified based on Tsukamoto's book [18]. Ecological data analysis used descriptive qualitative analysis [18].

2.2.2 Social data

Social data retrieval using the purposive sampling method through surveys, observations, and interviews [19]. The criteria for respondents as informants are different for each group, including fishers, local communities, traders, and tourists. Determination of the sample as respondents with the following criteria: fishers with the requirements (1) their catch area is around the seagrass area, (2) a minimum of 5 years as a fisherman (3) a minimum age of 20 years. Local communities with the criteria (1) registered as community members and domiciled in the research location, (2) over 20 years of age, (3) minimum length of stay of 20 years, and (4) knowing seagrass and fauna in the seagrass area. Traders with the criteria (1) have experience as a beach tourism trader at the research location for at least 15 years, (2) have a selling stall, and (3) know the benefits of seagrass for tourists. Meanwhile, the criteria for tourists as informants have knowledge related to environmental conditions (nature and infrastructure).

2.3 Data analysis

The process of analyzing the ecological data of seagrass using density analysis (D) and seagrass cover (C):

2.3.1 Density

Seagrass density per unit area varies greatly depending on the type of seagrass because seagrasses have different leaf morphology. To calculate the density is [20]:

$$D = \frac{Ni}{A} \quad (1)$$

Information:

- D : Density (number of individuals/m²)
 Ni : The number of individuals of type i;
 A : Total area of research (m²)

2.3.2 Cover

Cover is the area covered by seagrass species, the estimation results of seagrass cover in each observation plot are expressed in percent (%) with the formula [21]:

$$C = \frac{\sum M_i F_i}{\sum F_i} \quad (2)$$

Information:

- C : Seagrass vegetation cover (%)
 MiFi : The total product of the i seagrass vegetation cover estimate
 (Fi) : with the frequency of occurrence of the i-th type (Fi) in percent

13

3. Results and Discussion

3.1 The Composition of Seagrass and Macrofauna in the Mandalika

Seagrasses in the Mandalika consisted of 8 species, dominated by *S. isoetifolium* and *C. rotundata* (Table 1). The number of species found in this area is less than the number of seagrass species in 1994 in Kute Bay, as many as 11 species, and Gerupuk Bay 10 species [22]. Differences in observation stations can cause differences in the number of species.

Seagrass density per unit area varies greatly depending on the type of seagrass because seagrass species have different leaf morphology. The highest seagrass density value is *S. isoetifolium*, and *C. rotundata*. This can be influenced by internal factors such as physiological and metabolic conditions and external factors such as nutrients and water fertility levels [23,24]. The highest cover value was shown by *E. acoroides*, because of its large leaf size and high density [25]. The total value of seagrass cover was 63.43%, included in the solid category (51% - 75%). Seagrass conditions based on seagrass density of 13.46 ind/m² showed good conditions (12 - 15 ind/m²).

Table 1. Data on seagrass composition in the Mandalika Zone

No	Seagrass Species	Density (Ind/m ²) ± SD	Cover (%) ± SD
1	<i>Cymodocea rotundata</i>	18.24 ± 3.19	8.89 ± 2.15
2	<i>Cymodocea serrulata</i>	15.31 ± 4.48	8.64 ± 2.90
3	<i>Enhalus acoroides</i>	14.09 ± 4.92	16.41 ± 6.32
4	<i>Halodule pinifolia</i>	14.34 ± 6.39	5.25 ± 4.09
5	<i>Halophila ovalis</i>	1.87 ± 4.26	0.96 ± 1.58
6	<i>Halodule uninervis</i>	11.02 ± 0.88	5.30 ± 0.86
7	<i>Syringodium isoetifolium</i>	18.48 ± 4.90	9.19 ± 2.85
8	<i>Thalassia hemprichii</i>	14.34 ± 2.00	8.79 ± 1.60
	Average (\bar{x})	13.46	63.43
	SD	5.26	22.35

Local people have long used seagrass beds to catch various species of fish, bivalves, and echinoderms. The composition of fish species based on the number of catches is presented in Table 2. The 16 species of fish obtained at the study site, the species with the highest number of individuals were *Sardinella gibbosa* and *Herklotsichthys quadrimaculatus* (family Clupeidae), *Epinephelus bontoides* (family Serranidae), and *Sphyrnaena flavicauda* (family Sphyrnaenidae). The number above is more than the fish species in Ekas Bay, East Lombok, consisting of three families and four species [26]. The difference in the number of fish found at the study site is due to differences in seagrass density and the fishing season at that location [27].

