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Sustainability status of ecotourism-based seagrass ecosystem management on Maitara Island Indonesia

Salim Abubakar[1*], Rina[1], Riyadi Subur[1], Rene C. Kepel[4], Sunarti[1], Rugaya H. Serosero[1], Yuyun Abubakar[1], Nebuchadnezzar Akbar[2], Najamuddin[2], M. Janib Achmad[3], Ariyati H. Fadel[1], M. Said Al Hadad[1], Raut Nugrahening Widhi[1], Raut Wahyuning Paluphi[1]

[1]Aquatic Resources Management Study Program, Faculty of Fisheries and Marine Sciences, Khairun University, Ternate, 97719, Indonesia
[2]Marine Science Study Program, Faculty of Fisheries and Marine Sciences, Khairun University, Ternate, 97719, Indonesia
[3]Fisheries Resources Utilization Study Program, Faculty of Fisheries and Marine Sciences, Khairun University, Ternate, 97719, Indonesia
[4]Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Manado, Indonesia.

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ABSTRACT

Seagrass ecotourism is a tourism activity based on seagrass ecosystem as an educational tour by seeing the ecology of seagrass meadows and associated biota. Conservation awareness and improving community welfare, seagrass ecotourism is a nature-based tourism strategy with the aim of environmental conservation and containing aspects of community education and culture. Determining the sustainability status of seagrass ecosystem management is very important as a basis for future policy planning. The sustainability of seagrass ecosystems needs to be protected, so a policy strategy is applied in sustainable seagrass ecosystem management. The objectives of the study are: 1) determining the sustainability status of ecotourism-based seagrass ecosystem management based on ecological, economic and social dimensions, 2) determining the policy strategy for ecotourism-based seagrass ecosystem management. The results of the study obtained the sustainability status of ecotourism-based seagrass ecosystem management based on ecological dimensions is quite sustainable while the economic and social dimensions are less sustainable. The strategy for sustainable policy for managing seagrass ecosystems based on ecotourism on Maitara Island, Tidore Islands, namely education about seagrass ecosystems for the community, managing seagrass ecosystems based on ecotourism, increasing seagrass rehabilitation programs, maximum limits for carrying capacity of seagrass ecotourism, training for developing managers of seagrass ecotourism based on ecosystems, increasing job opportunities and business opportunities, legality of seagrass areas as conservation areas in the tourism utilization zone category and strengthening laws and institutions.

Introduction

Seagrass ecosystem is a monocotyledonous plant consisting of rhizomes and roots, can grow and develop in intertidal areas to photic areas and can be associated with mangroves and coral reefs. Seagrass requires high light intensity to carry out the process of photosynthesis (Abubakar & Ahmad, 2013; Alhaddad & Abubakar, 2016). Seagrass lives in various types of sediment, from mud to bottom sediment consisting of 40% fine mud deposits. Seagrass thrives especially in open tidal areas and coastal waters or goba whose base is mud, sand, gravel and coral fractures with a depth of 4 meters. Very clear sea, seagrass species can grow to a depth of 8-15 meters and 40 meters (Rina *et al.,* 2019; Zachawerus *et al.,* 2019).

There are numerous ecological and financial advantages to seagrass environments. ecological advantages as feeding grounds, nurseries, and spawning sites for different biota species (Assa *et al.,* 2015; Muzammil *et al.,* 2021, Iftinaan *et al.,* 2017; Rina *et al.,* 2021). The primary financial advantages of seagrass ecosystems for the fishing industry are fish stocks, crabs, shellfish, and more. Extensive

* Corresponding author.
Email address: salimbbkr@gmail.com

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seagrass provides habitat for various species of marine biota, including those living on the seabed (benthos), among seagrass leaves (nekton and plankton), and those attached to seagrass leaves either permanently (peribiota) or temporarily. This high biodiversity makes seagrass an important ecosystem in marine life (Abubakar & Ahmad, 2013; Rosalina *et al.,* 2024a). Seagrass can also be used as a place for recreation or ecotourism (Martini *et al.,* 2014; Rina *et al.,* 2019). The seagrass ecosystem has developed into a tourist destination in the form of snorkeling tourism at sea (Tanto *et al.,* 2017).

Tourism is a form of utilization of natural resources that relies on natural services for human satisfaction. Human activities for tourism purposes are known as tourism. Ecotourism is nature-based tourism that includes aspects of education and interpretation of the natural environment and community culture with ecological sustainability management (Tuwo, 2011). The suitability of seagrass ecotourism considers seven parameters with four assessment categories, namely seagrass cover, water clarity, fish species, seagrass species, substrate type, current speed and seagrass depth. Good seagrass cover to be used as a snorkeling ecotourism area is> 75% because it is related to the level of damage and fertility of seagrass growth (Yulianda, 2019).

Development activities in coastal areas have sacrificed seagrass ecosystems, such as reclamation activities for the development of industrial areas or ports, resulting in a reduction in the area of seagrass beds (Tanto *et al.,* 2017). Changes in environmental conditions, both spatially and temporally, have a significant impact on the growth and health of seagrass beds. This illustrates that efforts to maintain seagrass ecosystems are still very lacking (Patty, 2016; Rosalina *et al.,* 2024b).

Damage to seagrass ecosystems in Indonesia is caused by natural and human factors. The loss of seagrass is mainly due to the direct impact of human activities including mechanical damage (dredging and anchoring), eutrophication, fisheries cultivation, sedimentation, and the influence of coastal construction. The loss of seagrass beds is expected to continue to increase due to population growth pressures in coastal areas. Natural threats to seagrass ecosystems can include typhoons, cyclones (especially in the Philippines), tidal waves, underwater volcanic activity, population and community interactions (predators and competition), sediment movement, pests and diseases and vertebrates that prey on seagrass (Rosalina *et al.,* 2024a).

