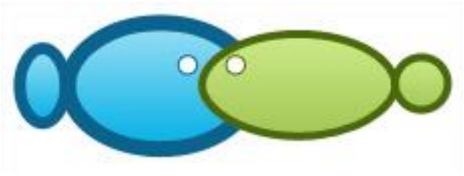

Feasibility of coral reefs to support marine ecotourism at Kampung Baru Beach, Sempu Strait, Malang Regency, Indonesia

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Abstract. Marine tourism is a tourism activity carried out by utilizing coastal and marine resources. Snorkeling is an element of marine tourism that is widely practiced because it does not require special skills. On the other hand, snorkelling also can have a negative impact on coral reefs. The carrying capacity of the area needs to be considered to reduce the negative impact of tourism. In this analysis, a geographic information system is applied to provide spatial information. There were seven parameters studied, namely the percentage of live coral cover, the number of coral lifeforms, the number of species of reef fish, current velocity, water clarity, water depth, and tides. All parameters are processed and converted into spatial information using the weighted overlay method. This method uses the classification and weighting of each parameter based on the tourism suitability index. The area that tourists can use for snorkelling is 10,008.46 m^2, which is divided into 4 zones at a depth of 1-6 m. Coral coverage was 54-76% with 8-10 coral lifeforms and was dominated by *Acropora* branching and coral foliose. The number of species of coral fish is 29-45, dominated by the Chaetodontidae family. Based on the average current velocity, August-December (0.25–0.35 m/s) is the suitable period for snorkeling. Based on the carrying capacity's area, Kampung Baru Beach can accommodate approximately 41 tourists in a day. The most suitable time for snorkeling is snorkeling is among 08.00 to 15.00 WIB.
Key Words: coral coverage, interpolation, physical parameters, snorkeling, weighted overlay.

Introduction. Marine tourism is carried out by utilizing coastal and marine resources (Yulianda 2019). Activities that can be done during marine tourism include enjoying the attractions of marine animals (whales, sharks, seals, and dolphins), boating, enjoying the beach views, diving, and snorkeling. Snorkeling is one of the activities in marine tourism that provides the experience of interacting with coral reef ecosystems. Snorkeling has become one of the tourist attractions that is mostly done by tourists rather than diving because it does not require special skills or a diver licensed with national or international standards (Noviama et al 2018; Simarangkir et al 2021). These tourism activities (snorkeling) can also have a negative impact on coral reefs. Snorkeling impact on coral reefs is resulted from kicks, standing, kneeling or holding/touching corals (Noviama et al

2018; Webler & Jakubowski 2016). Basically, coral reefs can tolerate disturbances that occur as long as these disturbances don't exceed the carrying capacity of their ecosystem. However, if these disturbances exceed the limits or capabilities of the ecosystem, degradation occurs (Yulianda & Mazaya 2021). To reduce this, interactions while snorkeling need to be limited by applying the concept of marine ecotourism (Yulianda 2019).

In an effort to utilize resources for tourism activities, it is necessary to apply the concept of ecotourism to minimize the impact of damage to coastal resources (Lelloltery et al 2018). Ecotourism is a conservation-based tourism activity that prioritizes ecological aspects (sustainability and use of nature) to support the sustainable use of natural resources (Yulisa et al 2016). In another source, Yulianda (2019) said that ecotourism management does not only look at sustainability but also maintains natural values and human resources. The number of tourist visits to tourist areas beyond capacity has also has a negative impact (Nurhayati et al 2019; Zamzami et al 2021). This then becomes the reason why tourism management requires an analysis of the carrying capacity of an area. Carrying capacity is defined as the maximum number of people who can visit a tourist attraction at the same time without causing environmental damage or reducing visitor satisfaction.

One area that has the potential to become an ecotourism attraction is Kampung Baru Beach. Kampung Baru Beach is a beach located in the Sempu Strait area, Malang Regency, Indonesia. In general, the waters of the Sempu Strait have coral reefs with good resilience for supporting tourism activities (Isdianto et al 2020). The location for Kampung Baru Beach was chosen for this study because this beach is new. In addition, access is still limited; it can only be reached on foot or by boat. This selection also fits with research conducted by Dharma et al (2021), which found that Kampung Baru Beach is suitable for snorkeling. The condition of coral reefs with a good proportion of life has a high attraction for snorkeling activities (Witomo et al 2020).

