JPPIPA 10(1) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Health Status of Seagrass Meadows Around the Special Economic Zone (SEZ), West Likupang, North Sulawesi

Satriani[1], Zulhamsyah Imran[2,4*], Fery Kurniawan[2,5], Perdinan[3], Akbar Ario Digdo[6]

[1] Magister Program in Aquatic Resources Management, Graduate School of IPB University, Indonesia.
[2] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, IPB University, Indonesia.
[3] Department of Geophysics and Meteorology, Faculty of Mathematics and Natural Sciences, IPB University, Indonesia.
[4] Director of SEAMEO BIOTROP, Indonesia.
[5] Center for Coastal and Marine Resources Studies (PKSPL), IPB University, Indonesia.
[6] Indonesian Environmental and Conservation Education (YAPEKA), Bogor, Indonesia.

Received: October 31, 2023
Revised: November 21, 2023
Accepted: January 25, 2024
Published: January 31, 2024

Corresponding Author:
Zulhamsyah Imran
zulhamsyahim@apps.ipb.ac.id

DOI: 10.29303/jppipa.v10i1.5908

Abstract: Seagrass ecosystems offer valuable ecosystem services but are highly vulnerable to physical damage caused by human activities and rapid environmental change. Currently, there is very limited information available on monitoring and reporting the health of seagrass beds in Indonesian waters. This study aims to assess the species composition, density, diversity index, percentage of seagrass cover, health condition, and identification of threats to seagrass ecosystems around the West Likupang Special Economic Zone (SEZ), North Sulawesi. The method used was a seagrass watch with line transects and quadrant-shaped frames measuring 50x50 cm^2. Transect lines were established through the seagrass ecosystem area at 50 m. There were three line transects at each station 25 m apart. Quadrant frame measuring 50x50 cm^2. West Likupang has eight seagrass species including *C. rotundata, E. acoroides, H. pinifolia, H. uninervis, H. ovalis, O. serrulata, S. isoetifolium,* dan *T. hemprichii*. The health status of the seagrass is currently healthy, with a dense percentage of coverage. The identification of potential risks from anthropogenic activities such as the household disposal of waste at sea, gleaning, the use of boat anchors and propellers, and the construction of infrastructure in coastal areas, such as hotels and harbonurs, pose significant threats.

Keywords: Ecosystem; Health; Seagrass; Special economic zone (SEZ), Threats

Introduction

Seagrass is a type of flowering plant that thrives in shallow waters. Seagrasses have flowers, fruits, leaves, and roots that allow them to grow and form large expanses of grass (Nugraha et al., 2021). Seagrass vegetation found along the shoreline is termed a seagrass bed. Seagrass ecosystems are significant providers of ecosystem services to the aquatic environment (Nordlund et al., 2018). Loss of seagrass habitat can significantly impact surrounding ecosystems. These impacts comprise the loss of fish spawning grounds, coastal erosion, and reduced carbon sequestration (Boudouresque et al., 2016; Unsworth et al., 2019). Seagrass ecosystems are frequently disregarded by communities, governments, and policymakers in Indonesia. Xu et al. (2016) reported a significant decline in global seagrass area. The decrease in global seagrass area from 160,387 km2 to 266,562 km2 (McKenzie et al., 2020) emphasizes the need for strict and continuous management and monitoring. However, seagrass monitoring faces global challenges due to the lack of information on seagrass habitats. This results in inaccurate, poorly measured, and poorly presented data (Fortes et al., 2018; Rifai et al., 2022).

