

## **Study of coral reef for marine ecotourism development based on region suitability and carrying capacity in Marsegu Island Nature Tourism Park, Maluku, Indonesia**

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**Abstract.** Lelloltery H, Pudyatmoko S, Fandelli C, Baiquni M. 2018. Study of coral reef for marine ecotourism development based on region suitability and carrying capacity in Marsegu Island Nature Tourism Park, Maluku, Indonesia. *Biodiversitas* 19: 1089-1096. The objectives of the research were to identify the potential of marine natural resources as the object and attraction of marine ecotourism, and to compile the development plan at Marsegu Island Nature Tourism Park (NTP) based on the Tourism Suitability Index (TSI) and carrying capacity. Data collection included coral reef and fish type using the Line Intercept Transect (LIT) method. Data were analyzed using the tourism suitability index and analysis of physical carrying capacity of the area. The results showed the potential of marine resources covering the coral reefs including 45 species within 23 genera from 14 families with 12 coral lifeforms. A high diversity of reef fish was found, documenting 129 species of fish within 60 genera from 22 families. The analysis result of the tourism suitability index (TSI) in the snorkeling category was 74.79% with a carrying capacity of 4,092 person(s)/day and the TSI of diving was 67.32% with a physical carrying capacity of 1,855 person(s)/day. The analysis showed that the area around Marsegu Island NTP is "suitable" for ecotourism activities and does not exceed the carrying capacity of the area. The strategy for marine ecotourism management needs to be completed, including elements such as determining the number of tourists that can be supported per day (based on limiting the number of divers/snorkelers per day), implementing boat moorings so coral is not damaged by anchors, making sure tourism operators brief divers/snorkelers not to touch, stand on or break the coral, and ensuring the tour operator is the organization responsible for the continuous monitoring of marine ecotourism activities and protection of dive sites.

**Keywords:** Carrying capacity, coral reefs, marine ecotourism, nature tourism park, reef fish, tourist suitability index

### **INTRODUCTION**

Marsegu Island Nature Tourism Park is located in West Seram District of Maluku Province with an area of 9,023 Ha (NRCC 2010). This area is a Marine Conservation Area that has coastal resources in the form of coral reefs, coral fish, mangrove, seagrass and various other marine biotas. This area is located between Marsegu Island and Osi Island, and is surrounded by several small islands such as Buntal Island, Bird Island and Tatumba Island, all with beautiful and interesting sea-scapes. However, the potential of these marine resources is still under threat due to both natural and human factors. Human factors are most associated with fishing activities, which are being conducted in an environmentally unsustainable manner by the surrounding communities. This condition is common in almost all coastal communities because the majority of coastal communities have a high dependence on and consumption of the surrounding natural resources (Dahuri 2003). To minimize the impact of coastal resource damage, one of the preventive measures is through the utilization of environmental services based on marine ecotourism. This is supported by the potential for diversity in the natural resources of small islands that are abundant and ideal for

development as ecotourism destinations (Baiquni 2013). Walters and Samways (2001), asserted that marine ecotourism contributes to the protection of coastal and marine ecosystems and has an impact in supporting the economy of local communities. In line with this, research conducted by Honey (2006) and Rhormens et al. (2017), asserted that ecotourism has the potential to serve as a means of education in enhancing the conservation action of sustainable biodiversity and cultural conservation that can improve the livelihoods of surrounding communities.

Currently, Marsegu Island NTP has become one of the marine ecotourism destinations in Maluku. This is indicated by the presence of domestic and foreign tourists in a limited quantity and with activities more focused on enjoying the natural scenery, coastal nature tourism, and snorkeling and diving (Tourism Office of Maluku 2015). However, Marsegu Island NTP is not yet under optimal management as a marine ecotourism destination. □

This is due to the lack of supporting facilities in the form of human resources and government support. Additionally, there is yet to be any comprehensive management of the area at potential points where resources are concentrated. The arrangement of areas is important so that it becomes a guide for managers and tourists to

perform various activities. To determine the best plan, we need to further study the suitability of the region and its carrying capacity as the foundation of policy development for sustainable marine ecotourism.

The objectives of this research are (i) to identify the potential of marine resources in the form of coral reefs and reef fish as the object and attraction of marine ecotourism, and (ii) Prepare the design of marine ecotourism development at Marsegu Island NTP based on the tourism suitability index and the carrying capacity of the area.