As a new beach with potential as an ecotourism area, it is fitting that there should be a scientific analysis regarding tourism resilience and carrying capacity before it is opened to the public, as well as a preventive measure against ecosystem damage. Kampung Baru Beach is currently not yet an ecotourism planning and development area, so the results of this research can be input for the responsible authorities. The expected results of this study are that a map and analysis of the carrying capacity of the area can be input for policymakers in planning the Kampung Baru Beach ecotourism area as a snorkeling destination. This research uses the help of GIS (Geographical Information System) to process field data and determine the availability of coral reefs as well as the opportunities or potential of the area to become an ecotourism destination. The result of its application is a map of the distribution of areas with predetermined ecotourism categories (Siregar et al 2020).

Material and Method

Research time and location. The location of the research is Kampung Baru Beach, Malang Regency, and it was carried out in March 2022. Data collection was carried out at coral reef data collection points (4 transects) and water parameter collection points (8 points), including current velocity and water clarity. The choice of this location was to cover the observation area, namely Kampung Baru Beach. Determination of the point of data collection using the purposive sampling method is shown in Figure 1.

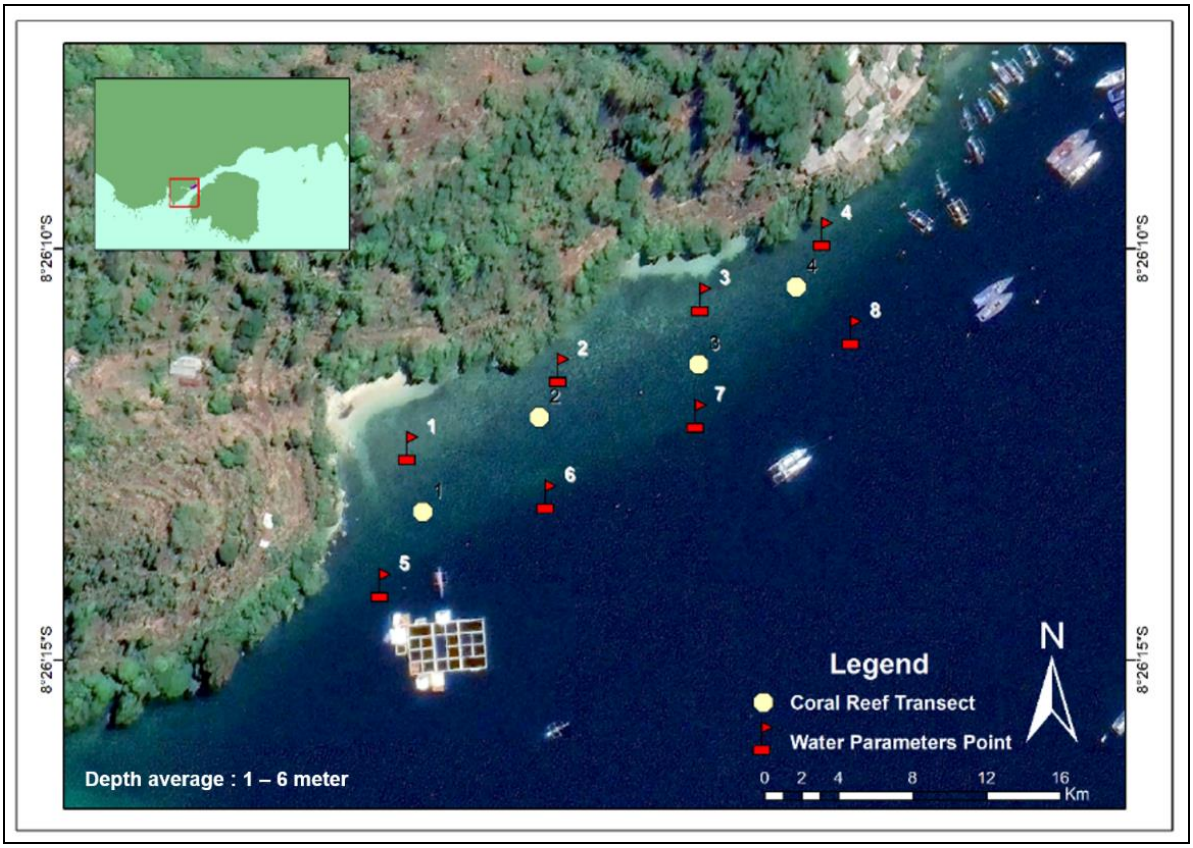

Figure 1. Location map of Kampung Baru Beach, Sempu Strait, Malang Regency (map generated using ArcGis 10.3).

