

Original Research Article
**Suitability of Tourism Zone Based on Oceanographic
Characteristics and Coastal Ecosystems in Sendang
Biru Waters and Sempu Island, Malang Regency**

ABSTRACT

Sendang Biru Tourism Beach and Sempu Island are tourism zones based on East Java Provincial Regulation No. 1 of 2018, which are part of the Sempu Strait, Malang Regency. Tourism activities depend on the quality of natural resources as the main tourism commodity. Activities that do not match or exceed the area's carrying capacity will also pressure coastal and water resources. This study aimed to determine the suitability of oceanographic and ecosystem characters in tourism zones as parameters for suitability. This study collects secondary and primary data obtained in January 2021, and the method of analysis uses the overlapping technique of physical and biological parameters. The study results show that these waters have a sloping - steep topography with tidal types is mixed tide prevailing semidiurnal, and a current type with a slow - medium category and conditions of temperature, salinity, and pH are still suitable for aquatic ecosystem life. The tourism zone of Sendang Biru Beach and Sempu Island has an oceanographic character that supports coastal tourism activities and ecosystem life, and aquatic biota. However, the existing ecosystem conditions less support coastal tourism activities in these waters. Based on the analysis, it appears that some coastal areas are suitable and very suitable for coastal tourism activities, and the ecotourism concept is recommended for coastal tourism activities.

Keywords: Suitability; oceanography; [coastal ecosystems](#); tourism zone

1. INTRODUCTION

The coast is an area that has great natural resource potential and high spatial utilization activities. One of the spatial utilization activities is tourism activities. Eight of the top ten largest cities in the world and most of the world's tourism are located on the coast [1]. East Java Province has many tourist attractions located in coastal areas and has determined the allocation of space for public use areas, namely tourism zones in Regional Regulation No. 1 of 2018 concerning Zoning Plans for Coastal Areas and Small Islands of East Java Province 2018-2038.

Sendang Biru Tourism Beach and Sempu Island in Malang Regency are tourism zones located in the southern coastal area of East Java Province, with sub-zones, namely beach/coastal tourism and small islands and underwater nature tourism. In its provisions, the tourism zone can not only be used for one tourist activity but other activities can be carried out in the zone. Uncontrolled and unregulated use of marine spatial will cause various problems.

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According to [2], the problems on the coast include land requirements, overlapping utilization areas, utilization zoning, threats of pollution, and environmental degradation. Activities that do not match or exceed the area's carrying capacity will also pressure coastal and water resources. According to [3], anthropogenic activities such as tourism, capture fisheries, ship activities, port waste disposal, ship waste, and household waste can put pressure on the Sendang Biru and Sempu Island tourism zones. Sempu Island is a small island with status as Conservation Area (Nature Reserve), so ecologically, there is a link between land, coastal and marine ecosystems.

The coastal zone, as a sensitive ecosystem providing critical habitat for many endangered species and essential ecosystem services in the form of coastal protection, fisheries, and other living resources, rich agricultural lands, areas of high aesthetic value, and is typically held as public heritage and connects land and sea [1]. Knowing the suitability of oceanographic characteristics and ecosystems is expected to determine and provide an overview of the suitability of tourism activities in the tourism zone in the waters of Sendang Biru and Sempu Island.

2. MATERIAL AND METHODS

2.1. Research location

The research area was located in tourism zones, namely Sendang Biru Beach and Sempu Island, which are part of the waters of the Sempu Strait, Malang Regency, with location coordinates in Table 1. The map of the data collection location can be seen in Fig. 1.

Table 1. Research location coordinates

Latitude	Longitude
8° 26' 15,28" S	112° 40' 44,57" E
8° 26' 21,30" S	112° 40' 57,86" E
8° 25' 57,68" S	112° 41' 25,57" E
8° 25' 48,48" S	112° 41' 17,84" E