## MATERIALS AND METHODS

### Location and time of research

This research was conducted in an area of Marsegu Island Nature Tourism Park (NTP), Western Seram District, Maluku, Indonesia, specifically Marsegu Islands for six months from June to December 2016. Location map of the study sample area is presented in Figure 1.

### Tools and materials

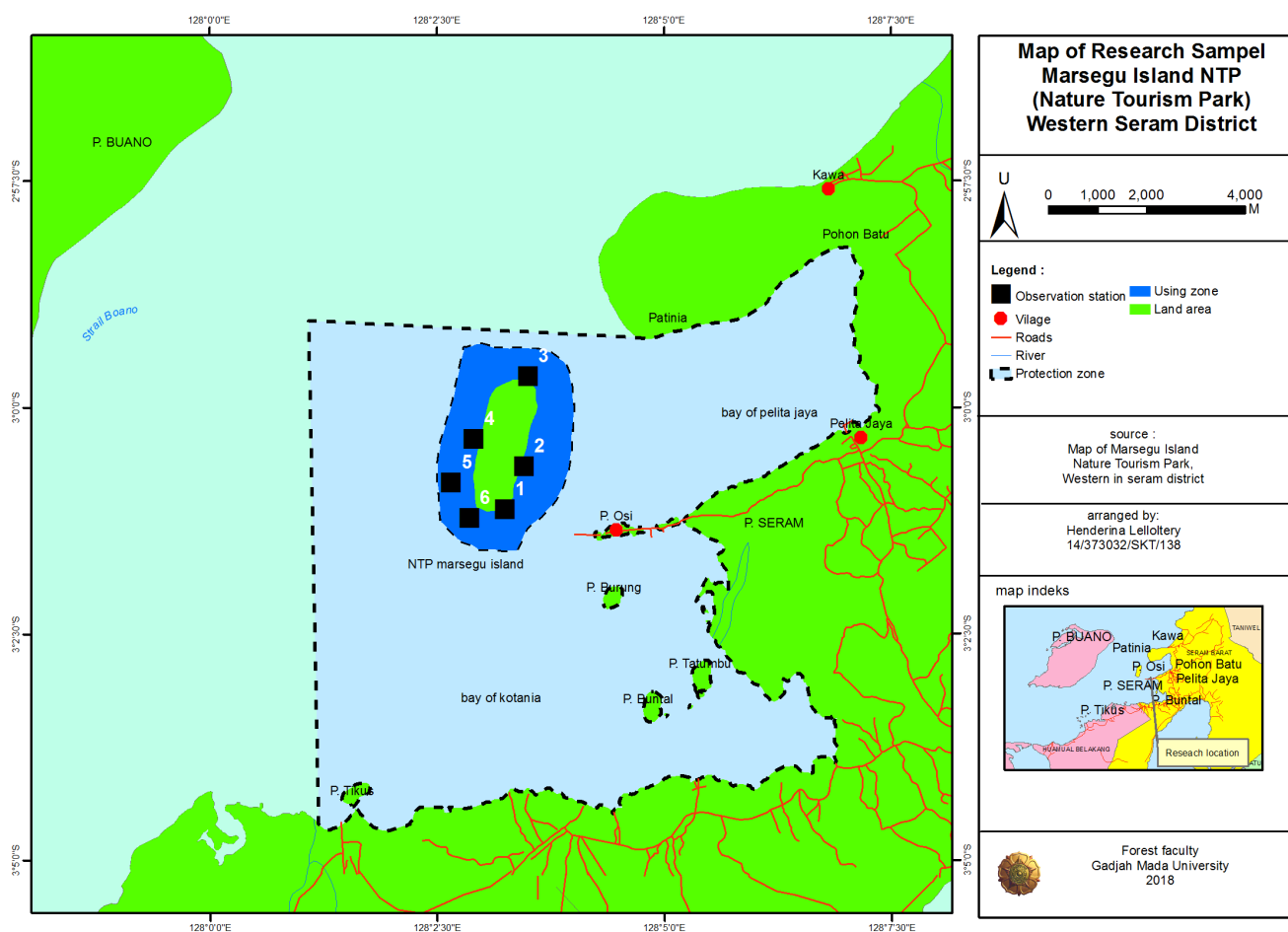
Tools and materials used in this study are Map of Marsegu Island NTP area, GPS, Coral reef and coral fish manuals, SCUBA equipment, meter roll, underwater stationery (paper, pencil and baseboard), underwater

camera, current meter, thermometer, refractometer, Secchi disk, and aquatic resources including coral reefs and coral fish.