Data collection method. The method used for observing coral reefs is using the Point Intercept Transect (PIT) method with a 25 m line transect and reef fish as biota that live on coral reef are observed using the Underwater Visual Census (UVC) method with a distance of 25x5 m (Manupputy & Djuwariah 2009). Water parameters were taken by direct data collection consisting of water clarity and current velocity. The tools used are a Secchi disk to measure water clarity and current meter to measure current velocity. Water depth data was collected using a single beam echosounder (Fuad et al 2016). Before doing the scanning, it is necessary to make a sounding path with a distance of 10 m (BSN 2010). The type of sounding route used in this research is systematic with parallel transects (Acoustics Unpacked 2022). Tidal data was also collected because it is a physical parameter of the suitability of snorkeling. Tides can affect sea level which affects snorkelling tourism activities. Tidal data uses tidal data for the Sempu Strait from the Geospatial Information National Agency (BIG 2022).

Snorkelling suitability analysis. The suitability analysis uses spatial analysis with the overlay method. Weighted overlay serves to complete multi-criteria data analysis. The weighting of the suitability of snorkelling area was conducted by considering the limiting factors such as water clarity, current velocity, depth, wide stretch of coral reefs, the percentage of coral cover, coral fish species, and coral lifeforms (Johan et al 2017). The percentage of coral cover refers to the coral reef monitoring guide of Giyanto and Muhammad (2014). Lifeform identification refers to English et al (1997), such as: *Acropora* branching, where coral resembles the branches of a tree; *Acropora* encrusting, where coral grows on base plates; *Acropora* digitate, where coral grows in a shape similar to the fingers of a hand; *Acropora* submassive, where corals that grow in branches resemble clubs or plates and are sturdy; coral branching, where the growth form has longer branches and generally has tapered ends; coral foliose, where the growth is in the form of sheets that resemble leaves and petals; coral encrusting, where growth on plates occurs; coral submassive, where growth is in the form of small columns

or sturdy protrusions; coral massive, where growth resembles a solid block; coral *Millepora*, where coral features structures resembling fine hairs; coral mushroom, where the growth form resembles a mushroom and is generally solitary. The Reef Health Monitoring (RHM) protocol of Coremap-CTI (Giyanto et al 2014) provided the protocols used to identify the reef fish species. The parameter of suitability of snorkeling tourism are rated according to the weight of the scale in Table 1, then overlayed with the weighted overlay method.

Table 1

Suitability index

Parameter	*Weight*	*S1*	*Score*	*S2*	*Score*	*S3*	*Score*	*N*	*Score*
Coral cover (%)	0.375	>75	3	>50-75	2	25-50	1	<25	0
Number of coral lifeforms	0.145	>12	3	>7-12	2	4-7	1	<4	0
Number of reef fish species	0.140	>50	3	30-50	2	10-<30	1	<10	0
Water clarity (%)	0.100	100	3	80-<100	2	20-<80	1	<20	0
Depth (m)	0.100	1-3	3	>3-6	2	>6-10	1	>10 or <1	0
Current velocity (m/s)	0.070	0-0.15	3	>0.15-0.3	2	>0.3-0.5	1	>0.5	0

Source : Yulianda 2019

Carrying capacity analysis. Carrying capacity is the most visitors that can be accommodated by an area in a certain period (Yulianda 2019). The calculation of the carrying capacity (DDK) is done by the following formula:

$$DDK = K \times \frac{LP}{LT} + \frac{WT}{WP}$$

The usable area (LP) can be determined by calculating the suitable area (Akbar et al 2019). Tourist ecological potential (K) is shown in the formula. The usable area (LT) is 500 m^2. The time spent by tourists to do activities (WP) is 3 hours and time spent by tourists (WT) in one day is 6 hours (Yulianda 2019).

Results and Discussion

Parameters of snorkeling suitability

Coral reef condition. Figure 2 shows a 3D description of the condition of the coral reefs at Kampung Baru Beach processed using surfer software. The map is divided into four zones (red, yellow, green, and orange) at a depth of 2-7 meters. The characteristics of the coral reef ecosystem in Kampung Baru Beach have a fringing reef type; the distribution of coral follows the coastline (Natha et al 2014). The map is divided into four zones (red, yellow, green, and orange) at a depth of 2-7 meters. These four zones are located 60 meters from the shore. Conditions regarding coral reef cover, the number of lifeforms that dominate, and the number of fish that can be enjoyed will be discussed further in the next paragraph.

