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Preliminary study on suitability and bearing capacity of snorkeling and diving tourism in the regional marine conservatory biluhu, Gorontalo province, Indonesia

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Abstract

This study aimed to analyze the suitability and bearing capacity of snorkeling and diving tourism in the regional marine conservatory in East Biluhu. The research was using survey and observation methods. The research location was divided into four observation stations. Analysis of suitability and bearing capacity was done by using the table method. The results of the study show that stations 1-3 are suitable for snorkeling tourism while station 4 is not suitable. For diving tourism, stations 1, 3, and 4 are categorized as suitable-very suitable, and station 2 is not suitable. The bearing capacity analysis shows that each station has a different capacity. This study shows that based on the suitability of the bearing capacity of snorkeling and diving tourism, the conservation area has the potential to be developed as a tourist area.

Keywords: Diving Tourism; Snorkeling Tourism; Suitability for Tourism; Bearing for Tourism

1. Introduction

Marine conservation areas are a policy instrument that is expected to be effective for conservation in marine waters. In particular, areas of high biodiversity such as coral reefs, seagrasses, and fish species which are under ecological threat. Marine conservation areas are areas designated by regulations to maintain sustainable biodiversity, resources, and ecosystem services. (Ochieng, et al., 2024).

One of the biotas found in the conservation areas is coral reefs. Coral reefs are unique ecosystems found along tropical coasts and cover approximately 0.176% of the ocean surface (Crossland, et al., 1991). Coral reef ecosystems are biologically diverse. This ecosystem plays an important ecological role, especially in the deep sea, because the productivity of the coral reef ecosystem contributes to the life of the biota in the deep sea. In addition, coral reef ecosystems provide a wealth of environmental services and resources. For example, food provisioning services, cultural services, natural protection, natural regulation, and marine tourism (Moberg & Folke, 1999). It is estimated that as many as 100 countries depend on protein sources derived from biota associated with coral reefs (Jennings & Polunin, 1996).

Crossland, et al, (1991) and Hasim (2021) stated several important roles of coral reefs, namely; (1) as a habitat for several organisms such as the phylum Mollusca, Colenterata, Annelida and several species of fish; (2) wave protection, especially coastal areas to reduce aberration; (3) a place to find food and lay eggs and nurture several species of fish that are economically important; (4) serves as a mitigation of climate change disasters through the absorption of carbon dioxide in the process of photosynthesis by zooxanthellae; (5) provides energy needs for the survival of deep-sea biota; (6) tourist attractions including diving and snorkeling, which are in high demand by tourists. Based on these important roles, the coral reef ecosystem is very strategic in its existence, so it must be preserved.

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Coral reef ecosystem services such as food provisioning, carbon sequestration, and ecotourism can be managed at the local level by involving local fishers (Cruz-Trinidad et al., 2014). The involvement of local communities, including fishers, in marine tourism management is considered important to protect coral reef ecosystems from anthropogenic threats so that their ecosystem services remain sustainable (Ochieng et al., 2024). Thus, the coral reef ecosystem will be healthy and have a high level of suitability and bearing capacity.

The Gorontalo Provincial Government has reserved 75,823.83 ha of marine conservation areas in Gorontalo Province through Regional Regulation No. 4/2018 on RZWP-3-K. One of the regional marine protected areas (MPA) included in Regional Regulation No. 4/2018 is the East Biluhu MPA. East Biluhu Village is one of the villages in the Tomini Bay area, which is more precisely located in Biluhu Sub-district, Gorontalo Regency. The majority of the population's livelihood is based on agriculture and fishing.

At present, East Biluhu Village is used as a beach and marine tourism area. This village is one of the ecotourism sectors that can be developed because it is a source of income for the Gorontalo Regency and the surrounding community. Mass ecotourism provides a large space for the intensive entry of capital into a tourist area and thus becomes a driving factor for the development of ecotourism in the restricted use zone of the East Biluhu MPA. However, there is no supporting information on the suitability and bearing capacity of snorkeling and diving tourism in the waters of East Biluhu as a tourism development zone. The purpose of this study was to analyze the level of suitability and bearing capacity of snorkeling and diving tourism in the East Biluhu coastal protected area.