Tropical seagrass meadows in Southeast Asia have experienced an annual average area decline of 4.7% (Sudo et al., 2021). Many development activities in coastal areas have sacrificed seagrass ecosystems, such as reclamation for the development of industrial areas or harbors, which has reduced the area of seagrass beds

How to Cite:
Satriani, Imran, Z., Kurniawan, F., Perdinan, & Digdo, A. A. (2024). Health Status of Seagrass Meadows Around the Special Economic Zone (SEZ), West Likupang, North Sulawesi. *Jurnal Penelitian Pendidikan IPA*, *10*(1), 201–209. https://doi.org/10.29303/jppipa.v10i1.5908

(Fahruddin et al., 2017). Recently, a Special Economic Zone (SEZ) was established through Government Regulation No. 84 of 2019 on the Likupang Special Economic Zone which is focused on the tourism and cultural sectors. The impact of SEZ designation on the growth and condition of seagrass ecosystems in the area is believed to be influenced by the lack of appropriate management measures. The aim of developing the tourism sector is to achieve a balance between economic growth and ecosystem preservation sustainably.

Seagrass beds covering 379 hectares in West Likupang are part of Indonesia's 1.8 million hectares of seagrass beds (Sjafrie et al., 2018). West Likupang, located in North Sulawesi, is a Special Economic Zone (SEZ) where the population relies heavily on coastal natural resources, especially fisheries (Digdo et al., 2016). Local communities utilize the seagrass ecosystem as a source of fish, shellfish, and other catches. Boats of fishermen also often anchor in the area. However, the SEZ designation and increasing community activities that interact directly with seagrass ecosystems pose a considerable threat to their sustainability. However, information on the condition and health status of seagrass beds remains limited. Therefore, it is crucial to make various efforts to maintain their sustainability, given the vital role of seagrass beds. One such effort is to assess the condition of seagrass beds to determine their health status.

The purpose of seagrass monitoring activities is to evaluate the health of seagrass ecosystems, which are crucial for their management and sustainability (Rustam, 2014). In some areas, the significance of seagrass ecosystems may be disregarded due to data limitations (Brodie et al., 2018). This study aims to evaluate the status and condition of seagrass beds in the SEZ, West Likupang. This study presents data on species composition, density, percentage cover, and seagrass diversity index. The results are intended to serve as a reference for the development of seagrass ecosystem management. Considering the government's plan to boost the tourism sector, particularly in super-priority destinations, it is crucial to align these efforts with environmental conservation. These efforts are essential to the tourism recovery plan in Indonesia, particularly in the waters of West Likupang, North Sulawesi. Furthermore, identifying the impact of activities on seagrass benefits is crucial for risk assessment and providing baseline information to local government for effective management in the area.

Method

The research site is located around the Special Economic Zone (SEZ) in West Likupang, North Sulawesi. The research was conducted from July to September 2022. West Likupang serves as a buffer zone around the SEZ. The study sites were identified in Bahoi, Bulutui, and Tarabitan based on seagrass composition and threat. Seagrass beds in the study sites extend along the shoreline to the edge of mangroves and coral reefs. Biota associated with seagrasses, including protected species such as turtles and dugongs, were also identified. Coastal community activities, such as shell collection, boat transport routes, anchorages, and the development of Special Economic Zones (SEZs), can indirectly affect the presence and sustainability of seagrass ecosystems.

Experimental Design

The first step in the research process was to collect data from three locations to determine the research site and mark the points of the transect lines using GPS. The seagrass observation method was carried out using line transects and quadrant-shaped frames measuring 50x50 cm^2. The transect line was drawn from the shoreline towards the sea, passing through the seagrass ecosystem area at a distance of 50 m. At each station, there were three transect lines spaced 25 m apart. Quadrat frames measuring 50x50 cm^2 were placed on both sides of the transect lines, with a 5 m gap between frames (Figure 2). Data collection involved identifying seagrass species, measuring seagrass density, and calculating the percentage of seagrass cover. Seagrass species were identified and characterized morphologically according to McKenzie (2008).