Source: East Java Provincial Regulation No. 1 of 2018

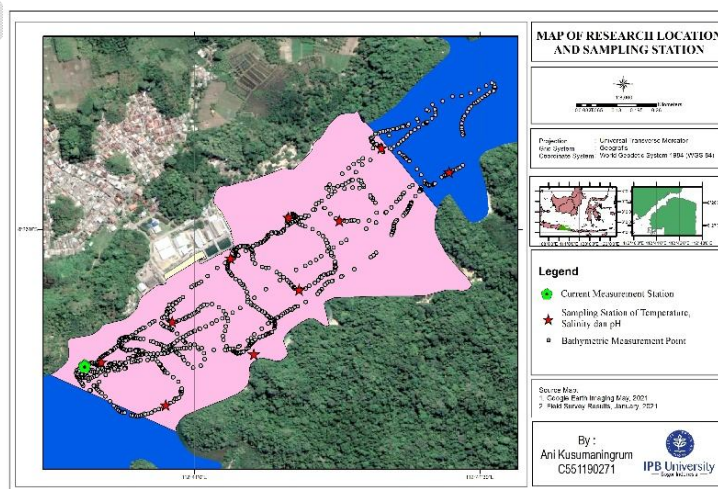


Fig.1. Map of research location at tourism zone in Sendang Biru Waters And Sempu Island

2.2. Datasets and analysis

This study uses primary and secondary data types. Primary data is data from observations and surveys conducted in January 2021. In contrast, Secondary data is obtained from studies of reports on research results, scientific publications, regional regulations, and data from government agencies, the private sector, and non-governmental organizations.

The primary data collection used included bathymetry, current, water quality parameter measurements (temperature, salinity, and pH), and ecosystem data. Primary data collection tools consist of Garmin GPS Echosounder, Valeport 106 Current Meter, and AAQ (Aqua Quality Sensor) model series AAQ 1183S-IF, transect quadrant, and underwater camera. Secondary data collection includes daily real-time tidal elevation data taken every day in January 2021 through the website <http://tides.big.go.id>. This real-time data is measurement data at the Geospatial Information Agency (BIG) tidal station in Sendang Biru, Malang Regency, East Java.

Oceanographic and ecosystem data processing is presented in bathymetric contours, stick plots of currents, vertical contours of water quality parameters, and tide charts. The area suitability analysis is carried out by overlaying the physical and biological parameters, which are the prerequisites for the area's suitability.

3. RESULTS AND DISCUSSION

The waters of the Sendang Biru Beach and Sempu Island, as a tourism zone are part of the Sempu Strait, are included in the administrative area of Tambak Rejo Village, Malang Regency. In these waters, there is a fishing port operational work area (WKOPP), Pondok Dadap Coastal Fishery Port which is the UPT Port of the Marine and Fisheries Service of East Java Province. This tourism zone is also a traffic flow for ships and a berth for fishing and tourist boats. The existence of the Sempu Island Nature Reserve makes the waters of Sendang Biru also a sensitive area because they will affect each other's ecosystems on Sempu Island. Utilization of space in the tourism zone can be used by several activities or utilization activities following permitted utilization regulations or permitted conditions. Tourism activities themselves are the main activities carried out in the tourism zone. The tourism activities can be carried out optimally if they are by the criteria for the suitability of the designated area. The following are the results of field measurements which are the physical and biological parameters that determine the area's suitability.

3.1. Bathymetry

After being corrected with a datum chart, the results of bathymetry measurements show that the bathymetry around the Sendang Biru Beach area ranges from 0 – 29.91 m with a gently sloping seabed contour, as shown in Fig. 2.