The average percentage of coral cover in the 4 zones ranged between 54%-76% which based on Table 1 has a score of 2-3, so it is in the good - very-good category. In Zone 1 (red), the percentage of coral cover was 54% (good). The percentage of coral cover in Zone 2 (yellow) was the highest at 76% (very good). Zone 3 (green) has a coral cover percentage of 72% (good). In zone 4 (orange), the percentage of coral cover was 68% (good). The condition of coral reefs with a good percentage of life has a high attraction for snorkeling activities (Witomo et al 2020). The purpose of tourists' snorkeling is not only limited to hard corals but also soft corals. In addition, the diversity

of soft corals, algae, and reef fish is also an attraction when snorkeling (Harahap & Susetya 2020).

The number of lifeforms was in the good category (Table 1). The dominance of a type of lifeform is influenced by good water conditions. In zone 1 (red), there are nine lifeforms, dominated by coral branching. In zone 2 (yellow), there were 10 lifeforms, dominated by *Acropora* submassive (good). Zone 3 (green) obtained nine lifeforms and is dominated by coral foliose (good). The last zone (orange) contained eight lifeforms and was dominated by *Acropora* branching (good). The waters of Kampung Baru Beach have a low sedimentation rate and good light penetration for coral life (Isdianto et al 2022), so there is a dominance of coral foliose. The calm current conditions in the waters allow the *Acropora* branching and coral branching species to survive (Wibawa & Luthfi 2017). In addition, the *Acropora* submassive species has sufficient resistance to various water conditions (Nusaputro et al 2019). Research in the Mentawai Islands by Zulfikar et al (2011) stated that snorkeling tourists prefer areas with varied life forms. The high diversity of lifeforms in a location is a high tourist attraction (Sinaga et al 2020).

Reef fish are an important parameter for the suitability of snorkeling. The presence of marine animals on coral reefs is part of the scenery of snorkeling (Harahap & Susetya 2020). In Zone 1, there were 29 species of reef fish (fair). The number of reef fish species on Zone 2 is 42 species (good). Zone 3 has the highest number of species, which is 45 (good) and in Zone 4, the number of species is 44 (good). Most species of reef fish found are from the Chaetodontidae family which is an indicator of the condition of coral reefs in an area (Luthfi et al 2019). Good cover conditions and diversity of lifeforms are suitable habitats for reef fish (Moira et al 2020). Because of the live reef, fish consider the coral reef as shelter, feeding ground and place to protect from predators (Harahap & Susetya 2020). Reef fish prefer to live in habitats with complex substrates (Natha et al 2014). Research in the Mentawai Islands by Zulfikar et al (2011) stated that the uniqueness of reef fish species is a snorkeling tourist attraction. The existence of local and rare fish will also be an attraction for tourists to see them directly in their habitat (Lelloltery et al 2018). The results of the number of reef fish species show good conditions to support snorkeling.