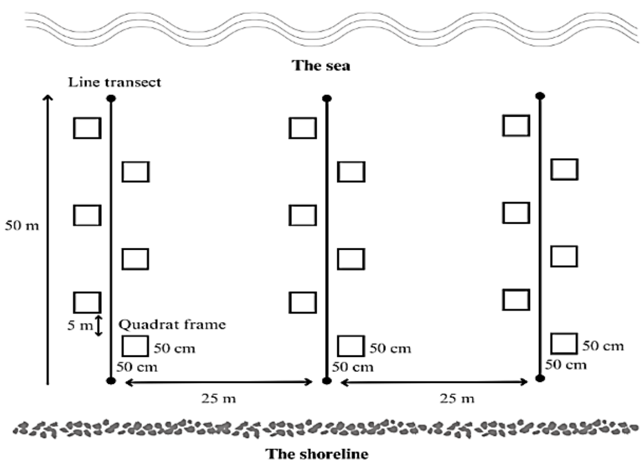

Figure 1. Transect plot

Diversity Index, Percentage Cover, and Health Condition Assessment

The seagrass diversity index is determined using the Shannon-Winner criteria in Krebs (1994). The categories for diversity are low (H' < 1), moderate (H' 1-1.5), high (H' 1.6-3), and very high (H' > 3). The percentage of seagrass cover is assessed according to the categories of sparse (0-25%), moderate (25-50%), dense (51-75%), and very dense (76-100%), as described by Rahmawati et al. (2014). The assessment of seagrass health condition is determined by the Minister of Environment Decree No. 200 Year 2004. The Decree categorizes seagrass condition into three groups: healthy (>60%), less healthy (30-59.9%), and poor (0-29.9%).

Result and Discussion

Seagrass Status

The seagrass area in West Likupang water is 379 ha. The area is spread from Palaes to Munte water. The seagrass found in West Likupang water was a mixed community. Based on the results of this research, two families of seagrass were identified in West Likupang water, namely Hydrocharitaceae and Cymodoceacea. The Hydrocharitaceae family consisted of three genera, namely *Enhalus, Thalassia,* and *Halophila*, whereas the Cymodoceacea family consisted of four genera, namely *Oceana, Cymodocea, Halodule*, and *Syringodium*. Generally, there were 8 species found, namely *Cymodocea rotundata* (Cr), *Enhalus acoroides* (Ea), *Halodule pinifolia* (Hp), *Halodule uninervis* (Hu), *Halophila ovalis* (Ho), *Oceana serrulata* (Os), *Syringodium isoetifolium* (Si), and *Thalassia hemprichii* (Th) (Table 1). The total of seagrass species found in West Likupang water represents 61.54% of the total 13 seagrass species in Indonesian water.

Table 1. Seagrass Species Composition in West Likupang Water

Location	Species							
	Cr	Ea	Hp	Hu	Ho	Os	Si	Th
Bahoi	+	+	+	+	+	+	+	+
Bulutui	+	+	+	+	+	+	+	+
Tarabitan	+	+	+	+	+	+	+	+

Description: *Cymodocea rotundata* (Cr); *Enhalus acoroides* (Ea); *Halodule pinifolia* (Hp); *Halodule uninervis* (Hu); *Halophila ovalis* (Ho); *Oceana serrulata* (Os); *Syringodium isoetifolium* (Si); dan *Thalassia hemprichii* (Th); (+) = found in the research site; (-) = not find in the research site.

Seagrass Species Density

The density of seagrass species in the waters of West Likupang refers to the number of individual plants or stands of seagrass species. Each observation quadrant contained between two and four associated seagrass species. The study site revealed the identification of eight seagrass species, each with different density values. This demonstrates that each seagrass species has a distinct distribution and can coexist with other seagrass species. The discovery of a variety of small and large seagrass species that can grow well indicates that the waters of West Likupang are still eligible for the requirements for seagrass growth. Seagrasses require healthy environmental conditions to survive and reach the reproductive stage (Fahruddin, 2017). The density of seagrass species is greatly influenced by favorable environmental conditions, which provide opportunities for growth and reproduction. Figure 3 presents the seagrass species density.