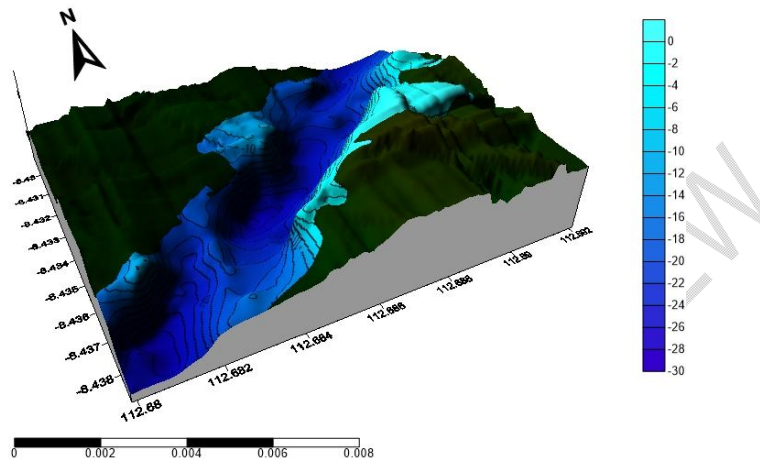
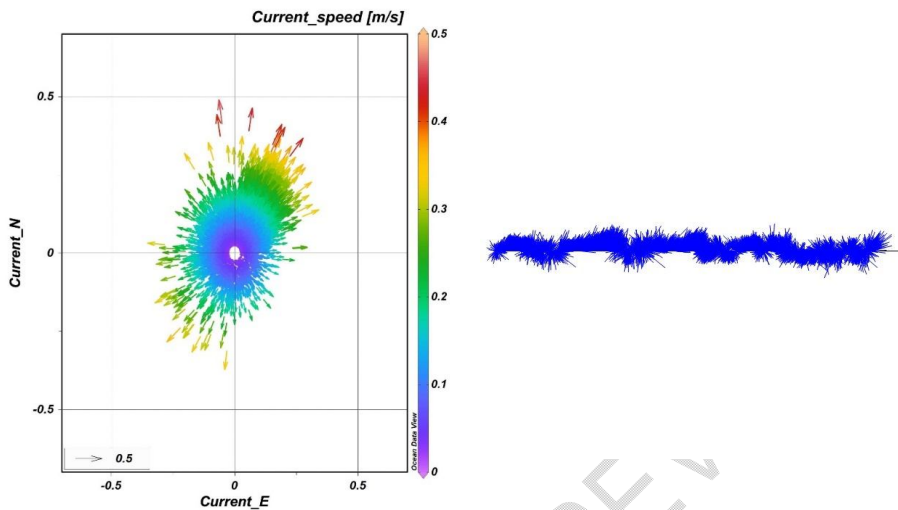


Fig.2. Bathymetry at tourism zone Sendang Biru waters and Sempu Island

The contours of the seabed with a sloping profile in the south of the Sempu Strait of Sempu Island are dominated by bays with a stretch of the sand substrate. In contrast, some steep profiles on the north side of Malang Regency are dominated by many cliffs. It is because the waters in this strait also still influence wave energy coming from the Indian Ocean, so the part that Sempu Island protects tends to be sloping. In contrast, the open part will directly influence the waves propagating in the Sempu Strait. According to [4], the southern coastal area is faced with waters with strong wave energy due to the swell from the Indian Ocean. The wave energy condition affects the geomorphological conditions of the southern coastal area dominated by steep and rocky beaches with sandy beaches interspersed. In the tourism zone of the waters of Sendang Biru and around Sempu Island, some parts of the beach have a steep morphology with cliffs, and some are sandy beaches with white and black sand types.

3.2. Currents

The currents characteristics of the waters in the tourism zone of Sendang Biru Beach and Sempu Island are influenced by tides. The west monsoon is the season when currents measurements are made. The currents direction in these waters is dominant to the Northeast and Southwest because it follows the tidal pattern, the shape of the strait, and the wind direction where the wind blows from West to East (Fig. 3).



The results of measurements of the currents speed ranged from 0.011 to 0.455 m/s. It is by Lutfi and Jauhari [5] stated that the average current velocity during the West Monsoon (December-April) and East Monsoon (June-October) was around 0.3 – 0.6 m/s. Currents in these waters belong to the category of slow (0 – 0.25 m/s) – medium (0.25 – 0.50 m/s) current [6]. Currents and tides are physical parameters that must be considered and become important when carrying out tourism activities, especially snorkeling and diving. Because Sendang Biru Beach is strait-shaped water, paying attention to these two parameters is necessary. The relationship between the two parameters is illustrated in Fig. 4, which shows that the dominant current is towards the southwest at high tide, while the current at low tide is towards the dominant tide towards the northeast.

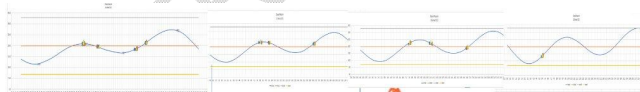


Fig. 3. Current rose and current stick plot

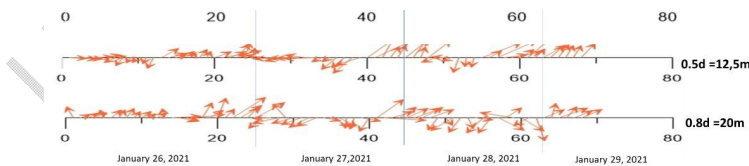


Fig. 4. Current and tidal relationship

3.3. Tide

The results of the value of the tidal harmonic constants are tabulated in Table 2.