Seagrass that has been disturbed or damaged due to natural disturbances or human activities. Continuous human disturbance or pressure has a major impact. The root causes of seagrass destruction include public ignorance, poverty, greed, weak legislation and law enforcement. Seeing the impact of damage to seagrass beds both naturally and caused by human activities, rehabilitation efforts are needed to reduce the impact of damage and maintain or even restore the condition of damaged seagrass beds to be better. Therefore, ecotourism-based seagrass management is one of the efforts in utilizing environmental services sustainably (Supyan & Samman, 2022).

Increasing conservation strategies and improving community welfare, seagrass ecotourism is a form of nature-based tourism with the aim of environmental conservation and contains aspects of community education and culture with ecological sustainability management. Seagrass ecotourism is a tourism activity based on the seagrass ecosystem. The components of seagrass ecotourism consist of seagrass vegetation and biota associated with seagrass. One of the benefits of seagrass ecotourism is as educational tourism, for example to see the ecology of seagrass beds and their associated biota (Apriana & Milla, 2017; Abubakar *et al.,* 2020).

Maitara Island has 3 leading tourism potentials, namely the Thousand Rupiah Monument, beach tourism and Ngusulenge mangrove tourism. Meanwhile, marine tourism in the seagrass tourism category does not yet exist, while Maitara Island has a seagrass ecosystem spread across all areas covering an area of 25.56 ha. Various anthropogenic activities such as coastal reclamation, sand mining, shipping activities, underwater national electricity company (PLN) electricity installation lines and coastal area development on Maitara Island. These activities have the potential to affect the condition of the seagrass ecosystem in the form of decreasing density, closure, and even its area. The decline in seagrass conditions on Maitara Island is marked by changes in the level of closure and density which have tended to decrease in recent years. Therefore, to maintain the sustainability of the seagrass ecosystem, a policy strategy is implemented in the sustainable management of the seagrass ecosystem. The concept of ecotourism bridges the interests of conservation and the tourism industry. Ecotourism is guided by the achievement of environmentally friendly tourism development and sustainable socio-economic empowerment of local communities (Zahra *et al.,* 2020; Kusuma, 2022).

Seagrass research in the North Maluku region is generally limited to seagrass communities (Alhaddad & Abubakar, 2016), distribution of seagrass fish communities (Kaeli *et al.,* 2016; Rina *et al.,* 2019), and the suitability of seagrass ecotourism land for ecological aspects (Abubakar *et al.,* 2020). Meanwhile, the strategy for managing seagrass ecosystems based on ecotourism in general and North Maluku in particular has never been carried out. Several previous studies were generally limited to general seagrass ecosystem management strategies and used SWOT analysis (Metekohy, 2016; Munandar *et al.,* 2020). Therefore, what is new in this study is the strategy for sustainable management of seagrass ecosystems based on ecotourism based on *Multidimensional Scaling* (MDS) analysis, namely the development of the *Rapid Appraisal of Fisheries* (*Rapfish*) method with the Rapid Appraisal of Seagrass Ecotourism Based Ecosystem (*Rap-Sbe*) model approach based on ecological, economic and social dimensions. The objectives of the research are: 1) to determine the sustainability status of ecotourism-based seagrass ecosystem management based on ecological, economic and social dimensions, 2) to determine the policy strategy for ecotourism-based seagrass ecosystem management.

Materials and Methods

Location and time of research

The research was conducted in June 2024 on Maitara Island, North Tidore District, Tidore Islands City, in 4 villages, namely Maitara Induk, North Maitara, Central Maitara and South Maitara Village (Figure 1).

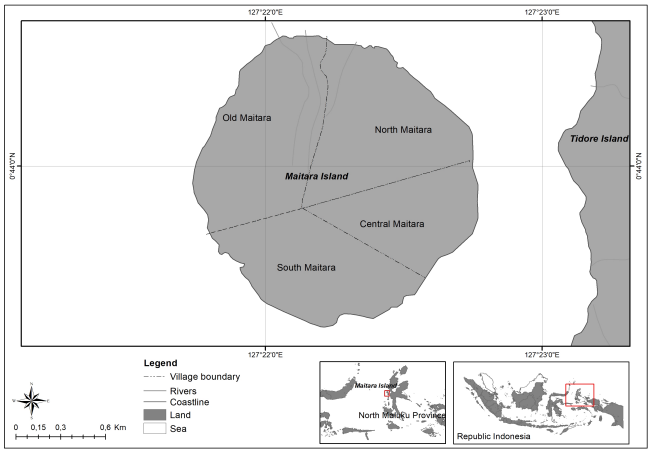

Figure 1. Research sites on Maitara Island. North Maluku. Indonesia.

Sampling

The data used in this study include primary data and secondary data. Primary data such as biophysical data were obtained and collected directly through field observations, while for several economic and social parameters, the focus group discussion (FGD) method was used, involving the government, namely the Marine and Fisheries Service of Tidore Islands City, the Environmental Service, the Culture and Tourism Service of Tidore Islands City Government, village heads, community leaders, and fishermen. Secondary data collection through literature studies from various documents in several related agencies and previous research results

Data analysis

The data analysis method uses *Multidimensional Scaling* (MDS) analysis, namely the development of the *Rapid Appraisal of Fisheries* (*Rapfish*) method with the Rapid Appraisal of *Seagrass Ecotourism Based Ecosystem* (*Rap-Sbe*) model approach. MDS is a statistical technique that tries to transform multimedia into simpler dimensions (Fauzi & Anna, 2002).