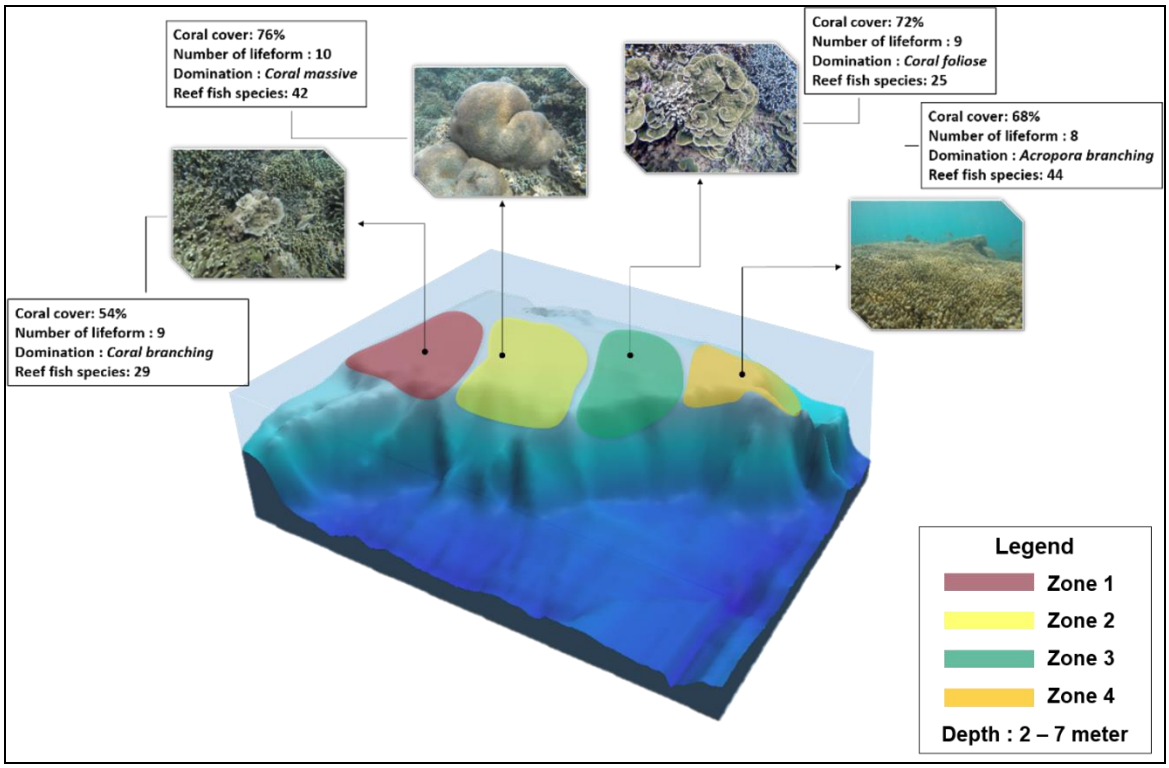

Figure 2. Coral reef condition in Kampung Baru Beach (figure generated using Surfer 10).

Water physical parameters. Based on Table 2 and Figure 2, the highest water clarity value obtained is 100% which is at a depth of 3-6 m. The lowest water clarity value obtained is 80% at a depth of more than 7 m. The water clarity at Kampung Baru Beach tends to be evenly distributed due to the basic contour which is quite sloping and suitable for the convenience of snorkeling. The factor of the clarity condition is because there are not many human activities on Kampung Baru Beach there is no pollution in the area (Fikri et al 2021). The bottom substrate which is densely packed with coral reefs shows low sedimentation which can make the water cloudy (Patty et al 2019). Water clarity is an important factor because it will affect the comfort of tourists. The good water clarity will provide good observations because it is clearer for enjoying the coral reef and the diversity of colorful reef fish with various sizes (Isdianto et al 2022; Saraswati et al 2017; Johan et al 2017). Overall, the value of the water clarity of the Kampung Baru Beach is included in the very suitable category based on the tourism suitability index (Table 1).

The value of the current velocity of the waters of Kampung Baru Beach is 0.1 to 0.4 m/s (Table 2). Waters with strong currents can be dangerous for tourism activities, especially snorkeling (Tangkudung et al 2018). Current characteristics at Kampung Baru Beach tend to be weak so that they do not interfere with coral life (Andaris et al 2015). Current conditions at Kampung Baru Beach vary greatly, so there are areas that fall into the categories of very suitable, suitable, and unsuitable (Table 1). This varying current velocity can be caused by the location, which is close to the mouth of the strait, which has a fairly fast current. The closer you are to the coast the current velocity will be weaker and weaker because it is blocked by coral reefs.

Table 3 shows the average current velocity at Kampung Baru Beach during August 2021 – April 2022. Wibawa & Luthfi (2017), stated that in 2017 the current speed ranged between 0.3-0.6 m/s (west-east season) and was faster during the transitional season. The current velocity is a limiting factor for snorkeling. The current velocity will affect the safety of tourists participating in snorkeling activities (Johan et al 2017). Current speed will affect divers' movements to maintain balance (Wibowo et al 2022; Wijaya et al 2017). The best average current speed for snorkeling is in August-December. High current velocity is not recommended for beginners.