Table 2. Tidal harmonic constants

Constants	S ₀	M ₂	S ₂	N ₂	K ₁	O ₁	M ₄	MS ₄	K ₂	P ₁
A (Cm)	199	71	29	10	26	15	1	1	8	8
g (°)	0	138	309	101	288	125	44	253	309	288

Source: analysis result

Based on the value of the tidal harmonic constants, the Formzahl (F) value is 0.41, which means that the types of tides at the waters of Sendang Biru Beach and Sempu Island is mixed tide prevailing semidiurnal (Fig. 5).

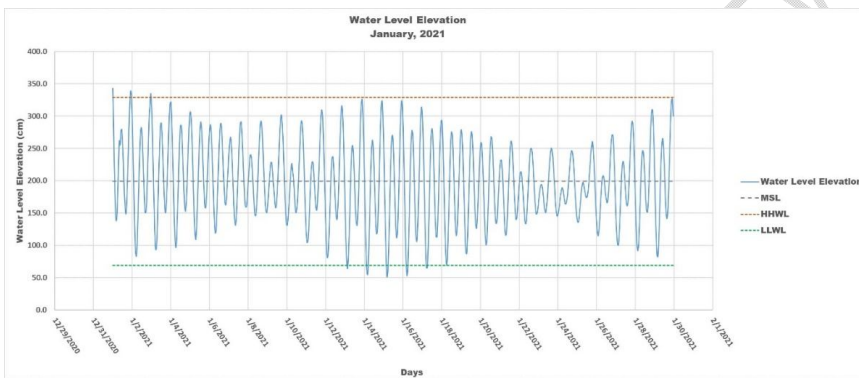


Fig.5. Tide chart

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The tides in these waters will experience 2 high tides and 2 low tides of different heights. This tidal period will determine the length of the current flowing and can be used as the basis for determining the time when traveling. The tidal range in these waters is 160 cm or 1.6 m which is included in the medium (2) class. Handartoputra, *et al.* [7] stated that the average tidal range around Sendang Biru Beach ranges from 1.0 – 2.0 m. According to [8], the tidal range will determine the speed of tidal currents, and the greater tidal range will generate a stronger current. It is in line with the current speed, which is categorized as slow-medium. These two things are significant for all tourism actors and activists. Both beach tourism, diving, and snorkeling are related to the comfort and safety of traveling.

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3.4. Temperature, salinity, pH

Temperature, salinity, and pH play a role in determining water quality and become a limiting factor for coastal ecosystems, especially coral reefs, and seagrass. The measurements of temperature, salinity, and pH up to a depth of ± 16 meters in the waters of Sendang Biru (Sempu Strait) are presented as a transverse profile in Fig. 6.