The stages of the Rap-Sbe ordination analysis are: (1) determining attributes in the ecological, economic and social dimensions; (2) assessing (scoring) each attribute based on the sustainability criteria of each dimension; (3) Rap-Sbe ordination analysis with the MDS method to determine ordination and stress values; (4) assessing the index and sustainability status of ecotourism-based seagrass ecosystem management in each dimension and multidimensional; (5) leverage analysis to determine sensitive variables that affect sustainability; and (6) Monte Carlo analysis to take into account uncertainty aspects (Kavanagh, 2001; Kuvaini *et al.,* 2019) (Figure 2).

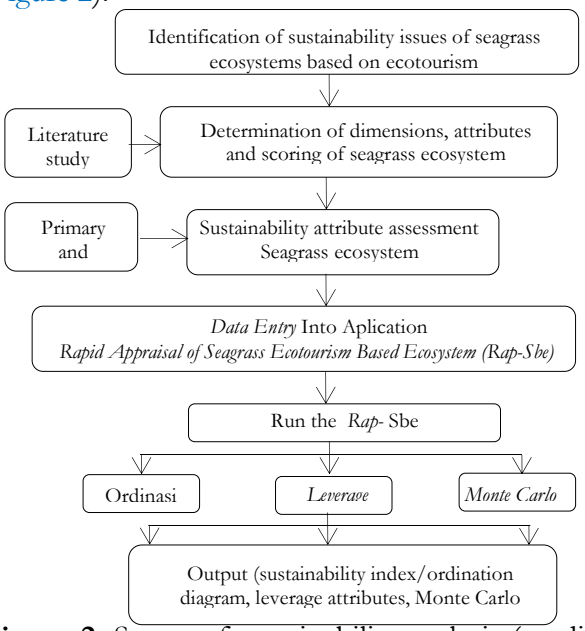

Figure 2. Stages of sustainability analysis (modified from Fauzi, 2019)

Determination and assessment of attributes for each dimension are obtained from the results of literature studies, field observations, and available secondary data.

The range of score values ranges from 0-2 depending on the condition of each attribute defined as a "bad" value and a "good" value. A "bad" value is defined as the most unfavorable condition for a sustainable ecotourism-based seagrass ecosystem management plan. Conversely, a "good" value is defined as the most favorable condition for a sustainable ecotourism-based seagrass ecosystem management plan. The dimensions and attributes of the sustainability analysis of the ecotourism-based seagrass ecosystem management plan on Maitara Island are ecology, economy and social (Table 1).

The sustainability index value of each dimension can be visualized in the form of a kite diagram and analyzed multidimensionally to determine the point or position of sustainability of ecotourism-based seagrass ecosystem management. The sustainability index value in the Rap-Sbe method is in the range of 0 (bad) to 100 (good), so to facilitate the determination of its sustainability status, a grouping of the index values in question is carried out. The sustainability status category of the ecotourism-based seagrass ecosystem management plan is based on the index range of 0 - 25 (bad / unsustainable), 26 - 50 (less / less sustainable), 51-75 (sufficient / fairly sustainable), and 76 - 100 (good / very sustainable) (Kuvaini *et al.,* 2019).

Table 1. Dimensions and attributes of sustainable ecotourism-based seagrass ecosystem management on Maitara Island.

Dimensions	Attributes
Ecology	(1) seagrass cover; (2) seagrass density; (3) seagrass types; (4) seagrass fauna types; (5) seagrass depth; (6) suitability of ecotourism land; (7) seagrass conditions
Economy	(1) accessibility of seagrass areas; (2) direct benefits of seagrass; (3) average community income from utilizing seagrass ecosystems; (4) seagrass ecosystem management plans; (5) government budget for seagrass management; (6) potential and number of tourist visits; (7) job opportunities and business opportunities.
Social	(1) community knowledge about seagrass meadows; (2) community participation in seagrass meadow management; (3) community education level; (4) damage to seagrass meadows by the community; (5) social impacts of the existence of seagrass meadows on the community; (6) local cultural practices in preserving seagrass meadows; (7) conflicts over the use of seagrass meadow resources.

Results

Assessment of seagrass ecosystems' sustainability status from an ecological perspective

The sustainability of the ecological dimension is a depiction of the level of sustainability of seagrass ecosystem management related to ecological aspects. The analysis of the sustainability index for the ecological dimension is 66.86% on a scale of 0-100% (Figure 3). Based on sustainability criteria, this index is in the fairly sustainable category. This shows that the ecological attributes in the ecological dimension are still quite supportive of maintaining the sustainability of ecotourism-based seagrass ecosystem management on Maitara Island.

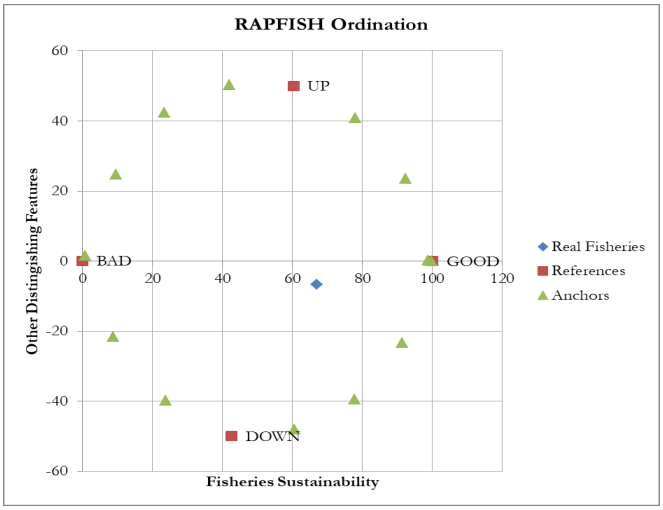

Figure 3. Sustainability of seagrass ecosystems ecological dimension

Ecological dimension, there are 7 (seven) attributes that affect the sustainability of the seagrass ecosystem on Maitara Island, namely (1) seagrass cover (2) seagrass density, (3) seagrass type, (4) seagrass fauna type, (5) seagrass depth, (6) suitability of the designation of the seagrass ecotourism area, (7) seagrass condition. Based on the leverage analysis expressed in the form of root mean square (RMS) values from the seven attributes assessed in this study, there are 6 attributes that are leverage factors because their changes have a sensitive effect on the ecological dimension sustainability index value (Figure 4). The

six attributes are seagrass fauna type (6.63%), seagrass density (6.24%), seagrass depth (6.10%), seagrass type (5.78%), suitability of the designation of the seagrass ecotourism area (3.85%) and seagrass cover (3.61%) (Figure 4).