18

The diversity of fauna species that live in seagrass beds and has a fairly large dependence on seagrass. Seagrass has a vital function for sustainability fish, particularly as a habitat for juvenile mass [28]. Seagrass contributes to the abundance of fish species related to the conditions of density, cover, and the size of habitat fragmentation [29]. Seagrass beds have a vital function in supporting the abundance and diversity of fish.

Table 2. Data of fish species associated with seagrass beds in the Mandalika Zone

No	Family Name	Species Name	Number of ind/species	Specimen/species (%)
1.	Muraenidae	<i>Richardson gymnothorax</i>	10	1.93%
2.	Plotosidae	<i>Plotosus lineatus</i>	1	0.19%
3.	Siganidae	<i>Siganus canaliculatus</i>	18	3.48%
		<i>Siganus guttatus</i>	28	5.42%
4.	Scaridae	<i>Leptoscarus vaigiensis</i>	33	6.38%
		<i>Calotomus spinidens</i>	16	3.09%
5.	Clupeidae	<i>Herklotsichthys quadrimaculatus</i>	79	15.28%
		<i>Amblygaster sirm</i>	35	6.77%
		<i>Sardinella gibbosa</i>	127	24.56%
		<i>Herklotsichthys dispilonotus</i>	29	5.61%
		<i>Ilisha striatula</i>	8	1.55%
6.	Hemiramphidae	<i>Hemiramphus far</i>	12	2.32%
7.	Belonidae	<i>Tylosurus crocodilus</i>	11	2.13%
8.	Fistulariidae	<i>Fistularia commersonii</i>	12	2.32%
9.	Sphyraenidae	<i>Sphyraena flavicauda</i>	43	8.32%
10.	Serranidae	<i>Epinephelus bontoides</i>	55	10.64%
		Amount	517	100%

Pelecypoda (Bivalves) is a class in the phylum Mollusca, including all shellfish [30]. Bivalves species found in the Mandalika consisted of 7 species (Table 3). Among these species, the most dominant are *Pinna muricata* and *Tapes belcheri*. The number of bivalves found above was more than that found on Kuwang Wae Beach, East Lombok, with five species [31], and fewer than on Pannikiang Island, with 14 species [32]. The few species and numbers of individuals found in the location were caused by the local community's exploitation (*Provisioning services*) with uncontrollable intensity, especially for bivalves with high economic value [27].

Table 3. Data of bivalves species associated with seagrass beds in the Mandalika Zone

No	Family Name	Species Name	Number of ind/species	Specimen/species (%)
1	Veneroidae	<i>Lioconcha fastigiata</i>	6	7.14%
		<i>Paphia gallus</i>	13	15.48%
		<i>Tapes belcheri</i>	16	19.05%
2	Arcidae	<i>Anadara antiquata</i>	9	10.71%
3	Pteriidae	<i>Pinctada imbricata</i>	3	3.57%
4	Pinnadae	<i>Pinna muricata</i>	21	25.00%
5	Cardidae	<i>Trachycardium flavum</i>	16	19.05%
		Amount	84	100%

The Echinoderms species found in the Mandalika consist of 9 species and 702 individuals (Table 4). The dominant species in the study area are *Tripneustes gratilla* and *Diadema setosum*. The results of this study were less than the number of echinoderms species but found a more significant number of individuals. Sekotong waters, West Lombok reported 29 species of echinoderms with 246 individuals [33]. Echinoderms in Babanlagan Philippines found ten species from 387 individuals [34]. The existence of echinoderm species in seagrass ecosystems with high density and cover can describe the ecological functions of seagrasses because the presence of echinoderms species can function in the process of oxygenating sediment layers for seagrass growth and helps control populations of pests and pathogenic bacteria [28].

Table 4. Data of echinoderms species associated with seagrass beds in the Mandalika Zone

No	Family Name	Species Name	Number of ind/species	Specimen/species (%)
1	Oreasteridae	<i>Protoreaster nodosus</i>	61	11.69%
2	Arcasteridae	<i>Archaster typicus</i>	35	6.70%
3	Toxopneustidae	<i>Tripneustes gratilla</i>	119	22.80%
4	Temnopleuridae	<i>Mespilia globulus</i>	75	14.37%
5	Diadematidae	<i>Diadema calamaris</i>	58	11.11%
		<i>Diadema setosum</i>	90	17.24%
6	Synaptidae	<i>Synapta maculata</i>	50	9.58%
7	Holothuriidae	<i>Holothuria leucospilota</i>	15	2.87%
		<i>Holothuria atra</i>	19	3.64%
Amount			702	100%

3.2 Respondents' perceptions regarding the presence of seagrass in the Mandalika

The assessment results of all respondents showed that the highest knowledge of respondents on fauna conservation related to the ecological function of seagrass was owned by fishermen by 67% and the lowest by tourists by 53% (Figure 2). Some respondents even think that the seagrass ecosystem in these waters has been getting better since the past until now. This is also an indication that the waters at the study site have not been degraded in the seagrass ecosystem. This is related to coastal environmental services, one of which is the primary source of livelihood for the local communities [13].