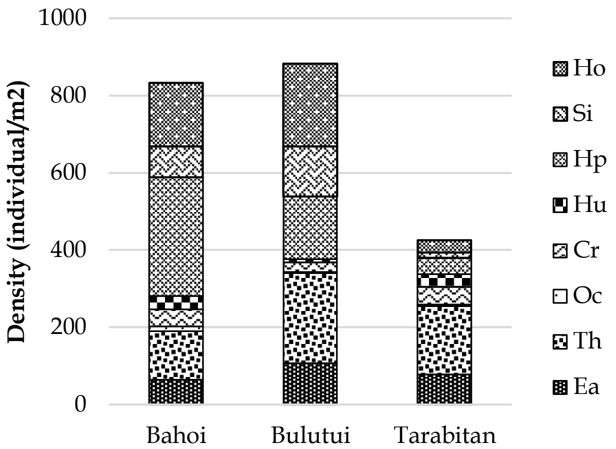

Figure 2. Seagrass species density in West Likupang water. *Cymodocea rotundata* (Cr); *Enhalus acoroides* (Ea); *Halodule pinifolia* (Hp); *Halodule uninervis* (Hu); *Halophila ovalis* (Ho); *Oceana serrulata* (Os); *Syringodium isoetifolium* (Si); *dan Thalassia hemprichii* (Th)

The study found eight seagrass species at all research stations, including *C. rotundata* (Cr), *E. acoroides* (Ea), *H. pinifolia* (Hp), *H. uninervis* (Hu), *H. ovalis* (Ho), *O. serrulata* (Os), *S. isoetifolium* (Si), dan *T. hemprichii* (Th). Each research station has different seagrass species density values. However, it is important to note that different density values between research stations do not necessarily indicate significant differences. The Kruskal-Wallis statistical analysis results showed that the density of seagrass species at each research station was not significantly different ($p>0,05$). Environmental conditions support seagrass growth on various substrates, which affects seagrass density. Seagrasses have a high level of adaptation to environmental changes, but they still require space to reproduce in certain environments.

The environmental characteristics of Bahoi are similar to those of mangrove vegetation and coral reefs. The total seagrass density in Bahoi was 832 ind/m^2, while in Bulutui it was 883 ind/m^2, and in Tarabitan it was 425 ind/m^2. Additionally, the highest seagrass species density in Bahoi was found to be *H. pinifolia*, with a density of 307 ind/m^2. *H. pinifolia* is typically found in shallow or tide-influenced waters with a depth of approximately 1 m at low tide. *H. pinifolia* can also thrive on hard substrates (Zurba, 2018). This species is considered a pioneer because it can grow in habitats that are unsuitable for other seagrass species (den Hartog, 1967). Irawan et al. (2016) explained that *H. pinifolia* is abundant on substrates dominated by fine sand that is often stirred by waves and exposed at low tide.

The distribution and abundance of *H. pinifolia* are closely related to the parameters of turbidity, temperature, and substrate gravel or coral fragments. Therefore, it can be considered a pioneer in habitats that do not support the growth of other seagrass species. The given condition aligns with the sampling location, which is situated between a coral reef and mangrove ecosystems and has a sediment type of gravelly sand. According to den Hartog (1967), the seagrass species *H. pinifolia* can adapt well to various types of substrate, salinity, depth, and sedimentation. In this study area, the dominance of *H. pinifolia* is determined by the type of sediment, which is gravelly sand. The species is more commonly found in turbid areas with above-average water conditions, where the percentage of gravel and coral fragments is also higher than average (den Hartog, 1967).