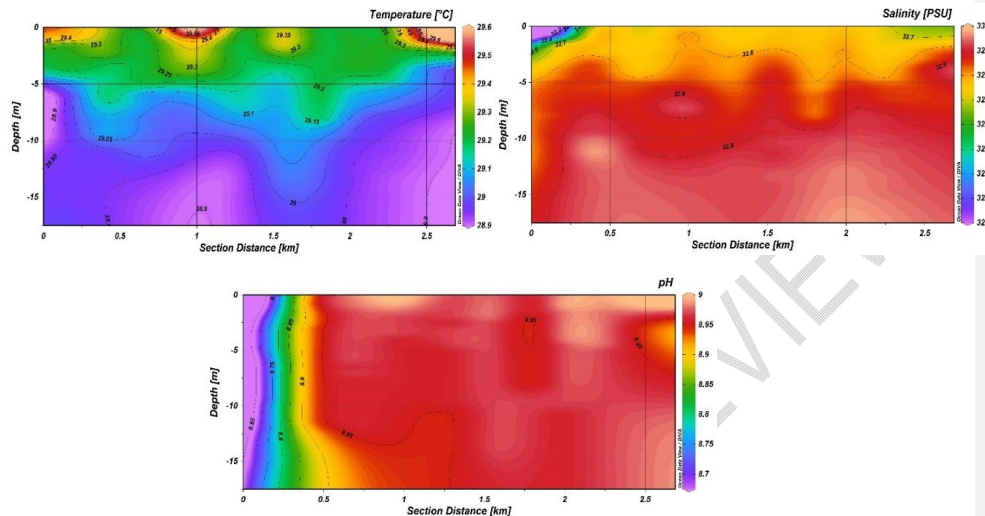


Fig.6. Transverse profile of temperature, salinity, and pH

The water temperature ranged from 28.92 – 29.82 °C. The surface temperature of the water tends to be higher and decreases with increasing water depth. On the surface of the waters between 0 – 5 m, the temperature ranges from 29.05 – 29.82°C. According to [9], the water temperature in Sempu Strait at a depth of 0 – 5 m in December (West season) ranges from 29.11 – 29.36°C. The results of temperature measurements at depths above 5 – 10 m ranged from 28.94 – 29.2°C, while temperatures above 10 – 16 m ranged from 28.92 – 29.06°C.

The salinity measurements showed a salinity range between 32.23 – 32.98 PSU. The cross-sectional salinity profile shows the homogeneity of salinity at each depth at all sampling points. The salinity distribution at a depth of 0 – 5 m ranges from 32.23 – 32.89 PSU. According to [9], salinity at a depth of 0 – 5 m in December (West season) ranges from 31.91 – 35.52 PSU. The results of salinity measurements at depths above 5 – 10 m ranged from 32.8 – 32.96 PSU, while at depths above 10 – 16 m, salinity ranged from 32.89 – 32.98 PSU.

The pH value range from 8.69 – 9.05. The pH distribution at a depth of 0-5 m ranged from 8.69 to 9.05. According to [9], the pH at a depth of 0 – 5 m in December (West season) ranges from 8.99 to 9.24. The results of pH measurements at depths above 5 – 10 m show a range between 8.74 – 8.97, while pH at depths above 10 – 16 m ranges from 8.75 – 8.97.

The Sendang Biru Waters (Sempu Strait) temperature character is high on the surface. It decreases with increasing depth due to differences in the penetration of sunlight into the water column. Temperature is a characteristic that is considered in suitability for the ecosystem environment, such as the growth of coral reefs, seagrasses, mangroves, and biota, which are objects and attractions for tourism in an area. Temperature and salinity are

limiting factors for coastal ecosystems, which are also objects of attraction for tourism activities. Temperature is also a sensitive attribute in the ecological dimension to determine the sustainability of spatial use on an island [10].

The average temperature results show the normal limit for the growth of coral reef and seagrass ecosystems, which is between 28 – 30 °C [11]. The average salinity of the waters shows a range value slightly below the quality standard value for biota, between 33 - 34 PSU. This is possible because the measurement time is in the West monsoon, where rainfall is high but is still within the salinity tolerance limit for coral and seagrass growth, which is between 25 - 40 PSU. Salinity affects coral fertility [12]. The pH parameter determines the stability of water. The pH in these waters is slightly above the range of quality standards for tourism and biota, which ranges from 7 - 8.5 but is still within the tolerance limit for underwater life. The activity from land and around the waters affects the pH value.

3.5. Coral reef and seagrass

Monitoring of coral reefs and seagrasses was carried out around the waters of Sendang Biru at the Banyu Towo Beach Bay location. The results of Reef Check monitoring at Banyu Towo Beach showed the water substrate cover consists of a living substrate, namely hard coral (HC) with a percentage of 18% and non-living substrate in the form of rock (RC) with 55%, sand (SD) 18% and rubble (RB) 9% (Fig. 7).