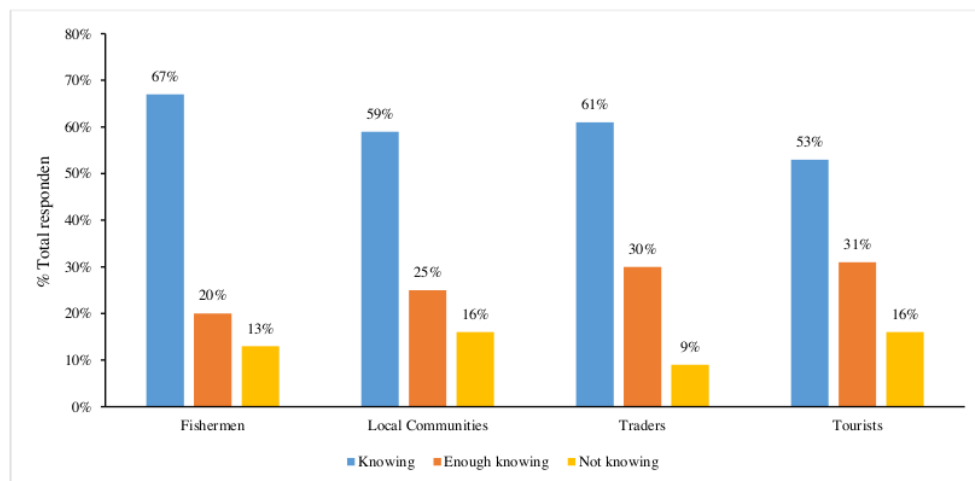


Figure 2. Perceptions of respondents on the importance of the existence seagrass ecosystems

The diversity of seagrass services in the perspective of the local communities is the value of the environmental services obtained from the existence of the seagrass ecosystem. Communities interviewed as respondents were able to distinguish between seagrass species based on morphological characteristics. Respondents stated that seagrass is essential for many habitats, such as; fish, echinoderms, and bivalves. The results of the identification of local communities ecological knowledge about seagrass at the highest to lowest percentage showed 47.2% answered very benefit, 26.8% benefits, 17.0% enough, 9.0% less, and 0.0% no benefit (Table 5).

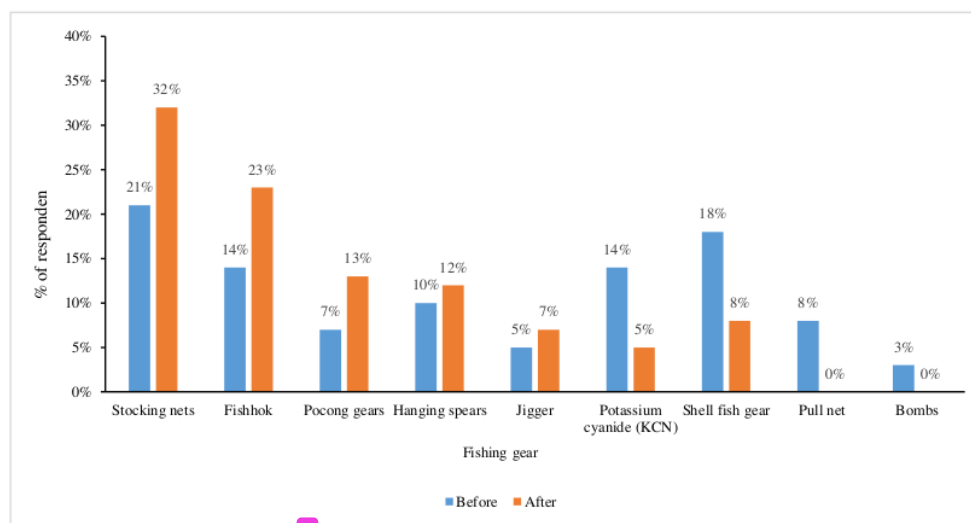
Table 5. The Knowledge of the respondents to the value of seagrass ecosystem, n= 100