In Bulutui and Tarabitan, *T. hemprichii* had the highest density, with 233 ind/m^2 and 176 ind/m^2, respectively (Figure 3). *T. hemprichii* is commonly found in mixed seagrass vegetation due to its high percentage density. den Hartog (1967) reported that *T. hemprichii* can grow on various substrates, including muddy sand, medium coarse sand, and coarse coral fragments. Seagrasses can overgrow most substrate types, from muddy to rocky (Nontji et al., 2012). Seagrass species *T. hemprichii* is a cosmopolitan seagrass with high adaptability to various aquatic environments (Short et al., 2007). *T. hemprichii* is often found around mangroves due to the high supply of nutrients from mangrove ecosystems, which can be utilized by seagrasses for growth and reproduction (Satrya et al., 2012). Seagrass density is closely related to substrate type and its adaptability for seagrass growth. The high density of *T. hemprichii* suggests that it is widespread and well-adapted.

Several factors affect seagrass density, including water physicochemical parameters, brightness, substrate type, and anthropogenic activities. It is important to consider these conditions when assessing seagrass density as they can have a significant impact on the condition of seagrasses in a particular area. Human activities in coastal areas are increasing, particularly in the tourism sector with hotel construction and land reclamation projects. The rise in the number of people interacting with seagrass beds poses a potential threat to the survival of seagrass ecosystems. The rate of seagrass habitat destruction has accelerated from an average of 0.9% per year before 1940 to 7% per year since 1990 (Rahmawati et al., 2014). The main reasons for seagrass destruction globally are reclamation activities, dredging, and water quality degradation, such as eutrophication. The activities of tourists and the local community around the seagrass ecosystem are believed to pose a new threat to seagrass health in the presence of the research site near the Special Economic Zone (SEZ).

Diversity Index

The diversity of seagrass species is influenced by various factors, including substrate, water conditions, and anthropogenic activities. A high diversity index suggests that the seagrass ecosystem in these waters is diverse and stable. Marine organisms associated with seagrass ecosystems include sea cucumbers, fish, gastropods, clams, sea urchins, macroalgae, turtles, and dugongs. Dugong feeding trails in West Likupang Sub-district, indicating the availability of dugong food in the area (Meidina et al., 2023). The study found that dugongs preferentially feed on the seagrass species H. pinifolia and H. ovalis, as evidenced by the presence of feeding trails. These seagrass species were observed in all study sites.

Table 2. Seagrass Diversity Index Assessment

Location	Index Value	Category
Bahoi	1.75	High
Bulutui	1.70	High
Tarabitan	1.70	High

The seagrass species diversity index value in West Likupang waters ranged from 1.70-1.75, as shown in Figure 5. Bahoi had the highest diversity index value of 1.75, while Bulutui and Tarabitan had the same value of 1.70. Overall, this indicates that the diversity of seagrass species in West Likupang waters is high, with a range of H' 1.6-3 according to Shannon-Wiener.

Seagrass Cover Percentage

Seagrass cover percentage is an indicator of the amount of seagrass cover in a water body (Minerva et al., 2014). The proportion of seagrass cover does not always have a linear relationship with the number of species present or their species density, as seagrasses can cover 30-40% of the substrate surface in a given aquatic ecosystem. This is because seagrass cover observations are based on the leaf blade, while species density is measured by the number of stands. Seagrass leaf width significantly influences substrate cover (Fahruddin et al., 2017). Plants with wider leaves have a greater ability to cover the substrate. The structure of seagrass communities is affected by differences in substrate type. Seagrass species with the highest density can occupy more space, providing more growth opportunities. Variations in composition and species are present in each area. The number of seagrass species found in the research location suggests that the waters are suitable for sustaining seagrass habitats. Seagrass is used as a bioindicator in water bodies (Fahruddin et al., 2017).