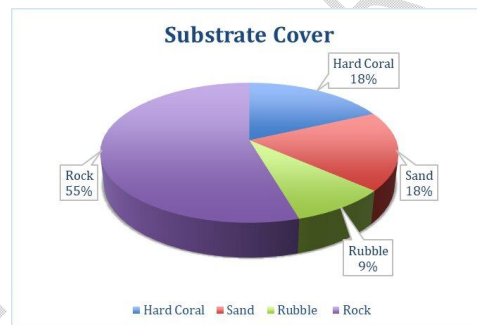


Fig. 7. Living and non-living substrate cover

The hard coral lifeforms consist of branching, massive, sub-massive *Acropora* dominance, and massive coral. Biota found several types of the blue devil (*Chrysiptera cyanea*), lik-lik (*Scolopsis bilineata*), kepe melano (*Chaetodon melannotus*), brown botana (*Ctenochaetus striatus*), bat rivet (*Thalassoma lunare*), spiny pufferfish (*Cyclichthys orbicularis*) and moss puffer (*Canthigaster compressa*), newspaper angel (*Centropyge eibli*), seabird (*Zebrasoma scopas*), betok (*Pomacentrus taeniometopon*), and rainbow armang (*Rhinomuraena quaesita*). The seagrass ecosystems found around Banyu Towo Beach are *Halophila minor* and *Halodule pinifolia* (Fig. 8).

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F **Fig.8. Coral reef and sea grass condition**

The low value of live coral cover with a percentage below 25% indicates that the coral reefs are in poor condition [13]. Luthfi, et al. [14] states that coral cover has decreased significantly with poor conditions marked by the dominance of non-living substrates in the form of rock (RC) and sand (SD) around the waters of Sendang Biru (Semut Bay, Waru-waru and Watumeja). Several factors that impact the sustainability of coral reefs, especially on coral growth in the Sempu Strait waters, include tourism factors, port waste, ship activities, and ship waste and household waste [3]. In addition, the type of coral with a slope fringing reef character on the side of Sempu Island which only lives at a depth of 1 -7 m with a hard coral typology of Poritiids, Favids, and Fungiids is the reason it is not possible to increase coral cover by 30% in a year [15].

3.6. Suitability area

Coastal and Small Islands Tourism is a subzone of the Tourism Zone, Public Use Areas in the Zoning Plan for Coastal Regions and Small Islands of East Java Province. Spatially, the suitability of the tourist area is the suitability of the space intended for various tourism activities. Some tourism activities include beach recreation, snorkeling, diving, fishing, seagrass tourism, and others. Marine tourism activities depend on physical and biological parameters. The following are the results of the overlay of the area suitability parameters for beach tourism, snorkeling, and diving (Figs. 9, 10 and 11).