### Data collections technique

The data was collected in the form of primary and secondary data. Primary data was obtained directly from the location through observation, survey and interview. The secondary data was obtained from literature study and related institutions. □

Coral reefs and fish data collection was conducted around Marsegu Island, with consideration that the area was a utilization zone of Marsegu Island NTP. To get coral reefs data and coral reef ecosystem components a line intercept transect (LIT) method was utilized at 6 observation stations. The shape of coral growth (lifeform) and percentage of coral cover (English et al. 1997) was determined. The observation stations were determined prior to field observations by looking at the width of the reef using satellite images. The observation stations were located around Marsegu Island and consisted of 50 meters long transects, with the distance between stations varying along the boundary line of the coral reef and sea level. Coral observations recorded all forms of coral growth and coral species.



**Figure 1.** Study site in Marsegu Island NTP, Western Seram District, Maluku, Indonesia

Coral fish data were collected using the Underwater Visual Census (UVC) method (English et al. 1997). The UVC method is done simultaneously with the LIT method, and consisted of a transect length of 50 meters, and a transect width of 2.5 meters on the left side and on the right side of the transect. During observations, the total, types, genus and family of the fish was recorded.

Measurements of environmental variables were carried out at each observation station including waters transparency, current velocity, temperature, and salinity. The coral flat width was measured based on Landsat ETM 7+ 2006. The result of environmental parameter measurements was then included in the maritime ecotourism suitability matrix to determine the value of the snorkeling tour suitability index based on Yulianda (2007).

### Data analysis

#### Analysis of coral reef and coral fish

Data on coral reef closure conditions were analyzed using Lifeform analysis of the following equation: (English et al. 1997):

$$\text{Percentage of coral cover} = \frac{\text{Length of each ecology}}{\text{Transect length}} \times 100 \%$$

After the percentage of coral cover was calculated, the coral reef condition was determined based on Gomez and Yap (1988) criteria of the Coral Reef Damage Standard, which consists of four categories: excellent (75-100%), good (50-74.9%), medium (25-49.9%), bad (0-24.9%).

Reef fish data from observations was classified as fish diversity data. Fish diversity data were then analyzed descriptively to determine the species, the number of

species, the family and the classification of the fish species based on the fish species protection status (IUCN red list).

#### Analysis of tourism suitability matrix

Analysis of the tourism suitability matrix for snorkeling and diving utilized the manual of tour suitability index measurements developed by Yulianda (2007).

The suitability of snorkeling tours utilized 7 parameters and was grouped into 4 categories (Table 1). The suitability of diving tours utilized 6 parameters and was grouped into 4 categories (Table 2).

Suitability analysis was conducted to determine the suitability of the area for the development of tourism. This was done to determine the ability of the area to support the various activities that would be undertaken in the area. The parameters used for the suitability of marine tourism by Yulianda (2007) were as follows:

$$TSI = \sum \left[ \frac{N_i}{N_{maks}} \right] \times 100 \%$$

Where:

TSI : Tourism suitability index

N<sub>i</sub> : The-i parameter value (weight x score)

N<sub>max</sub> : The maximum value of a category (snorkeling and diving)

The suitability class for diving and snorkeling were as follows:

S1 : very suitable, by TSI 83-100%;

S2 : suitable, by TSI 50-<83%;

S3 : conditional suitable, by TSI 17-<50% and

N : not suitable, by TSI <17%.