Table 2

Water physical parameters data in 8 observation points

Points	*Current velocity (m/s)*	*Water clarity (%)*
1	0.4	86
2	0.1	100
3	0.2	100
4	0.2	100
5	0.1	100
6	0.3	80
7	0.3	80
8	0.4	90

Table 3

Average current velocity

Month	*Current velocity (m/s)*
August 2021	0.35
October 2021	0.25
December 2021	0.3
February 2022	0.6
April 2022	0.4

Water depth. Another safety factor in marine tourism is the bottom contour of the water. Depth is also a limiting aspect of the safety of snorkeling and can become a barrier for coral reef growth. The survey results map also displays the bottom contours of

the waters, which show that there are areas with gentle contours, namely 1-3 m and 3-6 m. Furthermore, at a depth of 6–14 m, it shows a fairly steep contour. After the steep contour at a depth of 14–18 m, the contour slopes back down (Figure 3). Snorkeling has the ideal depth criteria, namely 1-3 m for the most suitable category and 3-6 m for the least suitable category (Yulianda 2019). In addition, Noviama et al (2018) stated that the ideal water depth for snorkeling is 3-5 m. Rudianto et al (2020) and Wibowo et al (2022) stated that the shallower the water depth is, the more it is preferred for snorkeling, because objects are much closer and are seen clearer. Johan (2016) adds that the estimated snorkeling depth for tourists is >2 m to reduce coral damage. Shallow and flat bottom contours provide a wider area in the most suitable category.

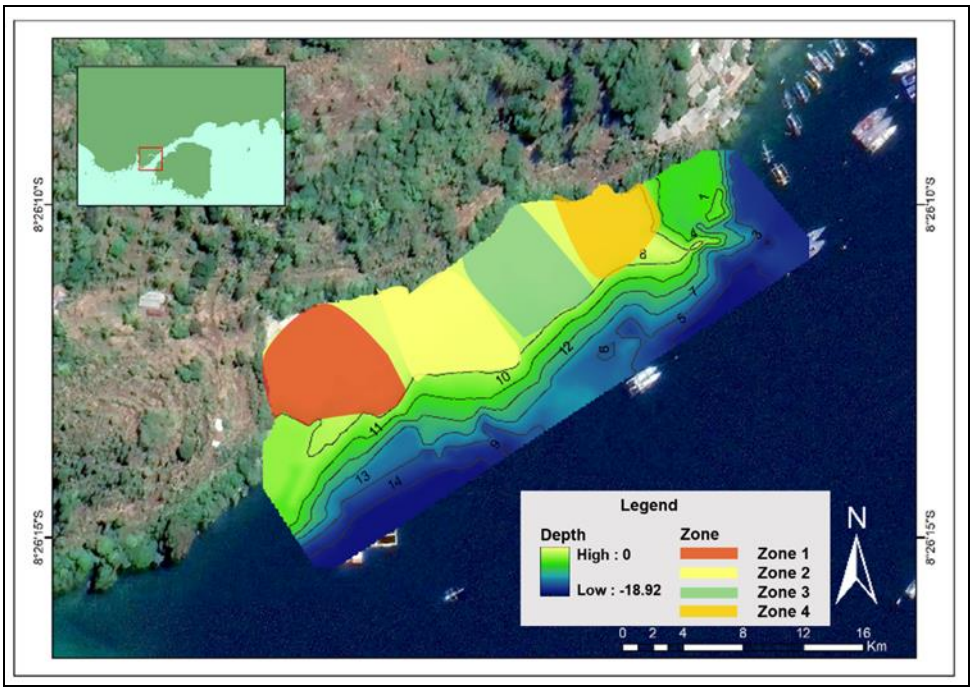

Figure 3. Water depth map (figure generated using ArcGIS 10.3 and Surfer 10).

Tides. Based on Figure 4, it is found that the mixed tidal type is double daily with a Formzahl value of 0.512 (Tanto et al 2016). The outcomes of the tide chart show a pattern of two highs and two lows. If there are two high tides and two low tides a day, then the tidal type at Kampung Baru Beach is called the double daily type (semidiurnal tides). Based on the lowest low tide and the depth and distribution of coral reefs, the tides at Kampung Baru Beach do not have a significant effect (Ferdi & Maliki 2021). Tide is a key parameter that needs to be considered whether snorkelling activities can be carried out or not. Snorkelling is performed at shallow depths (3-6 m), which is the optimal depth for the activity due to the risk of stepping on coral at depths shallower than 2 metres (Johan 2016). The tides are a concern because snorkelling cannot be executed at low tide. This is because snorkelling can increase coral damage due to being stepped on.