Based on the results of field observations and interviews with the community, the seagrass area of Maitara Island has various biota consisting of fish and *macrozoobenthos* (*gastropods, bivalves, holothuroidea, echinoidea, asteroidea*). The composition of fish species is 8 (*Siganus canaliculatus, S. Spinus S. Chrysospilos, Scarus quiyo, Scarus fraenatus, Lutjanus gibbus, Pristipomoides auricillia, Mulloidichtys flavolineatus*). The composition of gastropod species is 7 species (*Strombus luhuanus, S. aurisdianae, S. lentiginosus, S. gibberulus, Cypraea tigris, C. annulus, Tectus fenestratus*). The composition of bivalve species is 3 species (*Trachycardium orbita, Isognomon isognomon, Valaclamys singaporina*). The composition of the *Holothuroidea* species is 4 species, *(Holothuria opheodesoma, H. marmorata, H. atra, Bohadschia graeffei*). The composition of the *Echinoidea* species is 4 types (*Mespilia globulus, Tripnieustes gratila, Diadema setosum, Echinometra mathei*). The *Asteroidea* species composition consists of 3 species (*Protoreaster nodosus, Culcita novaguineae, Linckia laevigata*).

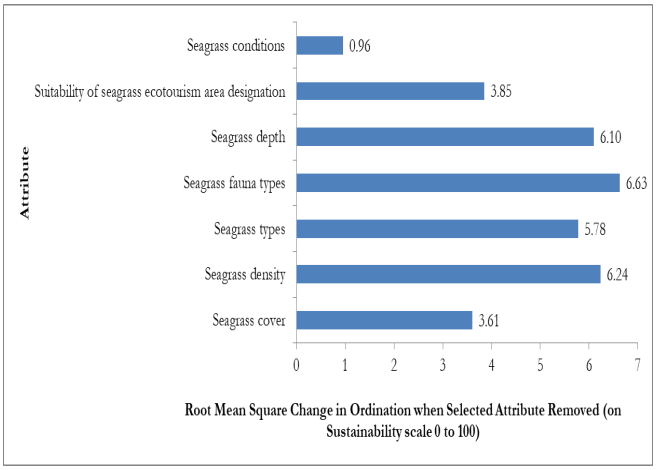

Figure 4. Results of ecological dimension leverage analysis

The composition of seagrass species on Maitara Island is 2 families and 10 species, namely Potamogenaceae and Hydrocaritaceae. There are 6 types of the Potamogenaceae family, namely *Cymodocea rotundata, C. Serrulata, Halodule uninervis, H. pinifolia, Syringidum isiotifolium, Thalassodendron ciliatum*) while there are 4 types of the Hydocaritaceae family, namely *Enhalus acoroides, Thalassia hemprichii, Halohila minor and Halophila spinulosa.* The percentage of seagrass cover on Maitara Island is an average of 74.52%, but there are several areas that have low seagrass cover which has an impact on the condition of the seagrass, namely damaged/poor.

Evaluation of sustainability status seagrass ecosystems in economic dimensions

Sustainability of the economic dimension is a depiction of the level of sustainability of seagrass ecosystem management related to economic aspects. The analysis of the sustainability index for the economic dimension is 26.37% on a scale of 0-100% (Figure 5). Based on the sustainability criteria, this index is in the less sustainable category. This value indicates that the attributes of the economic dimension are less supportive of maintaining the sustainability of ecotourism-based seagrass ecosystem management on Maitara Island.

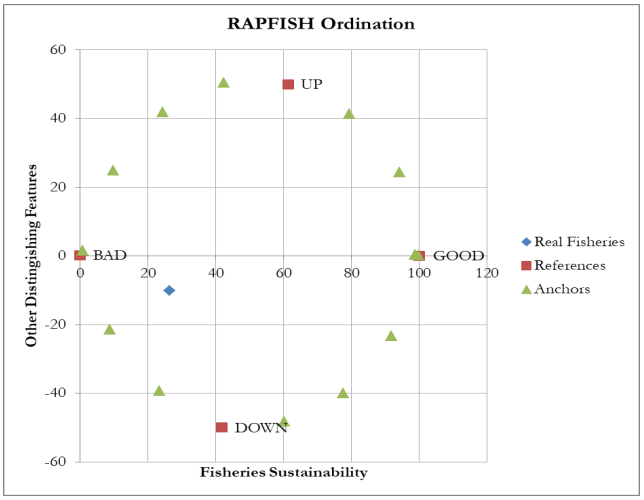

Figure 5. Ordination of seagrass ecosystems in economic dimensions

Economic dimension, there are 7 (seven) attributes that influence the sustainability of mangroves based on ecotourism in Jailolo Bay, namely (1) accessibility of seagrass areas, (2) direct benefits of seagrass, (3) average community income from utilizing seagrass ecosystems, (4) seagrass ecosystem management plans, (5) government budget for seagrass management, (6) potential and number of tourist visits and (7) job opportunities and business opportunities. Based on the leverage analysis (RMS) of the seven attributes assessed in this study, there are 3 attributes that are leverage factors because their changes have a sensitive effect on the value of the economic dimension sustainability index. The three attributes are seagrass ecosystem management plans (8.50%), government budget for seagrass management (4.92%) and average community income from utilizing seagrass ecosystems (4.69%) (Figure 6).