**Table 1.** Matrix of land suitability for snorkeling tourism (Yulianda 2007)

Parameter	Weight	Category (S1)	Score	Category (S2)	Score	Category (S3)	Score	Category (N)	Score
Water transparency (m)	5	100	3	80-<100	2	20-< 50	1	<20	0
Coral cover (%)	5	>75	3	>50-75	2	25-50	1	<25	0
Lifeform number	5	>12	3	<7-12	2	4-7	1	<4	0
Coral fish species	3	>50	3	30-50	2	10-< 30	1	<10	0
Current velocity (cm/sec.)	1	0-15	3	>15-30	2	>30-50	1	>50	0
Reef depth (m)	1	1-3	3	>3-6	2	>6-10	1	>10-<1	0
Reef width (m)	1	>500	3	>100-500	2	20-100	1	<20	0

Note: Number N Max = 57; N = score x weight

**Table 2.** Matrix of suitability for diving tourism (Yulianda 2007)

Parameter	Weight	Category (S1)	Score	Category (S2)	Score	Category (S3)	Score	Category (N)	Score
Water transparency (m)	5	>80	3	50-80	2	20-<50	1	<20	0
Coral cover (%)	5	>75	3	>50-75	2	25-50	1	<25	0
Lifeform number	3	>12	3	<7-12	2	4-7	1	<4	0
Coral fish species	3	>100	3	50-100	2	20-50	1	<20	0
Current velocity (cm/sec.)	1	6-15	3	15-20	2	>20-30	1	>30	0
Reef depth (m)	1	0-15	3	15-30	2	>30-50	1	>50	0

Note: Number N Max = 57; N = score x weight

### Analysis of area carrying capacity

The physical carrying capacity can be analyzed with the equation (Douglas 1975):

$$PCC = A \times \frac{V}{a} \times Rf$$

Where:

PCC : Physical carrying capacity (person/m<sup>2</sup>/day)

A : Area used for tourism (m<sup>2</sup>)

V / a : Number of visitors / m<sup>2</sup> (person/m<sup>2</sup>)

Rf : Rotation factor (magnitude Rf : duration of opening time for area ecotourism/time of average visit time) visits (Fandeli, 2002)

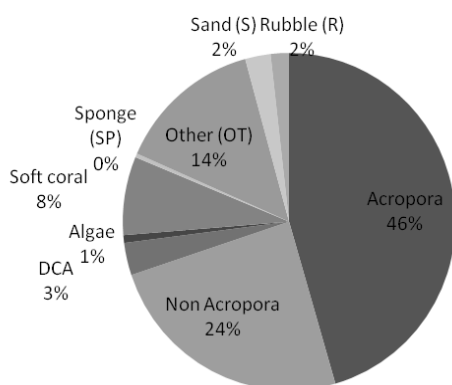
## RESULTS AND DISCUSSION

### Potential of marine resources in Marsegu Island Nature Tourism Park

#### Condition and potential of coral reefs

Based on the data of Citra analysis, the extent of coral reefs in Marsegu Island NTP was 1,557.68 Ha while the coral reef area within the utilization zone was 432.52 Ha. The observation of coral reefs in the utilization zone around Marsegu Island found 45 species belonging to 23 genera and 14 families. Coral cover was found in the form of hard coral covering *Acropora* and non-*Acropora*, dead coral algae, algae, sponge, soft coral, other biotas (OT) and abiotic (sand and coral fracture). □

The species of coral reefs and the percentage of benthic component coverings in the waters around Marsegu Island are presented in Figure 2. Based on Figure 2, hard coral cover consisting of *Acropora* and non-*Acropora* occupied the highest percentage at 69.86% and was categorized as "Good". The results of this study are comparable with Sitanala Research (2016) in the Kasa Island Marine Nature Tourism Park which showed that the coral cover percentage of 77.56% was categorized as "Good". This is comparable to the research on Marsegu Island because these two islands are still in a similar ecological region.



**Figure 2.** Benthic covering component at Marsegu Island Nature Tourism Park, Western Seram District, Maluku, Indonesia

Live reefs dominated coral benthic cover, where *Acropora* was widely dispersed, occupied large areas spread over 2 to 20 meter deep, and had various colors. *Acropora* live corals with branched growth forms (ACB) occupy large areas and have attractive colors. Tabulate *Acropora* (ACT) had large colonies and non-*Acropora* species like Coral Submassive (CS) live on the reef wall and have attractive colors like red which give a beautiful impression. Based on the assessment of live coral cover, it was found that the condition and health of the coral ecosystem were in the "Good" category. Overall a total number of 12 lifeforms were found.