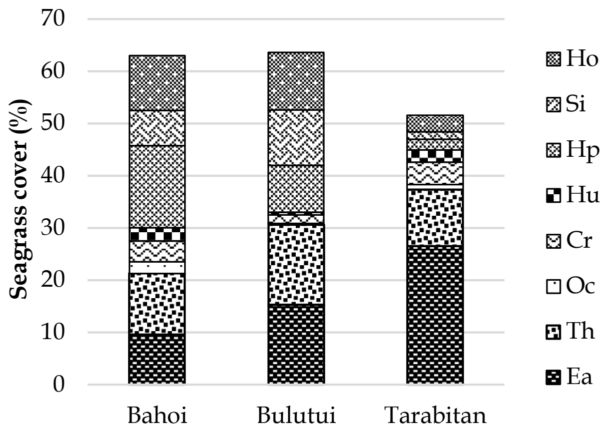

Figure 3. Seagrass cover Percentage in West Likupang water. *Cymodocea rotundata* (*Cr*); *Enhalus acoroides (Ea); Halodule pinifolia (Hp); Halodule uninervis (Hu); Halophila ovalis (Ho); Oceana serrulata (Os); Syringodium isoetifolium (Si);* dan *Thalassia hemprichii (Th)*

The highest percentage of seagrass cover in Bahoi was H. pinifolia at 16.25%, Bulutui was E. acoroides and T. hemprichii at 15.24%, and Tarabitan was E. acoroides at 27.52% (Figure 4). The dominant species of H. pinifolia was found in Bahoi because the sampling location was near mangrove and coral reef ecosystems. H. pinifolia seagrass habitat is located between mangrove and coral reef ecosystems and can be found on substrate types such as sand, muddy sand, and sandy mud (Hadad & Abubakar, 2016). In contrast, Bulutui is dominated by E. acoroides and T. hemprichii due to their larger size and high adaptability to fine and coarse substrate types, resulting in a high percentage of seagrass cover. It is worth noting that smaller seagrass species tend to have lower percentage values. Seagrass species such as T. hemprichii can grow in various types of substrates, including coral fragments and fine substrates (den Hartog, 1967). Seagrass species E. acoroides grow in various types of substrates, including mud, sand, and gravelly sand, and coexist with T. hemprichii. Tarabitan is dominated by E. acoroides due to its ability to adapt to different substrates and live in deep waters.

The seagrass cover percentages were 63.14% in Bahoi, 63.57% in Bulutui, and 51.52% in Tarabitan. Overall, Bulutui had the highest percentage of seagrass cover, followed by Bahoi and Tarabitan. The seagrass cover percentage in West Likupang falls within the healthy category (Meidina et al., 2023). The Kruskal-Wallis statistical analysis results indicate that there is no significant difference in the percent cover of seagrass species between stations. This is likely due to the good condition of the aquatic environment between stations. Field observations suggest that people utilize seagrass ecosystems for activities such as fishing and gleaning.

Seagrass Ecosystem Condition Assessment

The assessment of seagrass ecosystem conditions in West Likupang waters refers to the guidelines set out in the Decree of the Minister of Environment No. 200 of 2004, which outlines the criteria for determining the status of seagrass meadows. The seagrass ecosystems in West Likupang waters are generally healthy, except for Tarabitan which is in a less healthy condition (refer to Table 3). The percentage of seagrass cover in Tarabitan was also in a less healthy condition (Meidina et al., 2023). According to Coremap CTI LIPI, the percentage of seagrass cover falls under the dense category. Maintaining seagrass cover is crucial for the conservation of aquatic ecosystems as it plays a vital role in maintaining balance. Therefore, it is important to ensure a high percentage of seagrass cover.

Based on the findings in the field, eight seagrass species were identified in West Likupang, this finding is reinforced by previous studies of 6-10 species in North Minahasa waters (Bongga et al., 2021; Digdo et al., 2016; Kusumaningtyas et al., 2016; Meidina et al., 2023; Sondak & Kaligis, 2022), 8 species found in East Lombok (Rahman, 2018), 4 seagrass species found in Morotai Island (Muhammad et al., 2021), and 15 species identified in Indonesian waters (Sjarfrie et al., 2018).