Evaluation of sustainability status of seagrass ecosystems in social dimension

The sustainability of the social dimension is a depiction of the level of sustainability of seagrass ecosystem management related to social aspects. The analysis of the sustainability index for the social

dimension is 26.02% on a scale of 0-100% (Figure 7). Based on the sustainability criteria, this index is in the less sustainable category. This value indicates that the attributes of the social dimension are less supportive of maintaining the sustainability of ecotourism-based seagrass ecosystem management on Maitara Island.

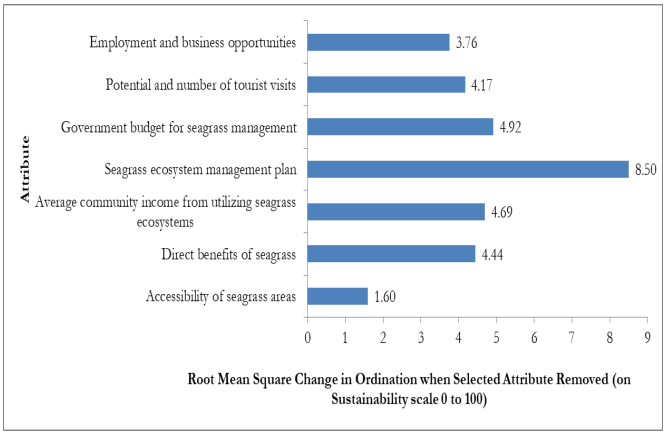

Figure 6. Results of economic dimension leverage analysis

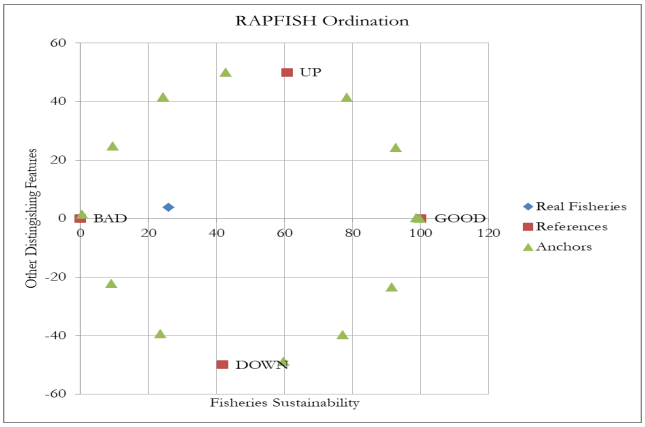

Figure 7. Sustainability of seagrass ecosystems in the social dimension

Social dimensions have 7 (seven) attributes that affect the sustainability of the seagrass ecosystem on Maitara Island, namely (1) community knowledge about seagrass, (2) community participation in managing the seagrass ecosystem, (3) community education level, (4) damage to seagrass by the community, (5) social impact of the existence of seagrass on the community, (6) local cultural practices in preserving the seagrass ecosystem, and (7) conflicts over the use of seagrass resources. Based on the leverage analysis (RMS) of the seven attributes assessed in this study, there are 4 attributes that are leverage factors because their changes have a sensitive effect on the value of the social dimension sustainability index. The four attributes are community education level (8.00%), damage to seagrass by the community (4.73%), community knowledge about seagrass (4.64%) and the social impact of the existence of seagrass on the community (4.57%) (Figure 8).

The low level of education of the Maitara Island community (generally elementary school graduates) is the cause of the damage to the seagrass ecosystem, because the community's knowledge of the seagrass ecosystem is relatively low where not all people know the function and benefits of seagrass. The low level of community knowledge of the benefits of seagrass and its preservation can cause their low concern for the sustainability of the seagrass ecosystem and will affect community behavior, especially in understanding and interacting with the seagrass ecosystem. If the community has good knowledge of the seagrass ecosystem, the social impact of the existence of seagrass by the community can be suppressed properly. The community does not feel and is not aware of the function and benefits of the existence of seagrass.

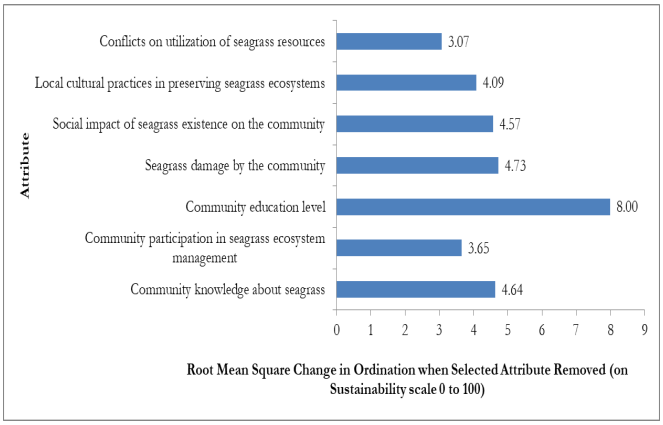

Figure 8. Leverage analysis results from social dimensions

Multidimensional sustainability status

Multidimensional analysis was conducted by combining all dimensions, namely ecological, economic and social dimensions. The results obtained showed that the multidimensional sustainability index of 39.78% was included in the less sustainable category (Figure 8). This value was obtained based on the assessment of 21 indicators from the 4 dimensions analyzed. The highest sustainability index value was in the ecological dimension of 66.86% while the lowest sustainability index value was in the social dimension of 26.02% (Figure 10). This means that dimensions that are not yet sustainable need to be improved while dimensions that are quite sustainable need to be made even better. The sustainability index value of each dimension in the kite diagram (Figure 9).

