Potential, suitability, and carrying capacity of coral reef ecosystem in West Buleleng MPA

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Abstract. Marine protected area (MPA) of West Buleleng, Pemuteran, Bali has the potential for the development of marine tourism activity through its coral reef ecosystem. Since 2011, the number of tourists visiting this area has been increasing every year and without proper management, it might harm the coral ecosystem. The purposes of this study are to analyze; the potential of coral reef resources based on the analysis of coral’s coverage area, the Tourism Suitability Index (TSI), and the carrying capacity to protect the coral reef ecosystem yet support the development of tourism activities in West Buleleng MPA. Data analysis methods consist of ecological analysis by measuring the potential and condition of coral reef ecosystems, the suitability index of tourism and the carrying capacity of the coral reef ecosystem. The results showed the potential of coral reef resources in West Buleleng MPA is fairly good with a percentage of coral cover about 57.08%. The suitability index of snorkeling and diving activities in the coral reef ecosystem was 76.9% with the carrying capacity of 36 tourists per day or 13.140 tourists per year for those tourism activities.

1. Introduction
Coastal ecosystems have high benefits as the primary productivity and home for many species of marine biotas, such as the coral reef ecosystem. Coral reefs themselves are vital spawning, nursery, and feeding ground for many species, an important aspect in coastal erosion protection and an attraction that can support tourism activities [1]. According to the report of IPCC [2], coral bleaching is happening increasingly in some countries, especially in developing countries that affect the high average of sea surface temperatures. One effort to manage marine resources effectively is to establish and develop the MPA [3]. Pemuteran Village in Buleleng Regency, which was subsequently planned following to Regent Decree related to MPA in Buleleng Regency, later called as West Buleleng MPA.

This area has coastal panorama and underwater beauties as the main reason for tourists to visit Pemuteran for snorkeling, diving, photography, beach walking, camping, and any other activities. The tourism activities encourage business opportunities for the local community to improve their economic level. Currently, West Buleleng MPA has become one of the most famous marine ecotourism destinations in Bali that focused on snorkeling and diving for domestic and foreign tourists [4]. The tourism activity is more. However, West Buleleng MPA is not yet under optimal management as a
marine protected area. This is due to the lack of supporting facilities from government or related ministries. Then, to determine the best MPA management, we need to know the suitability and carrying capacity for the sustainable coral reef ecosystem. The objectives of this research are; to analyze the potential of the coral reef ecosystem and to identify the tourism suitability index and the carrying capacity of the coral reef ecosystem in West Buleleng MPA.

Tourism activities in West Buleleng MPA are particularly managed by coastal community-based to develop the tourism sector [1]. To protecting and preserving the coastal environment in Pemuteran, there are NGOs, resort managers, and the most important role in that area is seashore security as known as pecalang segara, while the government is as the supervisor. In fact, the current condition of the coral reefs in Pemuteran is far different from how it used to a few years ago [5]. The establishment of the West Buleleng MPA is an effort to have a chain of impact on the ecosystem sustainability which affects the dynamics of tourism activities. The number of tourist visit has shown positive trend every year from 2008 to 2018 [4]. However, the high level of tourism activities in West Buleleng MPA brings up questions about the ecosystem’s carrying capacity to support those activities. Therefore, to improve and properly manage the coral reef ecosystem, it is necessary to research about the potential, suitability, and carrying capacity in coral reef ecosystem services as the objectives of this paper. The results can be used to strengthen the capacity of each element, especially local stakeholders, also to facilitate the sustainability of ecotourism activities itself.

2. Materials and methods
2.1 Location and time of research
This research was conducted in West Buleleng MPA located in Pemuteran village, Gerokgak district of Buleleng Regency, Bali Island with an area of 651.24 Ha for a week on July 2019. The location was chosen based on purposive method with several considerations such as; it is one of the coastal damaged coral reef ecosystem throughout Bali. The map of the location is presented in Figure 1.

2.2 Tools and materials
Tools and materials used in this study are GPS, scuba and snorkeling equipment, meter roll, underwater camera, secchi disk, current meter, thermometer, and aquatic resources including coral reefs and coral fish.

2.3 Data collections technique
This study uses primary and secondary data. The primary data obtained directly in the field by direct observation and in-depth interviews with the respondents. The secondary data obtained from related institutions and literature studies. Coral reefs and fish data collection conducted around Pemuteran village with the consideration that the area was a conservation zone. observations by looking at the utilization of tourism activities also the width of the reef by using satellite images.