2. Material and method

This research was conducted at East Biluhu MPA, Biluhu District, Gorontalo Regency, Gorontalo Province for three months from August to October 2023. The research site is shown in Figure 1.

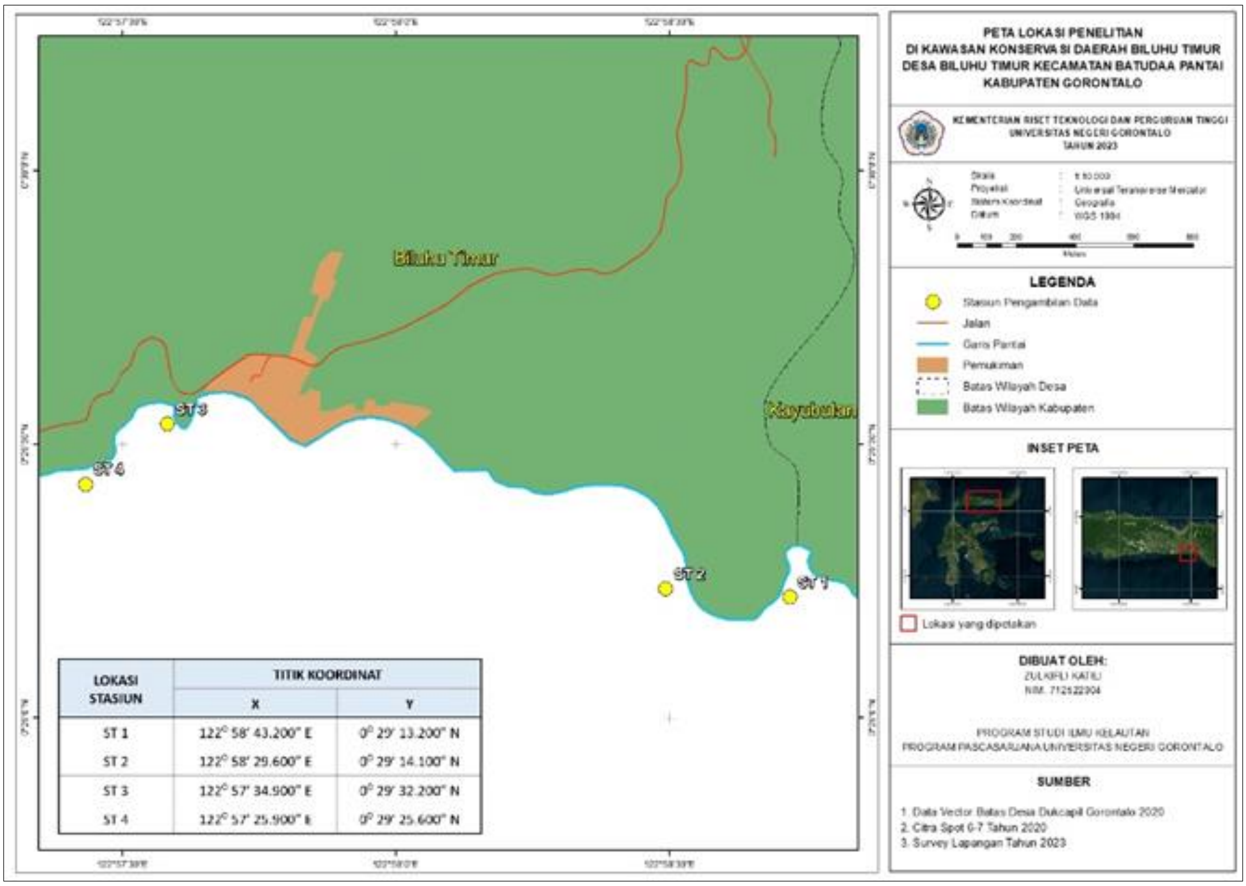

Figure 1 Research site in the East Biluhu Regional Marine Conservatory

2.1. Data Collection Method

Data collection was conducted in coastal and aquatic areas using purposive sampling, which is based on the representation of the area from direct observation in the field through an initial survey. In addition, qualitative observations were made by visually interpreting Google satellite images of the East Biluhu MPA to obtain an overview of the exact observation location. The number of stations in this study was 4. The four stations were chosen because they represent dive sites in East Biluhu. Two stations represent locations far from residential areas and the other two stations represent locations close to residential areas. The coordinates of the four stations are as follows:

- Station 1 with coordinates 00°29'13.2" N and 122°58'43.2" E.
- Station 2 with coordinates 00°29'14.1" N and 122°58'29.6" E.
- Station 3 with coordinates 00°29'32.2" N and 122°57'34.9" E.
- Station 4 with coordinates 00°29'25.6" N and 122°57'25.9" E.

2.1.1. Coral reef condition

Coral reef data were collected using the Line Intercept Transect (LIT) method at 3 (three) observation stations with 2 (two) depths, namely 3 m and 10 m depth. A depth of 3 m represents shallow water (snorkeling ecotourism activities) and a depth of 10 m represents deep water (diving tourism activities). The length of the tape transect line (roll) was 50 m (English et al., 1997). This survey was conducted to obtain data on the condition of coral reefs in terms of the percentage of live coral cover and to record the life forms or growth forms of coral species found at the site.

2.1.2. Abundance of reef fish

Observations of the number of species and abundance of reef fish were made using the visual census method, which identifies reef fish by observation. Observations of the number of species and abundance of reef fish using the visual census method (English et al., 1997), which is technically done using the belt transect method. Fish and coral data were collected sequentially. Fish data were collected a few minutes after coral data were completed to allow the fish to become accustomed to the presence of the diver/observer. Thus, coral fish will not hide, move away or even be attracted by the presence of divers. Fish abundance for each species was counted on a 50 m long transect with an observation distance limit of 2.5 m to the left and right of the transect (English et al., 1997). Based on the size of the observation area (5 m x 50 m), reef fish abundance was expressed in units of ind/250m2. As with corals, data on fish species number and abundance were documented using an underwater camera. This was also done to facilitate the calculation and identification of reef fish species. Reef fish species identification was done both directly in the field (for fish species recognized during observation) and in the laboratory using Kuiter and Tonozuka (2001) and the fish base website. Equipment used included SCUBA gear, underwater camera, underwater recorder, underwater watch, and GPS.

2.2. The speed of the current

Current velocities were measured directly using a drift pool (current kite). Current velocity is a physical factor that directly affects the shape of coral growth. Strong currents that flow regularly will be able to change the shape of coral growth more towards the form of encrusting growth (Supriharyono, 2000). In addition, the speed of the current is also related to the comfort and safety of tourists in conducting snorkeling and diving activities (Yulianda, 2019).

2.2.1. Coral Cover Analysis

The condition of the coral reefs in the study area was calculated by analyzing the percentage of coral cover based on UNEP (1993).

$$N_i = \frac{L_i}{L} \times 100$$

Description:
N_i = Cover percentage (%)
L_i = Total length of the category (cm)
L = Length of the line transect (5,000 cm)

The live coral cover condition data obtained from the equation is then categorized based on the standard criteria for coral reef damage (Minister of Environment Decree No. 04 of 2004).

Table 1 Coral Reef Damage Standard Criteria

Percentage (%)	**Damage Criteria**
0 - 24,9	Broken
25 - 49,9	Medium
50 - 74,9	Good
75 - 100	Very good

2.2.2. Reef Fish Analysis

The abundance of reef fish at the study site was analyzed following Odum's (1993) formulation:

$$N = \Sigma \frac{n_i}{A}$$

Description:
N = Reef fish abundance
n_i = Number of individuals of the i-th species
A = Area of data collection

2.2.3. Ecotourism Area Suitability Analysis

The suitability of the area for ecotourism uses parameters and criteria formulated by Yulianda (2019) as follows:

$$IKW = \sum_{i=1}^{n} (B_i \times S_i)$$

Description:
IKW = Tourism Suitability Index
n = Number of fit parameters
B_i = Weight of i-th parameter
S_i = i-th parameter score

The ecotourism suitability index is carried out in three stages, namely: (1) the stage of preparing a suitability matrix, (2) the stage of weighting each parameter limiting factor, and (3) the stage of giving the parameter/criteria value of a designation.

