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# Analysis of Water Suitability for Diving and Snorkeling Tourism in Darunu Tourism Village, Wori District, North Minahasa Regency

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**ABSTRACT:** The coastal waters of Darunu Village, located in Wori District, North Minahasa Regency, harbor a coral reef ecosystem with significant prospects for marine tourism sector development. This study was designed to analyze the characteristics of water environmental quality, measure the level of area suitability for diving and snorkeling activities, and establish regional carrying capacity to ensure sustainable utilization. Three observation points were established through purposive sampling technique considering depth diversity and habitat characteristics. Data were collected through the Line Intercept Transect (LIT) approach to measure coral reef coverage percentage and the Underwater Visual Census (UVC) method to record reef fish community density. Tourism Suitability Index (TSI) calculations showed that Station 2 (TSI 81.7%) and Station 3 (TSI 84.5%) fell into the highly suitable category (S1), while Station 1 (TSI 74.2%) was in the suitable category (S2). Live coral coverage percentage was recorded in the range of 72% to 83%, with reef fish density reaching 88-165 individuals per 500 m² area. Dominant coral families included Acroporidae (Acropora formosa, A. hyacinthus, A. pulchra, A. muricata, A. robusta, A. valida, A. gemmifera), Montiporidae (Montipora foliosa, M. digitata), Pocilloporidae (Pocillopora damicornis), and Merulinidae (Platygyra daedalea). Regional carrying capacity calculations indicated optimal visitor limits of a maximum of 5 people per day for diving activities and 58 people per day for snorkeling activities to maintain habitat sustainability.

**KEYWORDS:** coral reef ecosystem, tourism destination feasibility, carrying capacity, sustainable marine tourism, marine ecotourism

## 1. INTRODUCTION

Indonesia's position as one of the epicenters of global marine biodiversity is characterized by its vast coral reef areas, providing significant opportunities for the development of the marine tourism industry (Burke et al., 2018; Mahendrajaya et al., 2025). North Sulawesi, in particular, has an international reputation, with Bunaken National Park being one of the world's top diving destinations (Karauwan and Gumolili, 2023). Diving and snorkeling have become widely sought-after forms of recreation, particularly in locations with well-maintained coral ecosystems and optimal water clarity (UNEP, 2021; Pahlevi et al., 2025).

Coral reefs serve a vital function as habitats for the survival, reproduction, and feeding of diverse marine organisms, making these ecosystems highly aesthetically appealing as tourist attractions (Karauwan and Gumolili, 2023). Sustainable management of these marine resources requires comprehensive scientific studies to achieve a balance between tourism utilization and environmental conservation efforts (Suryanti et al., 2020; Karauwan, 2023).

The Darunu Village area in Wori District, North Minahasa Regency, represents a coastal zone with substantial marine tourism potential, but its utilization is still under-optimal. Currently, the primary tourism activity in the mangrove area, which is the main attraction of the "Mangrove Park," and the local economy still rely on the capture fisheries sector. Diversification into marine tourism has the potential to open up new alternative livelihoods and strengthen conservation efforts (Marasabessy et al., 2021; Amrullah et al., 2024). The study site is located not far from Bunaken National Park, which has demonstrated success in integrating tourism activities with conservation practices (Karauwan et al., 2024; Aldhana et al., 2025).

Previous studies in the North Sulawesi region, particularly around Bunaken, have noted the presence of rich coral communities with coral cover ranging from 39.5% to 82% in moderate to excellent condition (Karauwan and Solang, 2023). These findings suggest favorable conditions for tourism development. However, site-specific assessments are crucial for determining appropriate tourism activities and establishing sustainable management parameters (Littaqwa et al., 2020).

This research seeks to fill the knowledge gap regarding the marine tourism potential of Darunu Village through a holistic ecological and environmental assessment. The specific objectives of the study include: (1) identifying the characteristics of physicochemical parameters of water quality, (2) evaluating the condition of the coral reef ecosystem and reef fish density, (3) calculating the Tourism Suitability Index (IKW) for diving and snorkeling activities, and (4) determining the area's carrying capacity as a basis for a sustainable tourism management strategy.

## 2. RESEARCH METHODS

### Research Station Location and Selection

The research took place from May to August 2025 in the coastal zone of Darunu Village, Wori District, North Minahasa Regency, North Sulawesi Province, Indonesia. The study location was determined based on information from the local community regarding the presence of coral reefs and preliminary observations indicating promising tourism prospects. Three observation points were determined using purposive sampling techniques, with selection criteria that took into account depth variations and habitat characteristics, adopting an approach implemented in coral reef research in the North Sulawesi region (Karauwan and Gumolili, 2023; Marasabessy et al., 2021; Riyantini et al., 2023).