### Potential and condition reef fish

Results of observation of the species of fish found 146 species, 64 genera, and 21 families. When classified based on the function and role of the fish (major, target, or indicator), 81 species of major fish were found (55.48%), 49 species of target fish were found (33.56%) and 16 species of indicator fish were found (10.95%). Species of major fish (ornamental fish) were generally dominated by the family Pomacentridae, the target fish (fish consumption) was dominated by the Caesionidae, Lutjanidae, and Serranidae families. Indicator fish generally have a striking and attractive shape and color, and become an attraction for tourists. The species of indicator fish found in this aquatic ecosystem indicated that the coral reefs are in good condition. The most common indicator fish came from the Chaetodontidae family, such as *Chaetodon* sp. and *H. varius*. A species of Napoleon fish (*C. undulatus*) is a protected species due to its threatened status (IUCN), and was found within the Marsegu Island NTP. The existence of this increasingly scarce fish, can be an attraction for tourists who want to see it directly in its habitat. □

### Marine conditions around Marsegu Island Nature Tourism Park

The physical and chemical water conditions around Marsegu Island were normal and the average velocity was 0.16 m/s. Water temperature averaged 28,66°C. This temperature was very good for tropical marine organisms and suitable for tourism activity. Nontji (2005) asserted that Indonesian sea surface temperatures generally range from 26-29°C and affect the growth of marine biological resources such as coral reefs and fish. The waters around Marsegu Island was within that temperature range.

Water transparency is closely related to marine ecotourism activities as it relates to the convenience of snorkeling and diving activities for tourists. The average water transparency is 12 meters. According to the Decree of the Minister of Environment No. 51 of 2004 on Water Quality Standard, the water transparency for marine tourism is > 6 m. Thus the high water transparency around Marsegu Island can support marine tourism activities because visitors can enjoy a farther underwater viewing distance.

Salinity, or dissolved salt content in waters, is an environmental parameter that affects marine biological processes such as growth rate, quantity of food consumed, and survival of organisms. The results of salinity

measurements from the surface to a depth of 39 meters ranged from 34.00 to 34.15‰, averaging 34.10‰, which is very good for marine organisms. This is in accordance with the opinion of Bengen (2002), which stated that the salinity value is good for marine biota life ranged from 30 to 36‰. In general, the condition of waters around Marsegu Island is still in good condition and there is no pollution or visible garbage or waste from community activities in the waters, therefore it is suitable for marine tourism activities.

### Marine tourism suitability

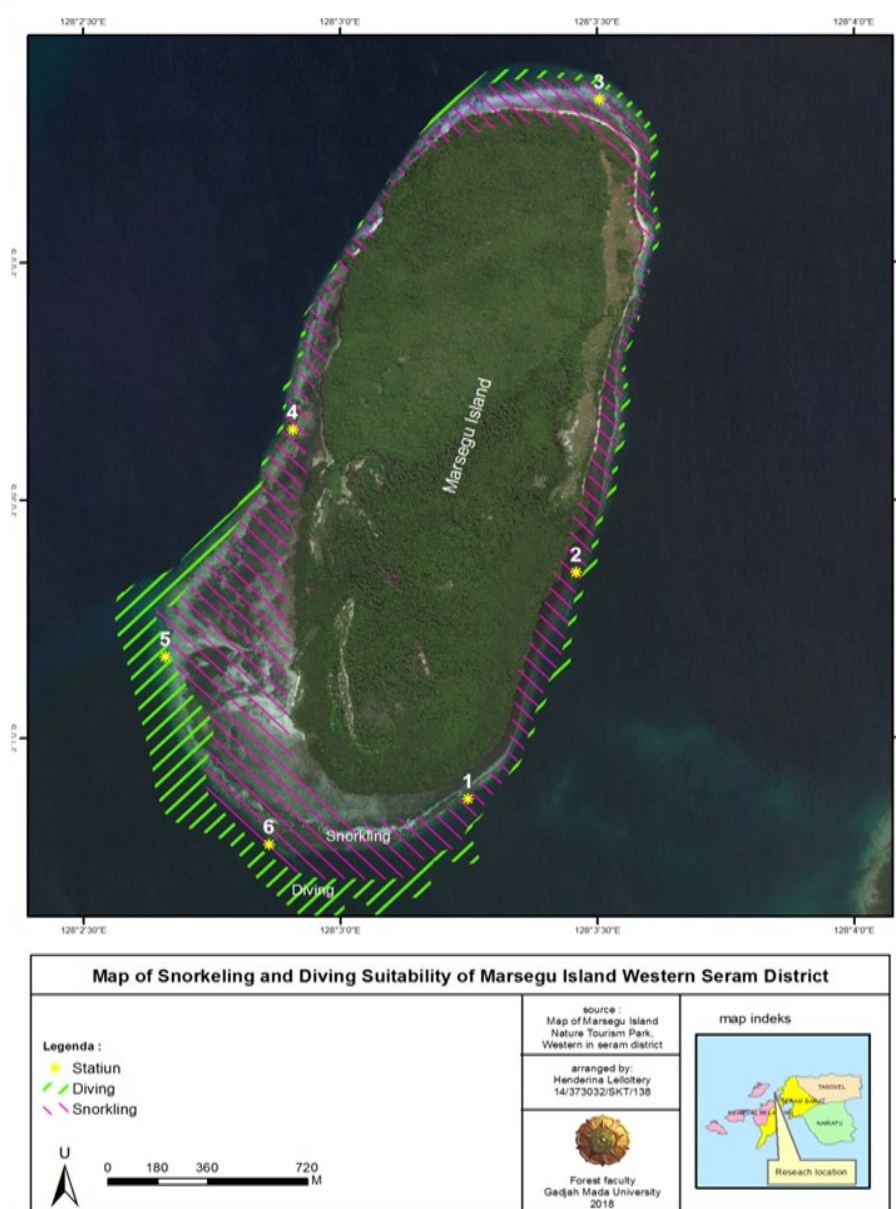
#### *Suitability of snorkeling and diving ecotourism*