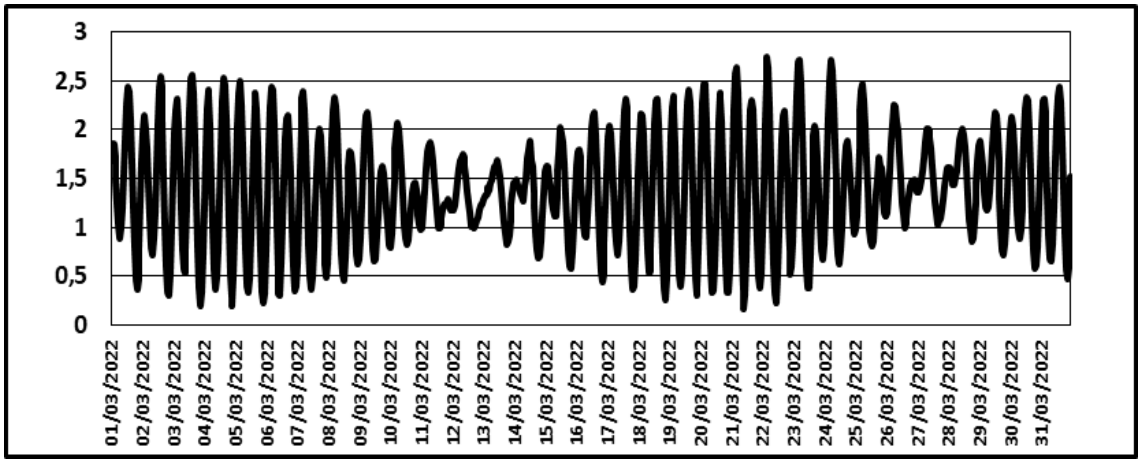

Figure 4. Tidal chart.

Suitability of snorkeling tourism. Based on the results of the analysis with a weighted overlay, each area parameter with a score of 3 falls into the most suitable category and is represented in green (Figure 5). Areas with a score of 2 fall into the suitable category represented in yellow. Areas in blue represent areas that are not suitable with the score of 1. Information and determination of the area were obtained from Natural Resources Conservation Center (BKSDA) (Natural Resources Conservation Center East Java 2022) and Ports and Management of Marine and Fisheries Resources (P2SKP) Pondokdadap (CFP Pondokdadap 2022) which manage conservation and utilization areas. In addition, other limiting factor is boat traffic which can interfere with snorkeling tourism activities. The existence of snorkeling tourism activities allows the declining condition of coral reefs (Emka et al 2020). For this reason, one of the efforts to offset the pressure from snorkeling tourism is by conserving coral reefs. Coral reef conservation can also be developed along attractive supporting tourism (Dharma et al 2021).