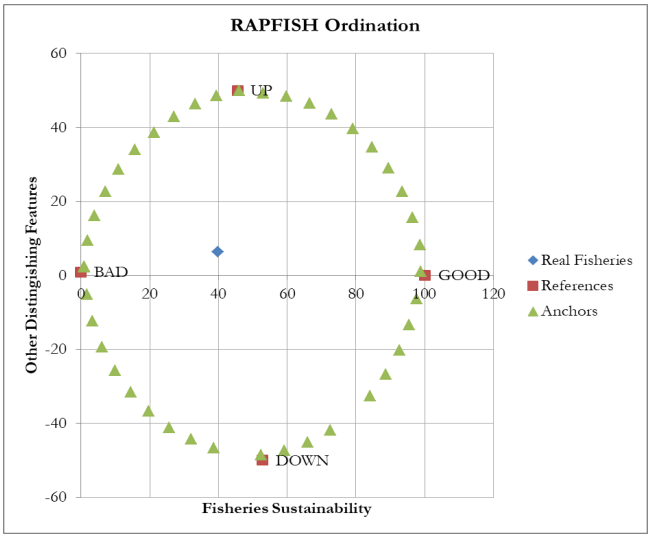

Figure 10. Multidimensional seagrass ecosystem sustainability coordination

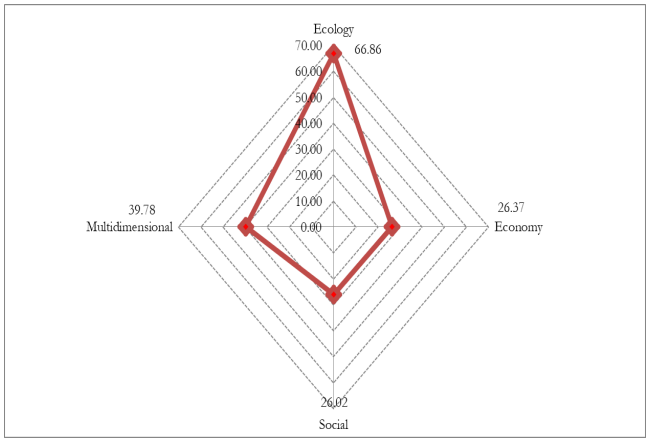

Figure 10. A flyover diagram of the sustainability status of ecotourism-based seagrass ecosystem management on Maitara Island.

Based on the results of leverage analysis on 21 multidimensional attributes, it was obtained that the attribute of conflict in the utilization of seagrass resources from the social dimension has a sensitive influence that can cause changes in the management of the ecotourism-based seagrass ecosystem on Maitara Island (Figure 11). This indicates that the social dimension has a strong influence on changes in the performance of ecotourism-based seagrass ecosystem management in the Maitara Island area, North Tiodre District, Tidore Islands City. Governance of these attributes needs to be a concern in the general policy of seagrass ecosystem management in the future.

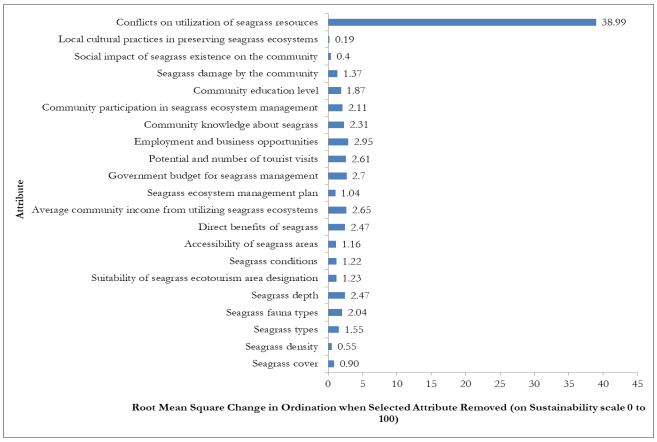

Figure 11. Results multidimensional leverage analysis

MDS validity test and accuracy test

Validity test was conducted using Monte Carlo analysis and MDS analysis at a 95% confidence level which showed that the sustainability index value of ecotourism-based seagrass ecosystem management on Maitara Island had differences in both three dimensions and multidimensions ranging below 5%. Differences in sustainability index values between MDS and Monte Carlo results (Table 2).

Table 2. Stress values and coefficient determination

Dimension	Values	
	Stres	R^2
Ecology	0.14	0.95
Economy	0.13	0.95
Social	0.14	0.95
Multidimension	0.13	0.96

The small difference in analysis results (Table 2) indicates that the Rap-Sbe analysis with the MDS method to determine the sustainability of the system studied has a high level of confidence. It can be concluded that the Rap-Sbe method in this study can be used as one of the evaluation tools for rapid appraisal of the sustainability of ecotourism-based seagrass ecosystem management on Maitara Island.

Discussion

The sustainability value can be explained that the management of the seagrass ecosystem based on ecotourism on Maitara Island if it is still implemented with the same pattern and conditions as at present, then the sustainability of the seagrass ecosystem on Maitara Island will continue to be sustainable without any further intervention that disrupts the ecological quality such as the current condition. Therefore, various ecological attributes that have a positive influence on the sustainability index value in the ecological dimension must be maintained and improved in order to encourage an increase in the

sustainability index value of the ecological dimension. As for attributes that have a negative effect, they need to be managed to be better.