The results of the snorkeling and diving ecotourism suitability analysis are presented in Table 3 and Table 4 and Figure 3. Based on Table 3, the tourism suitability

index (TSI) for the snorkeling category at all observation stations was "appropriate" with an average TSI value of 74.79% with an area of 102.3 ha. As seen in Table 4, the ecotourism suitability index for the category of "diving" at all observation stations was "appropriate" with an average TSI value of 67.32%, with a utilization area of 46.37 ha. Snorkeling and diving activity maps are shown in Figure 3.

#### *Physical carrying capacity*

The results showed that the area used for snorkeling activities was 1,023 ha with a carrying capacity of 4,092 people/ha. Diving activity used an area of 46.37 ha and has a carrying capacity of 1,855 persons/day. The calculation of the carrying capacity of the region is presented in Table 5. □



**Figure 3.** Map of snorkeling and diving activity location in Marsegu Island Nature Tourism Park, Western Seram District, Maluku, Indonesia

**Table 3.** Suitability of snorkeling ecotourism at each observation station of Marsegu Island Nature Tourism Park, Western Seram District, Maluku, Indonesia

Observation Station	Suitability Index (%)	Category Suitability	Description
1	73.68	S2	Area of acreage = 102.30 Ha
2	84.20	S2	
3	70.18	S2	
4	72.00	S2	
5	68.00	S2	
6	80.70	S2	
Average	74.79		

**Table 4.** Suitability of diving ecotourism at each observation station of Marsegu Island Nature Tourism Park, Western Seram District, Maluku, Indonesia

Observation Station	Suitability Index (%)	Category Suitability	Description
1	59.30	S2	Area of acreage = 46.37 Ha
2	75.90	S2	
3	66.70	S2	
4	72.20	S2	
5	55.60	S2	
6	74.10	S2	
Average	67.32		

**Table 5.** Carrying capacity of snorkeling and diving areas

Type of activity	Wide area (hectare)	Space needs (V/a) person/m <sup>2</sup>	Rf	PCC (person/day)
Snorkeling	1,023	1/500 = 0.002	2	4,092
Diving	46.37	1/1,000 = 0.001	4	1,855

## Discussion

### *Potential of coral reef and reef fish*

Generally, coral reefs in Indonesia are categorized coral reefs (fringing reef) i.e. coral reefs that exist along the coast, growing on the surface to the sea not more than 40 meters from shore (Djunaedi, 2011). Generally, coral reefs in the waters around Marsegu island include this type of fringing reef, from the shore to sea form reef flats (NRCC, 2010). The results of this research showed that live coral cover occupied the highest percentage (69.86%) of the reefs and was categorized as "good". The existence of coral species with various forms of growth such as branching *Acropora* (ACB), Tabulate *Acropora* (ACT), encrusting *Acropora* (ACE), submassive *Acropora* (ACS), and digitate *Acropora* (ACD) with attractive colors gives a very beautiful and attractive impression to tourists. These coral formations will be an attraction for tourists, especially those who will be snorkeling and diving. Burke et al. (2011) confirmed that coral reefs were vital to tourism

interests because their beauty was an important tourist attraction for water sports, such as scuba diving. Surpriharyono (2007) added that coral reefs have undoubted value because the mainstay of marine tourism was the beauty and uniqueness of the coral reefs. □