Data of coral reef ecosystem components used Underwater Photo Transect (UPT) method with 4 observation stations. The lifeform and percentage of coral cover were determined [6; 7]. The observation stations each consisted of 50 meters long transects were determined to the field. Furthermore, data analysis consists of ecological analysis obtained an overview of the conditions and potential of existing coral reef ecosystems as well as the suitability and carrying capacity of the area for tourism activities.

2.4 Data Analysis
2.4.1 Analysis of coral reef potential
The result of photo transect that has been carried out in the field is analyzed coral reefs life form data such as corals, non-corals, algae, and other abiotic components by a quantitative method with CPCe (Coral Point Count with Excel extensions) software developed by NCRI (National Coral Reef Institute), USA.
2.4.2 Analysis of tourism suitability index

Tourism suitability index (TSI) analysis was conducted to determine the ability of the area to support various tourism activities such as snorkeling and diving in the coastal area. The determination of the tourism suitability index of coastal tourism is formulated as follows [8]:

\[ TSI = \sum \frac{Ni}{N_{max}} \times 100\% \]  

(1)

Where \( Ni \) is the-i parameter value (quantity x score) and \( N_{max} \) is the maximum value of each category. The suitability category for diving and snorkeling classified as S1 (very suitable, TSI 83-100%), S2 (suitable, TSI 50-<83%), S3 (conditional suitable, TSI 17-<50%) and N (not suitable, TSI <17%).

2.4.3 Carrying capacity of coral reef ecosystem

The carrying capacity (CC) of this area should be measured to reduce the impact of tourists’ over-capacity in the coastal area. The carrying capacity is determined by the formula as follows [8]:

\[ CC = K \times \frac{L_p}{L_t} \times \frac{W_t}{W_p} \]  

(2)

Where \( K \) is the maximum visitors per unit of area, \( L_p \) is the length of area that can be utilized for tourism activities, \( L_t \) is the unit area for a particular category, \( W_t \) is time provided for tourism activities in one day, and \( W_p \) is time spent by visitors for certain activities.
3. Result

3.1 Potential resources of coral reef ecosystem

The coastal area of Buleleng regency is almost surrounded by coral reefs from fringing reef types. According to the Regent's Decree Number 523/630 / HK / 2011 concerning the Marine Protected Areas in Buleleng Regency, the West Buleleng MPA has a total area of 651.24 hectares, with the area of 448.71 hectares’ area of coral reefs cover obtained through Sentinel-2 satellite imagery analysis.

Then, the observation result of coral cover in the West Buleleng MPA consists of 4 observation stations, there are snorkeling and diving site in; near Sumberkima, Kesik, Pura Tembok, and Tangkad Jaran. Overall, the percentage of live coral cover in this area is 57.08% (good category). The detailed percentage of coral cover in each observation area is mentioned in Figure 2 and Table 1. According to the criteria of [9], for marine tourism activities a minimum condition of coral cover is required of 25% to more than 75%. The calculation results above indicate that observation stations can be utilized or potentially for marine tourism activities, especially for underwater tourism both diving and snorkeling.

![Figure 2. Percentage of coral cover in each observation area.](image)

| Major Category (% of Transect) | Coverage in Observation Stations (%) | Average (%) |
|-------------------------------|-------------------------------------|-------------|
| Coral (C)                     | 30.00 74.17 40.83 83.33            | 57.08       |
| Dead Coral (DC)               | 9.17   2.50  4.17  1.67            | 4.38        |
| Algae (ALGAE)                 | 30.83  8.33  32.50  3.33           | 18.75       |
| Abiotik (ABIOTIK)             | 30.00  15.00  22.50  11.67         | 19.79       |
| Total (%)                     | 100.00 100.00 100.00 100.00         | 100.00      |
The coral reefs in Pemuteran, as known as sites 24-25 in the northwest part of Bali, shows good diversity of microhabitats and supports a rich fish community [3]. There is a total of 191 species of coral reefs with reef fish associated in the Pemuteran site with type of coral such as Acropora branching, Acropora digitate, Acropora submassive, Coral branching, Coral encrusting, Coral foliose, Coral massive, Coral millepora, Coral mushroom, and Coral submassive. Then, there are abiotic components included sand and rubble substrate also dead coral. Based on the observation data of each station, a recommended location for snorkeling and diving is the fourth station in the northeast part of Pemuteran bay. In this site, the percentage of live coral cover was obtained by 83%, which is the highest coral cover compared to three other observation stations. The life form of the corals is also very diverse, consisting of corals in the form of Acropora branching (0.83%), Acropora digitate (0.83%), as well as submassive Acropora (17.50%) and non-Acropora species consisting of from Coral encrusting (3.33%), Coral massive (43.33%), Coral mushroom (1.67%), and Coral submassive (15.83%). Furthermore, the abiotic component consists of the sand substrate (3.33%) and rubble (8.33%), there is also a percentage of dead corals about 1.67%.