Description	Results of Respondent assessment				
	No benefit	Less	Enough	Benefits	Very benefit
Habitat and Fish feeding ground	0	0	14	24	62
The small fish habitat	0	0	21	31	48
Habitat of marine life other fish	0	0	11	25	64
The source of marine fertility	0	9	14	29	48
<i>Provisioning services;</i>					
Food	0	11	21	23	45
<i>Regulating and Maintenance;</i>					
Purification of water	0	12	4	27	57
Flood control	0	11	21	45	23
Regulation of the climate change via carbon sequestration	0	24	45	21	10
<i>Cultural Services;</i>					
Cognitive development	0	2	12	34	52
Recreation	0	17	13	14	56
Aesthetic experience	0	13	11	22	54
Total	0	99	187	295	519
Assessment Respondents	0.0%	9.0%	17.0%	26.8%	47.2%

2

3.3. Changes in the use of fishing gear before and after the enactment of ecotourism

The existence of seagrass in the study area has a reasonably significant meaning for the local community from an economic aspect. This is seen from the group of respondents, namely fishermen and local communities who look for fish in the seagrass area before and after the enactment of ecotourism.



2

Figure 3. The profile of changes in the use of fishing gear before and after the implementation of ecotourism in the Mandalika Zone.

Fishing is carried out using fishing gear which can be classified as environmentally friendly and non-environmentally friendly fishing gear. According to the respondent's perspective, it is known that the fishing gear used at the study sites before the introduction of ecotourism was stocking nets (21%) and bombs (3%) (Figure 3). Meanwhile, the fishing gear used after the implementation of ecotourism is *shhok* (23%). Since implementing ecotourism at the study sites, bombs fishing gear is no longer used to catch fish in the seagrass beds and the surrounding environment. The use of bombs does not meet the eight indicators of environmentally friendly fishing gear, and their use will impact changing the habitat of fish and other invertebrates [35].

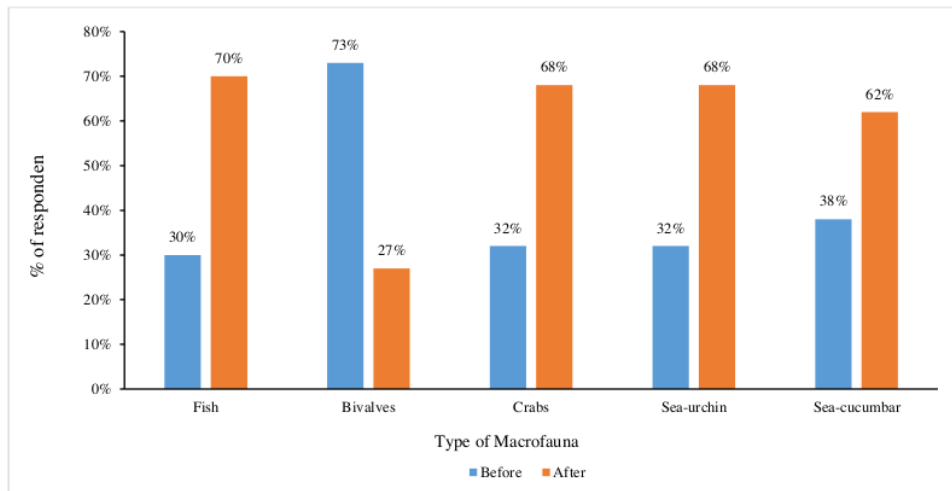


Figure 4. Respondent's opinion regarding the presence of macrofauna associated with seagrass before and after the implementation of ecotourism in the Mandalika Zone.

The macrofauna group associated with seagrass consists of fish, bivalves, crabs, sea-urchin⁹ and sea cucumbers. According to respondents at the study site, macrofauna such as fish, bivalves, crabs, sea-urchins, and sea-cucumber associated with seagrass have increased since the introduction of ecotourism in the Mandalika. The macrofauna species with the highest association were fish at 70%, and the lowest were bivalves at 27% (Figure 4). The increasing association of macrofauna with seagrass indicates a positive influence of ecotourism on the survival²¹ of macrofauna groups in the area. This condition is estimated to be correlated with the transition from the use of fishing gear that is not environmentally friendly to the use of environmentally friendly fishing gear after ecotourism.

4. Conclusion

Seagrasses on the coast of the Mandalika have eight species and associated fauna such² as fish, bivalves, echinoderms and become an attraction in ecotourism as a natural tourist attraction. There has been a change/shift in the use of environmentally friendly fishing gear since the implementation of ecotourism. This condition indicates a good correlation between macrofauna and seagrass. Therefore, the implementation of ecotourism in Mandalika, significantly supports the sustainability of the seagrass ecosystem which in turn contributes to the existence and biodiversity of macrofauna associated with seagrass.

Acknowledgments

3

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