Table 3. Seagrass *Cover Category*

Location	Seagrass cover (%)	COREMAP CTI LIPI Seagrass cover category (Rahmawati et al., 2014)	Ministry of Environment 200/2004: Health Status Category
Bahoi	63.14	Dense	Healthy
Bulutui	63.57	Dense	Healthy
Tarabitan	51.52	Dense	Unhealthy

Anthropogenic activities are the main cause of the unpredictable destruction of seagrass globally (Potouroglou et al., 2017; Unsworth et al., 2019). Globally, conservation and restoration efforts, such as seeding and planting, have not kept pace with the loss of seagrass beds (Damien & Pascaline, 2013). The risks identified at each study site were categorized according to the activities that were most likely to disrupt the condition and cover of seagrass (Table 4). If this activity continues without proper management, it may negatively affect the survival of seagrasses. The presence of relatively healthy seagrasses in the research location highlights the importance of taking action to prevent further damage.

Table 4. Identify Potential Risks to Seagrass Ecosystems Around the Special Economic Zone, West Likupang, Including Community Activities

Component	Potential risks	Risk mitigation efforts	Risk challenge
The practice of disposing of household waste in the sea by the community	Damaging water quality in seagrass ecosystem areas by polluting water	Local governments prepare regulations on household waste management (Mokoginta et al., 2023)	Public education about waste and an organized system for disposing of marine debris are necessary
Carbon storage in seagrass sediments	Loss of carbon stocks in seagrass sediments	There is a need for a risk assessment of the seagrass ecosystem to demonstrate the damage caused to the seagrass habitat	Infrastructure development in coastal areas
Anthropogenic activities, such as excessive gleaning	Walking on seagrass can damage the seagrass ecosystem	There is a need for a risk assessment of the seagrass ecosystem to demonstrate the damage caused to the seagrass habitat (Furkon et al., 2020)	The livelihoods of some fishermen are dependent on seagrass ecosystems.
Ship anchors and propellers	Anchors and boat propellers can cause harm to seagrass. Anchors can damage the stems and roots, while boat propellers can shred the leaves	There is a need for a risk assessment of the seagrass ecosystem to demonstrate the damage caused to the seagrass habitat (La Manna et al., 2015)	There are no designated boat lanes or berths
Infrastructure development, such as hotels and harbors, in coastal areas	Direct damage to seagrass ecosystems	There is a need for a risk assessment of the seagrass ecosystem to demonstrate the damage caused to the seagrass habitat	Likupang SEZ was established as a tourism SEZ with a focus on resort and cultural tourism, according to Government Regulation No. 84/2019

The Practice of Disposing of Household Waste in the Sea by the Community

The practice of disposing of household waste in the sea by the community can harm seagrass ecosystems. Household waste comes from the kitchen, bathroom, laundry, and human feces. The high intensity of household waste has the potential to pollute seagrass habitats. Human activities that threaten seagrass beds include waste disposal and littering (Rochmady, 2010). In the coastal area of West Likupang, some people live over the sea or in floating houses. Thus, all activities that produce organic and inorganic wastes are discharged directly into the sea, which can affect the survival of seagrasses. Seagrass habitats under high-intensity pressure have the potential to experience direct and indirect threats. Seagrass ecosystems are under pressure from human activities, such as the disposal of organic and inorganic household waste from coastal settlements, which can indirectly affect seagrasses (Subur et al., 2013). The local government needs to take action by drafting regulations on household waste management and educating the public that the West Likupang area is part of the Special Economic Zone in the tourism and cultural sectors.