Anthropogenic activities carried out by the community in the form of garbage disposal, boat landings, fishing in seagrass areas, underwater PLN electricity cable installation routes, sea transportation routes and sand mining cause the waters to become cloudy and inhibit the photosynthesis process for the growth of seagrass species. The impact of various anthropogenic activities has caused seagrass conditions to be damaged and seagrass density to be in the moderate category.

Various ecological attributes that are sensitive levers on the value of the ecological dimension sustainability index are parameters in determining the suitability of seagrass ecotourism land, therefore they must be maintained and improved in order to encourage an increase in the ecological dimension sustainability index value. Efforts to protect flora and fauna in the Maitara Island seagrass area are considered still lacking because there have been no concrete efforts or activities from the government that are specific to the purpose of protecting flora and fauna in the Maitara Island seagrass ecosystem. This indicator requires attention because the existence of flora and fauna is an important part of the balance of the seagrass ecosystem and is also a tourist attraction. In achieving the sustainability and function of the seagrass ecosystem in protecting biodiversity, protecting the coastline and coastal resources, it is necessary to develop research and science and technology in efforts to protect coastal areas and reduce the risk of seagrass-based disasters.

The diversity of seagrass species and fauna can be a supporting factor in the development of seagrass ecotourism because it can be an attraction when holding snorkeling activities, so that tourists can enjoy the beauty of both the seagrass itself and the organisms that live in association. Tuwo (2011), stated that the biota associated with the seagrass ecosystem provide a special attraction for tourists to see the beauty of the waters. Biota forms a beautiful ecosystem unity and provides a natural impression as an effort to develop ecological-based tourism (eco-tour) and educational tourism. In addition, associated biota also have economic value that can attract tourists such as by selling seafood to tourists. According to Yulianda (2019) an area has a diversity of 10 types of seagrass, including a very good category to be used as seagrass ecotourism.

Seagrass ecotourism is a tourism activity based on the seagrass ecosystem. The components of seagrass ecotourism consist of seagrass vegetation and biota associated with seagrass. One of the benefits of seagrass ecotourism is as educational tourism, for example to see the ecology of seagrass and its associated biota (Abubakar *et al.,* 2020).

Based on the results of the analysis of the lever factors in this ecological dimension, in planning the management of the seagrass ecosystem on Maitara Island, the seagrass restoration and transplantation program must continue to be carried out, especially in areas that have been damaged. Likewise, the program for preventing and controlling the conversion of seagrass land to other land uses must be a commitment of the government to maintain and increase the area of seagrass fields on Maitara Island. Various human activities and development activities in coastal areas are the causes of seagrass damage. Management of seagrass ecosystems so that their existence is sustainable in waters must consider several things, namely: an ecosystem approach, a socio-economic and cultural approach, a socio-political approach, and a legal and institutional approach. Restoration and transplantation are one of the ecosystem approaches. Restoration is recreating seagrass fields in conditions to support the seagrass that once existed, while transplantation is moving and planting in another place, removing and installing on other land or other situations (Rochmadi, 2010; Zurba, 2018).

Maitara Island can be developed as a coastal and marine ecotourism area because this island has many advantages that can be used as a tourist destination such as natural mountain panoramas, beaches with white sand and clear blue sea. Sunset views, underwater natural scenery that can be enjoyed by doing various diving or snorkeling activities to enjoy the diversity of fish and coral that have been strictly guarded by the Maitara Island community, various culinary delights available such as fried bananas, papeda, and yellow fish soup. From the potential of Maitara Island, this island is used as an icon for the Rp. 1,000 currency which holds colonial history, where this island which is part of the Ternate archipelago was the first island visited by the Portuguese.

Maitara Island already has 2 types of tourist attractions, namely the Ngusulenge mangrove forest tourist attraction located in Maitara Tengah Village and beach tourist attractions located in Maitara Utara Village, Maitara Selatan Village and Maitara Induk Village. The variety of tourist activities on Maitara Island causes many tourists to come so that it has the potential to open up employment opportunities and business opportunities for the community. Efforts to utilize sustainable and continuous seagrass ecosystem services on Maitara Island have never been carried out

so that the direct socio-economic benefits of the existence of the seagrass ecosystem have not been felt by the community. Based on the results of interviews with the community who utilize the seagrass, the average income of the community from utilizing the ecosystem is less than IDR 1 million/month. The low income is a result of the increasing degradation of the seagrass ecosystem so that the area of seagrass begins to decrease and has an impact on the reduction of organisms associated with seagrass as a livelihood for the community. The seagrass ecosystem has great economic value for the community. So far, the Maitara Island community has received direct benefits, especially in the form of fishery products (such as fish, shellfish, shrimp and crabs). Utilization of the seagrass ecosystem, especially in the field of capture fisheries, can increase community income and welfare.

Although the potential for coastal and marine biological resources is very rich, most people living on the coast are still below the poverty line. This is one of the driving factors for coastal communities to exploit marine resources beyond their carrying capacity so that they can meet their living needs (Rochmadi, 2010). The government budget requirement for sustainable seagrass ecosystem management is not yet available, this is because there is no planning in sustainable seagrass ecosystem management. The source of APBD both at the provincial level and Tidore Islands City for coastal ecosystem management is generally focused on mangrove ecosystems and coral reef ecosystems. Therefore, special attention is needed with an increase in the budget sourced from APBN and APBD funds including the role of the private sector in supporting seagrass ecosystem management.