Brander et al. (2007), asserted many tourist activities in coastal areas depend on the quality of coral reefs. Marine tourism activities such as swimming, snorkeling, diving, and enjoying the coastal seascapes may be disrupted in the event of a decline in coral reefs (Principe et al., 2012). Based on the assessment of live coral cover, the condition and health of the coral ecosystem are in the "good" category. This is evident from the different coral shapes that form complex habitat structures for reef fish and invertebrates. The more complex the habitat, a more extensive range of species can be supported and the healthier the coral reefs will be. □

A total number of 12 coral lifeforms were identified. The abundance of lifeforms will provide an attraction for tourists. This is in line with Planthong et al. (2000) which stated that for marine tourism, a variation in type of coral lifeform is needed to maximize enjoyment by tourists.

Others abiotic coral cover components such as sand, dead coral covered Algae (DCA) and coral fragments/rubble (R) can still be found on the western side of Marsegu Island. This indicates that there were disruptions to the coral reefs. Disruptions to coral reefs generally come from community activities such as fishing. Disturbances were seen from coral fractures at two observation stations (station 4 and station 5). However, it can be seen that the damaged coral reefs have begun to recover, with the emergence of young coral colonies in several locations.

The main conservation measures within the living habitat and coral reef development are preventive actions against structured environmental damage (UNEP-WCMC, 2006). In addition, preventive action in the management of marine conservation areas needs to be protected against observation stations, especially in the development of marine ecotourism for diving and snorkeling activities. □

The existence of coral reefs with a high diversity of coral fish species, especially those with a variety of colors and forms, is of interest to marine tourism attraction. Napoleon fish (*C. undulates*) is a species of Endangered fish (Endangered/EN). Due to the low numbers of this species found in natural habitats, it is protected by the government and not widely traded (Appendix II). The existence of this increasingly scarce fish can be an attraction for tourists who want to see it directly in nature. Based on the potential of reef fish, it is necessary to protect the area through the limiting of fishing activities. Currently, the area is still open access for fishing by the surrounding community. Wabnitz et al. (2018), asserted that protection of an area can minimize the loss of endemic fish species in nature.

This requires intensive supervision through periodic monitoring, increasing the number of personnel, involving the surrounding community, and establishing regulations related to the utilization of the area. Walters and Samways



(2001) report that monitoring the impact of human activities on coral reefs was needed to protect coral reef ecosystems with a sustainable management approach. Rhormens et al. (2017), asserted that continuous environmental monitoring between partnerships and stakeholders is essential in the management of marine ecotourism. □

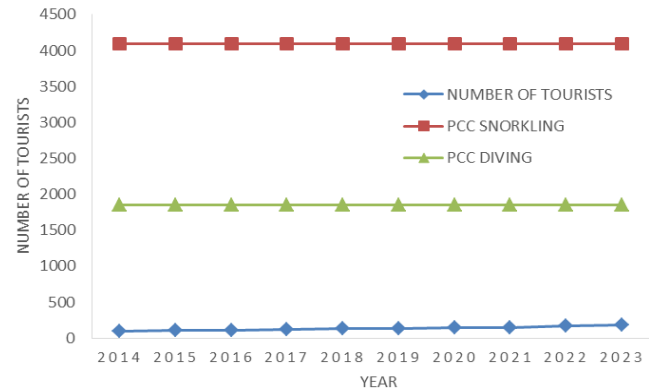
#### *Development of marine ecotourism based on suitability of tourism and carrying capacity*

To optimize the benefits of the area, we conducted a tourism suitability analysis, especially for snorkeling and diving (Table 4 and Table 5). The results indicated the area was classified as 'Suitable' (S2), meaning that the utilization zone can support snorkeling and diving ecotourism activities. The results of the TSI on Marsegu Island of Maluku were comparable to the results found by Arif et al. (2013), which showed that the TSI of snorkeling and diving in Lara Island in Southeast Sulawesi ranged from 60 to 80%, and was classified in the "Suitable" category (S2). □