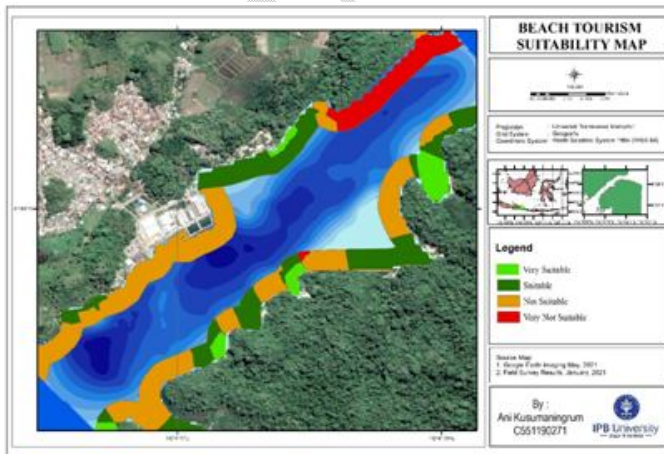


Fig.9. Beach tourism suitability map

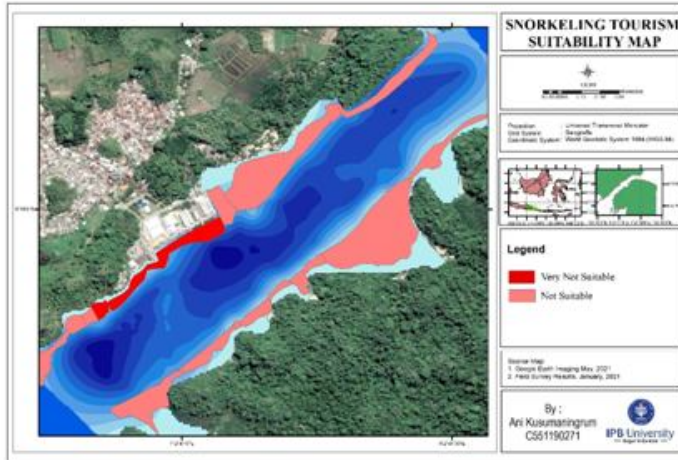


Fig.10. Snorkeling suitability map

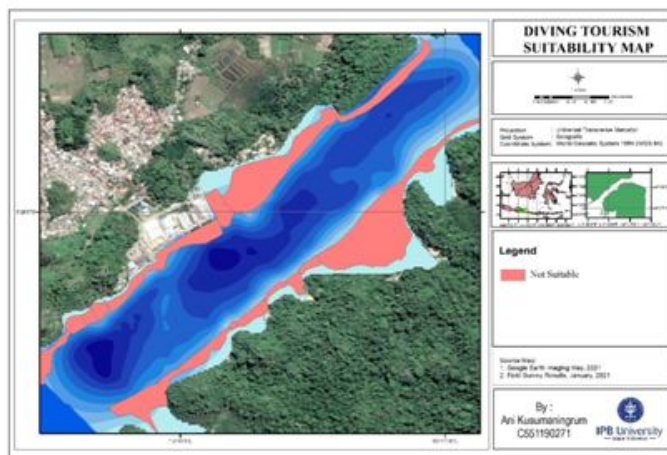


Fig. 11. Diving suitability map

The coastal waters of the Sendang Biru Beach tourism zone and Sempu Island have various complex spatial uses considering that in this tourism zone. The existing uses include ship traffic activities, mooring of ships, and fishing vessels, tourism, coastal fishing port (PPP Pondok Dadap), and beach tourism activities. Utilization of space in this zone will be more complex in line with the enactment of regulations regarding the use of what space is allowed, allowed with conditions, and which is not allowed as well as the status of the Sempu Island

Nature Reserve which limits tourism activities around Sempu Island. Based on the oceanographic parameters (physical and biological) in the coastal tourism zone of Sendang Biru and Sempu Island and based on the results of the overlay suitability parameters of the area in the tourism zone of the Sendang Biru waters, several points of the area are suitable as a sub-zone for beach tourism (Fig. 9). However, specifically for the Sendang Biru Tourism Beach, it is necessary to monitor and follow up on handling abrasion around the coast. At some points, there is abrasion/erosion caused by seawater, and this will cause a decrease in the carrying capacity of the area on this beach (Fig. 12).

For snorkeling and diving tourism, although based on the results of the overlay suitability parameters indicate a mismatch of the area as a sub-zone of mass tourism (Figs. 10 and 11), by carrying out the concept of ecotourism, this zone still has potential as a location for diving activities. It is alternatively, snorkeling in the context of protecting natural resources, education, increasing public awareness, research, and developing of science around Sempu Island, considering that this area is a sensitive area due to the status of Sempu Island as a Nature Reserve. It will align with sustainable marine development, an effort to utilize natural resources and environmental services in coastal and marine areas for human welfare, especially for stakeholders. The rate (level) of the utilization of natural resources and environmental services does not exceed the carrying capacity provided by coastal and marine areas [16].



Fig.12. Photos of the abraded condition of Sendang Biru Beach

4. CONCLUSIONS

Oceanographic characters in Sendang Biru Beach and Sempu Island's tourism zone have a steep topography sloping with a depth of 29.91 m. The tidal type is a mixed tide prevailing semidiurnal with currents that fall into slow-medium currents. These waters have a temperature, salinity, and pH which are still within tolerance limits for ecosystem growth. The bottom substrate cover consists of non-living cover, dominated by rock types, and living cover, dominated by Hard Coral species with Branching and Massive coral lifeforms dominant. Several types of seagrass ecosystems and biota are also found in the tourism zone of Sendang Biru and Pulau Sempu.

Based on the analysis suitability of the area in the Sendang Biru waters and Sempu Island tourism zone, it shows that some coastal areas are suitable and very suitable for coastal tourism activities. However, only Sendang Biru Beach can be used as a beach tourism destination according to its designation, namely the coastal/coastal natural tourism sub-zone and small islands. Although the area is not suitable for mass tourism activities, the tourist waters of Sendang Biru on this side of Sempu Island can still carry out ecotourism in the

context of protecting natural resources, education, and increasing public awareness, research, and scientific development.

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