1. **Station 1** represents a shallow water zone (3-5 m depth) with a gently sloping bottom topography, particularly suitable for snorkeling. This station is located close to the coastline, where coral formations stretch along the coastal zone.
2. **Station 2** is located in the medium-depth zone (6-10 m depth), serving as a transition area suitable for both snorkeling and diving. This station exhibits moderate topographic complexity, characterized by coral slopes.
3. **Station 3** encompasses the deepwater zone (12-18 m depth) with steep vertical formations, predominantly suitable for scuba diving. Characterized by steep, wall-like reef topography and clear waters, these areas are generally home to exotic biota that attract diving tourism (Karauwan et al., 2025).

The geographic position of each station was recorded using a Global Positioning System (GPS), and depth measurements were obtained using a dive computer to ensure spatial accuracy and facilitate replication for future monitoring activities.

### Data Collection Procedure

#### Physicochemical Water Quality Parameters

Water quality measurements were conducted directly in the field (in situ) at each observation point during optimal weather conditions to minimize measurement variability. Several parameters were assessed to characterize environmental conditions relevant to coral reef health and tourism suitability (Pahlevi et al., 2025; Karauwan and Gumolili, 2023).

1. **Water clarity** was measured using a 30-cm-diameter Secchi disk, lowered vertically until it disappeared, then raised until it reappeared. The average depth of disappearance and reappearance was recorded and expressed as a percentage of visibility relative to the total depth. Water clarity is an important parameter in determining the suitability of a location for underwater tourism activities (Yulianda, 2019).
2. **Current velocity** was quantified using a mechanical current meter placed at mid-depth for three consecutive 5-minute intervals at each station. Measurements were averaged to obtain a representative current velocity value (m/s).
3. **Water temperature** was recorded using a calibrated digital thermometer and dive computer sensors at several depth intervals to detect thermal stratification patterns. Temperature values are expressed in degrees Celsius (°C).
4. **Salinity measurements** were obtained using a handheld refractometer, calibrated with distilled water before each measurement session. Salinity values were recorded in milliliters per milliliter (‰). pH measurements used a portable pH meter calibrated with standard buffer solutions (pH 4.0, 7.0, and 10.0) before field use. Dissolved oxygen (DO) concentration was determined using a portable DO meter, with measurements recorded in milligrams per liter (mg/L). All water quality parameters were compared with Indonesian seawater quality standards for marine tourism (Ministerial Decree No. 51/2004).

#### Coral Reef Assessment

Coral community assessments used the Line Intercept Transect (LIT) methodology, widely recognized for providing accurate quantitative data on coral cover and community structure (Littaqwa et al., 2020; Mahendrajaya et al., 2025; Aldhana et al., 2025). This method has been widely used in coral reef research in North Sulawesi, with reliable results (Karauwan and Solang, 2023). At each station, a 50-meter measuring tape was placed parallel to the shoreline at a predetermined depth. Data collection involved diving with scuba gear and recording conditions along the transect (Karauwan and Gumolili, 2023). Two replicate transects were established at each station, separated by 10 meters, to increase statistical reliability. Divers recorded the length of each coral

lifeform category that intersected the transect line with precision to the nearest centimeter. Coral categories documented included Acropora branching (ACB), Acropora tabulate (ACT), Acropora encrusting (ACE), Coral massive (CM), Coral foliose (CF), Coral mushroom (CMR), and additional growth forms following a standard classification system (Wahib and Luthfi, 2020). Non-living substrate categories, including dead coral, rubble, sand, and rock, were also recorded.

Coral species identification was performed in situ by trained researchers using underwater identification guides and morphological characteristics. Taxonomic classification was performed to the species level whenever possible, with special attention to dominant families. Underwater photography was systematically used for documentation and subsequent identification verification by coral taxonomists.

The percentage of live coral cover was calculated using the formula:

$$\text{Live Coral Cover (\%)} = \frac{\sum \text{Live Coral Length}}{\text{Total Transect Length}} \text{ X } 100$$

Coral reef health status is classified according to Indonesian environmental standards: very good (76-100%), good (51-75%), moderate (26-50%), and poor (<25%) (Aldhana et al., 2025).

**Reef Fish Survey**

Reef fish communities were assessed using the Underwater Visual Census (UVC) methodology, conducted concurrently with the coral survey to maximize diver efficiency and maintain temporal consistency (Riyantini et al., 2023; Anim, 2020; Karauwan et al., 2022). Two trained observers conducted fish surveys along the same 50-meter transects used for the coral assessments, with each observer responsible for monitoring one side of the transect. The survey area extended 2.5 meters on each side of the transect line, creating a total survey corridor 5 meters wide and 50 meters long (250 m² per transect). Observers swam at a consistent speed along the transect, recording all reef fish species encountered within the designated survey corridor. Recorded data included taxonomic identification (at least to genus level), abundance counts, and size class estimates (Febrianti et al., 2020). Fish abundance was standardized and expressed as individuals per 500 m² to facilitate comparisons between stations and with other studies. Particular attention was paid to indicator species families including Chaetodontidae (butterflyfish), Pomacentridae (damselfish), and Labridae (wrasse), which showed strong associations with coral reef health status (Setiawan et al., 2020).