The recommended location for snorkeling and diving is the northeast side of Marsegu Island, at station 1, station 2 and station 3. The highest coral cover percentage was at station 2 with 80.12% and was dominated by hard coral with coral reefs of 500-800 m in width. A total of 12 lifeforms and an average velocity of 16.7 m/sec further support snorkeling and diving activities. The low current velocity is an ideal requirement for diving tours because this directly relates to the comfort and safety of tourists (Arifin et al. 2002). The physical condition of these waters supports snorkeling and diving activities, so it can be done in the west season (December to March) and the east season (May to October). □

On the western side to the south of Marsegu Island (station 4, station 5 and station 6), the water transparency was around 12 m and the coral reef range from 700 to 900 meters, but the high current velocity (averaging 25.23 m/sec) and presence of a rip current on the south side indicate seasonal patterns need to be accounted for when snorkeling and diving. Based on the results of this research, all observation stations are suitable locations for marine ecotourism activities, but must be well managed to prevent damage to the coral reefs at the dive stations. Tratalos and Austin (2001) asserted that excessive dive activity will have an impact on coral damage, therefore the dive spots need to be well managed. Wabnitz et al. (2018), asserted that to keep the coral reef ecosystems sustainable, tourists need to reduce direct contact with coral reefs and reef fish consumption must be reduced by both tourists and local communities.

Tourism area management needs to calculate the carrying capacity of the area to prevent environmental damage and environmental quality degradation. The carrying capacity of the area is related to the ability of the area to accommodate various tourist activities. Brander et al. (2007), asserted that marine ecotourism should be conducted within the limits of power, as it does not directly correlate positively with coral reefs.



**Figure 4.** Comparison of number of tourist and area carrying capacity for snorkeling and diving at Marsegu Island Nature Tourism Park, Western Seram District, Maluku, Indonesia

Based on the tourist data from the last 2 years (2014-2015), it can be seen that the number of tourists visiting Marsegu Island Nature Tourism Park averaged as many as 96 people per year. If based on the assumption of an increase in the number of tourists as much as 7% for 10 years to come, the carrying capacity of snorkeling and diving areas or the carrying capacity of the area will not be exceeded, as presented in Figure 4.

Based on the graph in Figure 4, it can be seen that the current number of active tourists has not exceeded its carrying capacity, but to prevent over capacity and degradation of marine environmental quality, a strategy for marine ecotourism management needs to be completed and implemented; including limiting the number of divers/snorkelers per day, implementing boat moorings so coral is not damaged by anchors, making sure tourism operators brief divers/snorkellers not to touch, stand on, or break the coral, ensuring the tour operator is the organization responsible for the continuous monitoring of marine ecotourism activities and protection of dive sites. Currently, for marine ecotourism activities, the number of tourists is still limited so there is no garbage or plastic waste around the activity area, but the provision for places of waste in the tourist locations must be implemented. Overall, Marsegu Island Nature Tourism Park is suitable for marine ecotourism, maintaining the sustainability of coral reef and coral fish resources, and the conservation of aquatic ecosystems. □

In conclusion, potential coral reefs in Marsegu Island consist of 45 species, 13 genera, and 14 families with coral cover of 69.86%, classified under "Good" condition, and including 12 coral lifeforms. There is an abundance of fish species consisting of 146 species, 64 genera, and 21 families with 16 indicator fish species (these serve as an indicator of the condition of coral reefs). The tourism suitability index (TSI) for snorkeling and diving was 74.79% and 67.32% respectively. The carrying capacity of snorkeling and diving was calculated as 4,092 persons/day and 1,855 persons/day respectively. This demonstrates that Marsegu Island Nature Tourism Park is "appropriate" for marine ecotourism activities without exceeding the

carrying capacity. A strategy for marine ecotourism management needs to be completed, including elements such as limiting the number of divers/snorkelers per day, implementing boat moorings so coral is not damaged by anchors, making sure tourism operators brief divers/snorkellers not to touch, stand on, or break the coral, and ensuring the tour operator is the organization responsible for the continuous monitoring of marine ecotourism activities and protection of dive sites.

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