Carbon Storage in Seagrass Sediments

The seagrass ecosystem is one of the ecosystems that play an important role as a carbon sink, also known as blue carbon. Sediment as the place where seagrass grows is the largest carbon store. The amount of carbon dioxide absorbed by seagrass is determined by its carbon storage capacity (Namoua et al., 2022). The greater the carbon stock of an ecosystem, the better, as this helps to mitigate climate change. Fourqurean et al. The average carbon storage in seagrass sediments is estimated to be ± 600 MgC/ha (Fourqurean et al., 2012; Pendleton et al., 2012). Carbon stocks in each seagrass substrate network are sequestered even after the seagrass shoots have decomposed and died (Kennedy et al., 2010). This suggests that the presence of seagrass habitats is a fundamental strength for sustainable conservation. Until now, infrastructure development in the West Likupang coastal area has resulted in the release of carbon dioxide (CO_2) gas stored in seagrass sediments into the atmosphere, triggering the greenhouse effect. This is due to the excavation of seagrass ecosystem areas. To prevent further damage, it is important to consider alternative methods of infrastructure development that do not damage seagrass ecosystems.

Anthropogenic Activities, such as Excessive Gleaning

Gathering or fishing for shellfish is an intensive activity carried out by communities on the west coast of Likupang. Generally, this activity is carried out by mothers and children in seagrass habitats during low tide. This activity is generally carried out by mothers and children. The results of harvesting are usually partially consumed by the community or sold to resort owners for fresh seafood for visiting tourists. Popular coastal scavenging activities usually target organisms that live around seagrasses and are easy to catch. This activity has both direct and indirect negative impacts on the sustainability of seagrass ecosystems but is still rarely recognized by those who carry out these activities.

Ship Anchors and Propellers

The use of boat anchors and boat propellers has serious impacts that can affect the sustainability of seagrass habitats. Anchors passing through seagrass beds can damage seagrass stems and roots, while boat propellers can tear seagrass leaves. Some of the study sites have jetties where boats dock, potentially damaging seagrass beds. Ship anchors driven into seagrass beds cause direct physical damage (Cullen-Unsworth et al., 2018). Small and large ship anchors can cause free excavation of seagrass sediments, releasing large amounts of sequestered CO_2 gas into the atmosphere. Anchors can cause turbidity, which then reduces the intensity of sunlight entering the water column, which can affect seagrass growth (Rustam, 2014; Browne et al., 2017).

The results of this study provide information on the status and condition of seagrass ecosystems around the Special Economic Zone (SEZ), West Likupang, North Sulawesi, to increase the conservation value of seagrass ecosystems in the area. As the development of SEZs is one of the triggers for economic growth in the region, it can also be a source of controversy in terms of both social and environmental aspects. Furthermore, Yustinaningrum (2017) argues that environmentally friendly tourism destinations must pay attention to aspects of co-ownership, co-management, and co-responsibility. One of the objectives is to protect ecosystem areas to be in harmony with the use of marine tourism.

Conclusion

Based on the research results, eight seagrass species were obtained around the West Likupang Special Economic Zone (SEZ), North Sulawesi, namely *C. rotundata* (Cr), *E. acoroides* (Ea), *H. pinifolia* (Hp), *H. uninervis* (Hu), *H. ovalis* (Ho), *O. serrulata* (Os), *S. isoetifolium* (Si), dan *T. hemprichii* (Th). The seagrass community in the waters of West Likupang is a mixed. The seagrass meadows appear to be in healthy condition, with a dense percentage of seagrass cover. The identification of potential risks from anthropogenic activities may pose a new threat to the survival of seagrass, necessitating appropriate management by local governments.

Acknowledgments

The authors would like to appreciate financial support for this research from the IKI Project (Internationale Klimaschutz Initiative) and Yapeka (Indonesian Environmental and Conservation Education).

Author Contributions

All authors have contributed to the final manuscript. The contributions of each author are as follows: Conceptualization and methodology (S, F.K); data curation and visualization (S); investigation (Z.I, P, F.K, A.A.D); writing-original draft preparation and writing-review and editing (S, Z.I, F.K, P, A.A.D). All authors have discussed and agreed to the published version of the manuscript.

Funding

This research was partially supported by the IKI Project (Internationale Klimaschutz Initiative) and Yapeka (Indonesian Environmental and Conservation Education).

Conflicts of Interest

The authors declare that they have no competing interests.

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