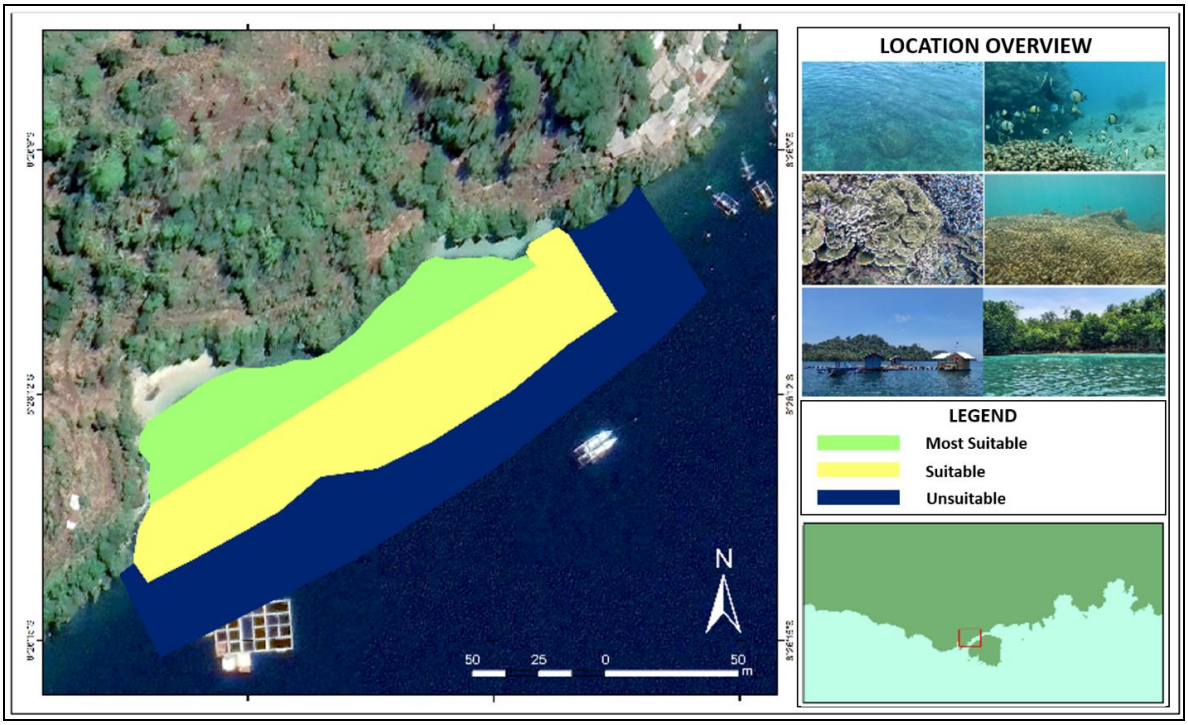

Figure 5. Suitability of snorkeling map (figure generated using ArcGis 10.3 and Surfer 10).

Carrying capacity. Based on Table 4 carrying capacity calculation, a suitable area of 3,301.72 m^2 is obtained. These results were obtained from the results of overlaying several parameters with a score of 3. In this area, several facilities can be enjoyed while snorkelling. Visitors can enjoy the beauty of coral reefs at a depth of 1-3 meters. The

suitable area is wider than the very suitable one, which is 6,706.73 m^2. This is because the majority of parameter measurement results show results with a score of 2. The condition of Kampung Baru Beach's coral reefs is still relatively good, but not optimal.

Tourism activity will effect to the coral reef ecosystem, so regulation to limit the number of tourist is needed to limit the tourism activities and to preserve the resources (Harahap & Susetya 2020). The carrying capacity of the area shows that a total of 41 tourists can go snorkelling comfortably in an area of 10,008,46 m^2. To carry out snorkelling activities comfortably, one person needs an area of 500 m^2 (Sukandar et al 2017). The results of carrying capacity are influenced by the dynamics of the environment which limits tourism activities (Yudhistira & Komarudin 2021). The time that can be used in snorkelling can also be seen through tidal patterns. Based on the admiralty calculation, the sea level at 8 am to 3 pm is the most optimal for snorkelling tourism activities. The time provided for snorkelling in a day is around 7 hours where the time spent by visitors for snorkelling activities is 3 hours (Mazaya et al 2020).

Table 4

Carrying capacity calculation

Category	*Area (m^2)*
Most suitable	3,301.72
Suitable	6,706.73
Total	10,008.46
Carrying capacity	$DDK = 1x\frac{10{,}008.46}{500}x\frac{7}{3} = \mathbf{41}$

Conclusions. The research location is divided into 4 zones, shown by the colors red, yellow, green, and orange. These zones have coral coverage, lifeforms, and fish species that can be observed. Coral coverage ranges between 54-76%, with 8–10 lifeforms observed among others: coral branching, *Acropora* submassive, *Acropora* branching, coral foliose, *Acropora* encrusting, coral mushroom, coral encrusting, coral massive, coral *Millepora*, *Acropora* digitate, and coral submassive. The number of coral fish species from zones 1 to 5 ranges from 29–45 species, dominated by the Chaetodontidae family. The suitability analysis calculation show that the suitable area is 10,008.46 m^2. Based on the area, the carrying capacity of the area for snorkeling tourism at Kampung Baru Beach is 41 people in one day. The most suitable time for snorkeling tours is 8 am to 3 pm. Based on the average current velocity of each month, August-December are suitable for snorkeling.

Acknowledgements. We are grateful for the close collaboration with Universitas Brawijaya who has financed this research through a research grant scheme for lecturers from the Faculty of Fisheries and Marine Sciences, Universitas Brawaijaya, and UPT Pondokdadap who have empowered extraordinary staff to complete this research.

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Received: 07 July 2023. Accepted: 27 November 2023. Published online: 30 May 2024.
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How to cite this article:
Isdianto A., Harahab N., Kurniawan A., Wicaksono A. D., Lelyemin B. Y., Fuad M. A. Z., Fathah A. L., Putri B. M., Haykal M. F., Bintoro G., Setyanto A., Luthfi O. M., Pratiwi D. C., 2024 Feasibility of coral reefs to support marine ecotourism at Kampung Baru Beach, Sempu Strait, Malang Regency, Indonesia. AACL Bioflux 17(3):971-983.