Anthropogenic activities on the seagrass ecosystem on Maitara Island include conversion as a port area, sea transportation routes, boat landings, fishing in seagrass areas, underwater PLN electricity cable installation routes, waste disposal and sand extraction, causing damage to several areas. To support the sustainability of seagrass ecosystem management on Maitara Island, the local government needs to implement strict regulations on anthropogenic activities carried out on the seagrass ecosystem and the types of environmental service utilization through tourism activities. Utilization of the potential value of seagrass can improve community welfare, but without sustainable management it will reduce the function of this ecosystem. Human activities in utilizing seagrass resources often have negative impacts on their sustainability. Seagrass in Indonesia have experienced a lot of quality decline, both due to natural processes and human activities. Human activities that threaten seagrass beds are the impact of fishing activities, waste and garbage disposal, pollution, recreational activities, shipping and anchorage activities, industrial and factory waste disposal, and others (Rochmadi, 2010; Abubakar *et al.,* 2020).

To improve the sustainability status of the social dimension, the main thing that must be done is a program to increase public understanding of the seagrass ecosystem, increase community involvement in various types of seagrass ecosystem management programs, management of the social impact of the existence of the seagrass ecosystem must be accommodated in the planning and implementation of seagrass ecosystem management policies on Maitara Island in the future. strengthening the role of coordinating seagrass ecosystem management, implementing socialization, both government regulations and other forms of seagrass ecosystem management strategies and organizing activities that are intended to unite understanding with social movements to protect seagrass.

The results of the assessment of the sustainability status analysis of the ecotourism-based seagrass ecosystem on Maitara Island generally show that the level of sustainability is still not good, although the ecological dimension is categorized as quite good. Improvement of all attributes of all dimensions by means of appropriate policy interventions needs to be carried out so that the level of sustainability of seagrass ecosystem management on Miatara Island becomes better. Sensitive attributes which are leverage attributes must be the basis for carrying out these policy interventions. Influential attributes are attributes with Root Mean Square (RMS) values in the middle to high. Sensitive attributes are attributes that have RMS values on the x-axis, the greater the RMS value, the more sensitive the role of the attribute is to increasing the sustainability status (Kavanagh, 2001). From the results of the leverage analysis, sensitive attributes or key attributes were obtained for the sustainability index value of each criterion, namely 6 attributes for the ecological dimension, 3 attributes for the economic dimension and 4 attributes for the social dimension (Table 2).

Monte Carlo analysis was conducted to account for the uncertainty dimension [8]. This analysis observes and evaluates the effects of errors by assessing the dimensions. The level of model validity is obtained from the difference in ordination values with Monte Carlo analysis. The model is considered valid if the difference is below 5%. The difference in the MDS analysis result index with the small Monte Carlo analysis result index indicates that in the analysis

process the occurrence of scoring errors is relatively small, the variation in scoring due to differences of opinion is relatively small, the repeated analysis process is stable, and data entry errors or missing data can be avoided (Pithcher & Preikshot, 2001). This means that the validity of the MDS analysis used is good enough to assess the sustainability of the ecotourism-based seagrass ecosystem management plan on Maitara Island.

The accuracy value of MDS is reflected in the number of S-stress values calculated based on the stress value (S) and the coefficient of determination (R^2). A lower stress value indicates a condition of suitability and a high S value indicates the opposite. Through the Rap-Sbe approach, a good model can be obtained from a stress value that is smaller or less than 0.25 (S <0.25) and a good R^2 value approaching 1.0 (Kavanagh and Pitcher, 2004). The results of the Rap-Sbe analysis validation show that the coefficient of determination (R2) obtained ranges from 0.95-0.96 or close to 1 (Table 4). This indicates that the sustainability index estimation model is good and adequate. The stress value ranges from 13-14% or less than 25% (Table 3). This means that the accuracy of the point configuration or goodness of fit model built for the sustainability criteria can present a good model (Pithcher and Preikshot, 2001). The stress value range of 0-2.50 is a perfect suitability condition (Handayan *et al.,* 2020). Based on the stress and R2 values, it indicates that in the case studied, the addition of attributes is not necessary and the aspects are analyzed accurately approaching the actual conditions. The attributes used can explain the sustainability conditions of the ecotourism-based seagrass ecosystem and the results can be used for further analysis.

Conclusion

The sustainability status of ecotourism-based seagrass ecosystem management based on the ecological dimension is quite sustainable while the economic and social dimensions are less sustainable. The sustainability policy strategy for ecotourism-based seagrass ecosystem management on Maitara Island, Tidore Islands City, namely education about seagrass ecosystems to the community, ecotourism-based seagrass ecosystem management, increasing seagrass rehabilitation programs, maximum limits on seagrass ecotourism carrying capacity, training for developing ecosystem-based seagrass ecotourism managers, increasing job opportunities and business opportunities, legality of seagrass areas as conservation areas in the tourism utilization zone category and strengthening laws and institutions.

Table 3. Sensitive attributes of ecotourism-based seagrass ecosystem management in Maitara Island.

No.	Dimension		Sensitive attributes	RMS (%)
1	Ecology	1	Types of seagrass fauna	6.63
		2	Seagrass density	6.24
		3	Seagrass depth	6.10
		4	Seagrass types	5.78
		5	Suitability of seagrass ecotourism area designation	3.85
		6	Seagrass cover	3.61
2	Economy	7	Seagrass ecosystem management plan	8.50
		8	Government budget for seagrass management	4.92
		9	Average community income from utilizing seagrass ecosystems	4.69
3	Social	10	Community education level	5.22
		11	Destruction of seagrass beds by the community	4.75
		12	Community knowledge about seagrass beds	4.64
		13	Social impacts of the existence of seagrass beds on the community	4.57

Table 4. Differences in sustainability index values of ecotourism-based seagrass ecosystem management on Maitara Island in Rap-Sbe analysis and Monte Carlo analysis.

Dimension	MDS (%)	Monte Carlo (%)	Difference (%)
Ecology	66.86	65.65	1.21
Economy	26.37	27.95	-1.58
Social	26.02	28.25	-2.23
Multidimensinsion	39.78	40.41	-0.63

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