Some of the spots in West Buleleng MPA have the best potential of coral reefs with a high percentage of coral cover as a “no-take” zone. The aim of those zonation enriching fisheries and providing a high quality of underwater tourism activities. The decline of coral reefs conditions affected by anthropogenic activities, such as the high intensity of snorkeling and diving [10]. The potential of fisheries in Pemuteran is quite high compared to other villages in Gerokgak district even in Buleleng Regency. The highest yields of fisheries utilization occurred in 2012 which was almost 160 tons per year, while the lowest record in 2013 was only around 60 tons per year [4]. The condition or quality of waters is an important factor that plays a role in the growth and development of coral reefs. The water quality in the West Buleleng MPA that consist of water clarity, temperature, pH, salinity, DO, BOD, Phosphate, and Nitrate is classified as good based on the Decree of the Minister of Environment No. 51 Year 2004 concerning about Water Quality Standards for Marine Tourism. However, some water quality parameters are not suitable and affect the growth of coral reefs as the main attraction of tourism activities in West Buleleng MPA [11].

3.2 Tourism suitability index for coral reef ecosystem

Suitability is also an important element in the development and utilization of resources in the coastal area for optimally and sustainably tourism activities. The following is a suitability criterion [8] and scoring of West Buleleng MPA as a tourism site presented in Table 2.

| No. | Parameter                     | Criteria* | Quantity | Score | Total |
|-----|-------------------------------|-----------|----------|-------|-------|
| 1.  | Live coral cover (%)          | > 50 – 75 | 3        | 2     | 6     |
| 2.  | Waters brightness (%)         | 100       | 3        | 3     | 9     |
| 3.  | Number of life form types     | < 7 – 12  | 2        | 2     | 4     |
| 4.  | Type of reef fish             | 20 - < 50 | 2        | 1     | 2     |
| 5.  | Coral reef depth (m)          | 4 – 15    | 2        | 3     | 6     |
| 6.  | Current speed (cm / sec)      | 0 – 15    | 1        | 3     | 3     |
|     | Total Scoring                 |           |          |       | 30    |

Information: $N_{max} = 39$

Tourism suitability index (TSI) for snorkeling and diving activities in West Buleleng MPA is 76.9 or with the S2 category (suitable). Coral Ecosystem in West Buleleng MPA has potential to be developed into tourism destinations, especially coastal tourism. The utilization of tourism potentials should be well managed to maintain ecosystem balance and tourism sustainability. Then, compared to the previous research results conducted by [12], West Buleleng coast is categorized very suitable...
(87.17) when viewed from the condition and potential of its marine natural resources that able to support tourism activities with the level of regional suitability based on the tourism suitability index. However, the research area of the former study is wider which includes Pemuteran Village, Sumberkima, and Menjangan Island, which also calculate not only the coral reef ecosystem but also mangrove resources in the west part of Buleleng regency.

3.3 Carrying capacity of coral reef ecosystem

Tourism area management needs to calculate the carrying capacity of the area to prevent environmental damage and environmental quality degradation [13]. The carrying capacity of the area is related to the ability of the area to accommodate various tourist activities. Diving and snorkeling are the main tourism activities also the main local income in the tourism sector at Pemuteran. There are many dive resorts and dive centers to rent the equipment for diving also snorkeling, because as mentioned before, the coral reef ecosystem is the main attraction of this location. Carrying capacity of reefs ecosystem is the maximum number of visitors who can physically be accommodated by the area at a certain time without causing disruption to nature as well as to the humans [14]. As result, the carrying capacity in this area is 36 people per day, with a total of tourism carrying capacity is about 3.6. So, the carrying capacity value measured in one year as many as 13,140 people in West Buleleng MPA. Then, compared to the total of tourist arrivals in Pemuteran Village in 2017 about 27,018 people. This indicates that the number of tourist visits has exceeded the carrying capacity of the coral reef ecosystem if it is assumed that those 27,018 tourists did snorkeling and diving as their activities around the reef’s ecosystem. Assuming the time, visitor takes is about 4 hours in average. The time provided by the tourist area in one day depends on the area management and can be different in each location. Referring to research conducted by Davis and Tisdell [13], the carrying capacity for snorkeling and diving in a conservation area is around 200,000 people per year. So, if the result compared to former studies, the carrying capacity of marine tourism activities in the coral reef ecosystem at West Buleleng MPA is still eligible.