**Data Analysis**

**Tourism Suitability Index (TSI)**

The tourism suitability assessment used the Tourism Suitability Index (TSI) methodology developed by Yulianda (2019) and modified by Marasabessy et al. (2021) for the context of Indonesian marine tourism. This analytical framework has been applied in various studies of dive tourism suitability in North Sulawesi, including in Bunaken National Park (Karauwan and Gumolili, 2023). This framework evaluates several environmental parameters, assigning weighted scores based on their relative importance to tourism activities:

$$IKW = \sum i=1n(NmaksNi) \times 100$$

Where IKW represents the Tourism Suitability Index (%), Ni represents the score for parameter i (weight × score), and $N_{max}$ represents the maximum possible score for the tourism category.

Parameters evaluated include water clarity, current velocity, depth, coral cover, fish abundance, and coral lifeform diversity. Each parameter receives an assigned weight reflecting its significance to the visitor experience and safety considerations. The suitability classification follows predefined categories: Very Suitable/S1 (IKW ≥ 2.5 or 83-100%), Suitable/S2 (2.0 ≤ IKW < 2.5 or 50-<83%), Conditionally Suitable/S3 (1.0 ≤ IKW < 2.0 or 33-<50%), and Not Suitable/TS (IKW < 1.0 or <33%) (Suryanti et al., 2020; Karauwan and Gumolili, 2023; Amrullah et al., 2024).

**Area Carrying Capacity Analysis**

Carrying capacity calculations determine the maximum number of visitors that can be accommodated while maintaining ecosystem integrity and the quality of the visitor experience. Physical Carrying Capacity (PHC) is calculated using the formula:

$$DDK = Lt \times WtA \times Vt$$

Where A represents the effective area (m²), Vt represents the visiting time per day (hours), Lt indicates the time required per visit (hours), and Wt represents the area required per visitor (m²).

Real Carrying Capacity (RDC) incorporates correction factors that address environmental limitations and management considerations:

**RDC=RDC×(Cf1×Cf2×...×Cfn)**

Correction factors considered include ecosystem fragility, environmental conditions, accessibility, and management capacity, following the methodology established by Yulianda (2019) and adapted to local conditions.

**Statistical Analysis**

Data analysis used SPSS version 26 for statistical calculations. Descriptive statistics (mean, standard deviation, range) characterized environmental parameters and biological metrics. Analysis of variance (ANOVA) tested for significant differences between stations, with Tukey's HSD post-hoc test identifying station-specific differences. Correlation analysis examined the relationship between environmental parameters, coral cover, and fish abundance. Statistical significance was determined at $\alpha = 0.05$.

## 3. RESULTS AND ANALYSIS

### Physico-Chemical Water Quality

The results of the water quality assessment indicate generally favorable environmental conditions at all stations, meeting Indonesian seawater quality standards for marine tourism activities (Table 1). This water quality is comparable to that found in the coral reefs of Bunaken National Park, known as a world-class diving destination (Karauwan and Gumolili, 2023).

**Table 1. Physico-Chemical Water Quality Parameters at Three Observation Stations in Darunu Village**

| Stasiun | Visibility (%) | Temperature (°C) | Salinity (‰) | pH | DO (mg/L) | current (m/s) |
|---|---|---|---|---|---|---|
| **1** | 100 | 29,4 | 33 | 8,1 | 7,1 | 0,18 |
| **2** | 97 | 29,2 | 34 | 8,2 | 6,9 | 0,22 |
| **3** | 95 | 28,8 | 34 | 8,1 | 7,2 | 0,25 |

Water transparency values were excellent at all stations, ranging from 95-100%, indicating minimal water column turbidity and optimal conditions for underwater visibility. Station 1 exhibited perfect transparency (100%), likely due to its shallow depth and proximity to clear waters. This transparency level significantly exceeds the minimum requirements for diving and snorkeling and is comparable to the 3-10 meter clarity at top Bunaken dive sites (Karauwan and Gumolili, 2023; Pahlevi et al., 2025).

Water temperatures ranged from 28.8°C to 29.4°C, within the optimal range for tropical coral reef ecosystems (26-30°C) and comfortable for extended recreational diving. The slight temperature decrease observed at Station 3 reflects the normal thermocline pattern in deeper waters. This temperature regime supports coral metabolism and calcification processes while providing comfortable conditions for tourists (Mahendrajaya et al., 2025).