Table 2 Snorkeling Category Tourism Suitability Matrix

No.	**Parameters**	**Weight**	**Score Category 3**	**Score Category 2**	**Score Category 1**	**Score Category 0**
1.	Coral community cover (%)	0.375	> 75	> 50-75	25-50	< 25
2.	Lifeform type	0.145	> 12	> 7-12	4-7	< 4
3.	Types of Reef Fish	0.140	> 50	30-50	10-,30	< 10
4.	Water Brightness (%)	0.100	100	80-<100	20-<80	< 20
5.	Coral Reef Depth	0.100	1-3	>3-6	>6-10	>10; <1
6.	Current Speed	0.070	0-15	>15-30	>30-50	>50
7.	Coral flat bed width (m)	0.070	>500	>100-500	20-100	< 20

Table 3 Diving Category Tourism Suitability Matrix

No.	Parameters	Weight	Score Category 3	Score Category 2	Score Category 1	Score Category 0
1.	Coral community cover (%)	0.375	> 75	> 50-75	25-50	< 25
2.	Water Brightness (%)	0.150	>80	50-80	20-<50	< 20
3.	Coral Reef Depth	0.150	6-15	>15-20;3-<6	>20-30	>30; <3
4.	Lifeform Type	0.135	>12	>7-12	4-7	< 4
5.	Reef fish species	0.120	>100	50-100	20-<50	<20
6.	Current Speed	0.070	0-15	>15-30	>30-50	>50

Based on Tables 2 and 3, the tourism suitability criteria for the snorkeling and diving categories are as listed in Table 4.

Table 4 Tourism Suitability Criteria

IKW	Criteria
IKW ≥ 2.5	Very suitable
2.0 ≤ IKW < 2.5	As per
1.0 ≤ IKW < 2.0	Not suitable
IKW < 1	Very Unsuitable

2.2.4. Analysis of Tourism Area Support

The bearing capacity of the area for ecotourism uses parameters and criteria formulated by Yulianda (2019) as follows:

$$DDK = K \times \frac{L_p}{L_t} \times \frac{W_t}{W_p}$$

Description:
DDK = Area Support Capacity (people)
K = Ecological Potential of visitors per unit area (people)
L_p = Area (m2) or length (m) that can be utilized
L_t = Area unit for a specific category (m^2 or m)
W_t = Time provided by the area for tourist activities in 1 day (hours)
W_p = Time spent by visitors for each specific activity (hours)

3. Results and discussion

3.1. Suitability of Snorkeling Tourism

The calculation of the suitability of snorkeling tourism in the limited use zone of the East Biluhu MPA uses seven parameter indicators, namely coral community cover, life form type, reef fish species, water brightness, coral reef depth, current speed, and coral bed width (Yulianda, 2019). The research results of the Tourism Suitability Index (IKW) analysis at Biluhu Timur MPA can be seen in Table 5.

The calculation of the IKW of the four observation stations in the East Biluhu MPA shows that Stations I and II get an IKW value of 2.51 - 2.65 which is categorized as very suitable, station III gets an IKW value of 2.4 which is categorized as suitable, while Station IV with an IKW value of 1.99 is categorized as unsuitable for snorkeling tourism. The suitability parameters that provide a large role of the four research stations are coral reef cover, types of life forms, and types of reef fish, which are in accordance with the scoring and weighting table of the Snorkeling Tourism Suitability Index (IKW) Yulianda (2019) these three parameters have the highest weight in determining the suitability of snorkeling tourism locations. Station IV has the lowest value of coral reef cover, type of life form, and type of reef fish.