Based on the observation, the majority of tourists who visit Pemuteran come from cities in Bali Province, such as Singaraja, Tabanan, and Denpasar. The reason for visitors is due to the close distance from their home to the location. Also, some tourists come from other countries such as Australia and Germany as a majority. The demography of the tourists is in general young visitors ranging from 20-26 years old; mostly they are employers in private sectors and divers from abroad. During one visit period, the majority of tourists spend 2-3 days, usually on weekends or during the summer holiday. The accumulation of tourists during peak season or holidays may affect the availability of their needs during the travels. Not only logistics needs such as water, food, and electricity but also the needs for homestays or lodgings that must easier to get around the tourism area. Based on the report of BPS [4], there are 44 lodgings with 10 dive resorts in Pemuteran village.

The carrying capacity is different in each tourism location. The carrying capacity of a region is not a fixed value but diverge according to the ecological or biogeophysical conditions of the area as well as the human needs for natural resources and environmental services. Human activities and natural forces such as natural disasters may also degrade the carrying capacity of an area. It is the reason that marine ecotourism should be conducted within the limits of power, as it does not directly correlate positively with coral reefs [15].

4. Discussion

In the early 1990s, fishermen around Pemuteran Village carried out fishing activities that were not environmentally friendly by using potassium and explosives [5]. This activity lasted for almost 7 years, until the end of 1997. As a result of damage to coastal ecosystems in the West Buleleng region, in 1998 there was new management of coastal and marine resources due to community awareness of the impact of resource exploitation. The rehabilitation of coral reefs continues to be carried out by the community with support from the Yayasan Karang Lestari which is an organization to preserve the coral reef ecosystem through artificial coral, known as Biorock technology. This technology is a
technology application that was introduced by scientists from Germany, namely Prof. Wolf Hilbertz and Dr. Tom Goreau. Biorock can stimulate the growth of coral reefs two to six times faster than normal technology [1]. So, the success of the coral reefs recovery is the result of cooperation between various communities.

The tourism activities in Pemuteran village particularly are managed by coastal community-based. The area has underwater beauties as the main reason for tourists to have tourism activities such as snorkeling and diving that encourage business opportunities for the community to improve their economic level economy. Walters and Samways [15] asserted that marine ecotourism contributes to the protection of coastal and marine ecosystems also has an impact on supporting the economy for local communities. Furthermore, people began to open business opportunities in the field of tourism. There are some alternative businesses for the community such as rental services for diving and snorkeling equipment, boat and canoe, bicycle and motorcycle, tour guide, restaurant and cafeteria, minimarket, homestays, and hotels. People claim that their economy has increased since the developing tourism site in that area.

According to one of the tour managements in a dive resort, there is a minimum amount of trash West Buleleng MPA that indicate good collaboration among stakeholders’ appeal and tourist’s awareness in preserving the coastal and coral reefs ecosystem. Based on interviews some relate stakeholders who taking apart of the initiative to restore the ecosystem, they arrange the regulations of local coastal conservation as known as awig-awig and develop a village-based marine protection area to decrease the probability of coral damage. However, the potential of this ecosystem is still under threat due to both human and natural factors. The pressure exerted by the environment can take the form of pollution from the land, destructive fishing practices, and illegal extraction of coral reefs. Besides, global climate change is also a threat to coral reefs, where the increasing sea surface temperature causes coral bleaching [16]. To minimize the impact of coastal resource damage, one of the preventive measures is through the utilization of environmental services based on marine ecotourism. From the social point of view, both government and coastal communities are very supportive of the management of tourism activities. However, in terms of ecology, the increasing number of tourists has the potential damage and pressure of the coastal environment, especially for the coral reef ecosystem. Excessive dive activity will have an impact on coral damage [13], therefore the diving spots need to be well managed and keep the coral reef ecosystems sustainable by reducing direct contact of divers with coral reefs.

5. Conclusion
The potential of coral reef resources in the West Buleleng MPA is classified as good with a percentage of coral cover of 57.08%. This area has a diverse life form of coral reefs, where there are 10 types of life forms are found. This condition is supported by the quality of waters which also has an impact on fisheries yield of 75 tons per year and the diversity of reef fish around the coral reef ecosystem. The suitability index of snorkeling and diving activities in the coral reef ecosystem is 76.9 with the category S2 (suitable). While the carrying capacity of the coral reef ecosystem in West Buleleng MPA is 36 people per day or equivalent to 13,140 people per year. Furthermore, the management approach in this area is needed to preserve its ecological and aesthetic quality as a conservation zone and tourism site.

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