Table 5 Snorkeling IKW Value of Each Research Station

Location	Extensive	IKW Value	Category
Station I	1200	2.65	Very suitable
Station II	1900	2.51	Very suitable
Station III	1600	2.40	Suitable
Station IV	1700	1.99	Not suitable

The next suitability parameter that plays a role in determining IKW is current speed, where station IV has the highest current speed with a value of 19.37 cm/s. Yulianda (2019) states that good currents for snorkeling and diving tourism activities range from 0 - <15 cm/s. Johan *et al.* (2011) stated that a relatively weak current speed is an ideal requirement for snorkeling category marine tourism because it is related to the comfort and safety of tourists.

3.2. Diving Tourism Suitability

The research results of the Tourism Suitability Index (IKW) analysis for diving can be seen in Table 6. Based on table 6, from four observation stations, it shows that station III gets the highest IKW value of 2.74 which is categorized as very suitable for diving tourism. Stations I and IV get IKW values of 2.4 - 2.45 which are categorized as suitable, while station II gets the lowest IKW value of 1.72 which is categorized as not suitable for diving tourism. Station II gets the lowest IKW value compared to the other 3 stations because it has the lowest value of coral reef community cover, life form types, and reef fish species.

Table 6 IKW Diving Value of Each Research Station

Location	Extensive	IKW Value	Category
Station I	2200	2,45	Suitable
Station II	2800	1,72	Not suitable
Station III	2000	2,74	Very suitable
Station IV	2600	2,40	Suitable

3.3. Bearing Capacity of the Area

Bearing capacity of the area (DDK) is a concept based on an environmental approach and is an important part of natural resource management studies. Bearing capacity is defined as the ability of nature to tolerate human activities, Yulianda (2019). Of the four stations observed in the limited-use zone of the eastern Biluhu MPA, the DDK value for snorkeling and diving activities was obtained.

Table 7 DDK Snorkeling Value of Each Observation Station

Station	L_p (M2)	L_t (M2)	W_t (Hours)	W_p (Hours)	DDK Person/Day
I	1200	500	6	3	5
II	1900	500	6	3	8
III	1600	500	6	3	6
IV	1700	500	6	3	7

Based on the calculation of the DDK value, data for snorkeling activities in the limited use zone of the East Biluhu MPA at station I obtained the DDK value for snorkeling tourism is 5 people/day, Station II DDK value for snorkeling tourism is 8 people/day, Station III DDK value for snorkeling tourism is 6 people / day and station IV for snorkeling tourism is 7 people/day.

Table 8 DDK Diving Value of Each Observation Station

Station	L_p (M2)	L_t (M2)	W_t (Hours)	W_p (Hours)	DDK Person/Day
I	2200	2000	8	2	9
II	2800	2000	8	2	11
III	2000	2000	8	2	8
IV	2600	2000	8	2	10

Based on the calculation of the DDK value for diving activities in the limited utilization zone of the East Biluhu MPA, the data for diving activities at the station I DDK value is 9 people/day, station II DDK value is 11 people/day, station III DDK value is 8 people/day, station IV DDK value is 10 people/day.

Calculation of the bearing capacity of marine ecotourism areas based on the characteristics of resources and their designation. Yulianda (2019) states that the bearing capacity of diving and snorkeling is determined based on the area of coral reefs that can be utilized, the ecological potential of visitors per unit area used for activities and whether nature is still able to tolerate the presence of visitors and the predicted time needed for each type of activity. Bengen (2012) states that bearing capacity is the level of sustainable utilization of natural resources or ecosystems without causing damage to natural resources and the environment.

4. Conclusion

Based on the results of the study, the following conclusions can be drawn:

- The level of suitability of tourist areas in the East Biluhu MPA for snorkeling activities at stations I and II is categorized as very suitable, station III is categorized as suitable, and station IV is categorized as not suitable. While diving activity at station III is categorized as very suitable, stations I and IV are categorized as suitable, and station II is categorized as unsuitable.
- The bearing capacity of the area for snorkeling tourism in East Biluhu MPA at station I is 5 people/day, station II is 8 people/day, station III is 6 people/day, and station IV is 7 people/day. For diving activities, at station I amounted to 9 people/day, station II amounted to 11 people/day, station III amounted to 8 people/day, and station IV amounted to 10 people/day.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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