Salinity measurements (33-34‰) remained within the normal oceanic range, indicating minimal freshwater influence and stable ocean conditions. Current velocities increased progressively from Station 1 (0.18 m/s) to Station 3 (0.25 m/s), following the expected pattern of intensified water movement in deeper areas. These moderate current velocities enhance nutrient delivery to the coral community while remaining manageable for recreational diving (Riyantini et al., 2023).

The pH value (8.1-8.2) remained within the optimal range for coral reef ecosystems, indicating adequate buffering capacity and minimal acidification stress. Dissolved oxygen concentrations (6.9-7.2 mg/L) exceeded the minimum requirements for marine life, reflecting healthy ecosystem metabolism and adequate water circulation patterns (Aldhana et al., 2025).

### Coral Reef Community Structure

Coral reef assessment results revealed robust coral communities at all stations, with live coral cover ranging from 72% to 83% (Table 2). This coverage value classifies the reefs as "good" to "very good" according to Indonesian coral reef health standards, indicating minimal anthropogenic disturbance and favorable environmental conditions. This condition is comparable to coral cover at various dive sites in Bunaken National Park, which ranges from 39.5% to 82% (Karauwan and Solang, 2023; Littaqwa et al., 2020).

**Table 2. Coral Cover and Health Status At Observation Stations**

| Station | Live Coral Cover (%) | Health Category |
|---|---|---|
| **1** | 72 | Good |
| **2** | 79 | Very Good |
| **3** | 83 | Very Good |

Station 3 exhibited the highest coral cover (83%), characterized by extensive coral growth on vertical wall substrates with diverse coral morphologies. With its steep, wall-like reef topography and clear waters, this area harbors an attractive array of exotic biota, typical of high-quality dive sites in North Sulawesi (Karauwan et al., 2025). The deeper waters and stronger currents at this station likely increase nutrient delivery and reduce sedimentation stress, promoting robust coral growth (Mahendrajaya et al., 2025).

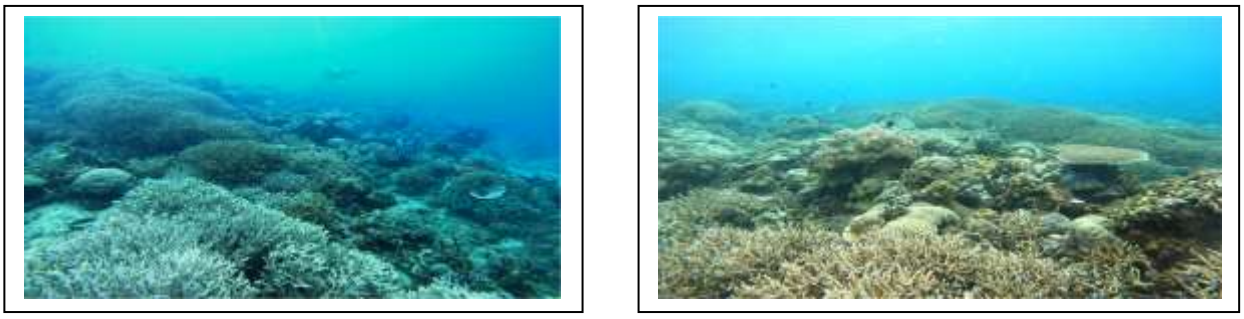

**Figure 1. Coral Reef Ecosystem in Darunu Waters**

Taxonomic analysis identified eleven coral species from four families, with a clear dominance of fast-growing Acropora species (Table 3). This pattern of Acropora dominance is consistent with findings from high-quality coral reef sites in the Bunaken area (Karauwan and Gumolili, 2023).

**Table 3. Coral species composition in the waters of Darunu Village**

| Family | Spesies |
|---|---|
| Acroporidae | *Acropora formosa*, *A. hyacinthus*, *A. pulchra*, *A. muricata*, *A. robusta*, *A. valida*, *A. gemmifera* |
| Montiporidae | *Montipora foliosa*, *M. digitata* |
| Pocilloporidae | *Pocillopora damicornis* |
| Merulinidae | *Platygyra daedalea* |

The Acroporidae family dominated the community composition, represented by seven species. The dominance of Acropora species indicates favorable environmental conditions and relatively low anthropogenic stress, as these corals are sensitive to water quality degradation and sedimentation (Littaqwa et al., 2020). The presence of Pocillopora damicornis from the Pocilloporidae family was also found, as recorded at various dive sites in Bunaken with an average growth of 7 cm (Karauwan and Gumolili, 2023).

**Reef Fish Community**

Reef fish surveys documented substantial abundance and diversity, with clear trends of increasing richness and abundance at deeper stations (Table 4). These patterns reflect the strong dependence of reef fish communities on coral habitat complexity and structural diversity (Riyantini et al., 2023; Setiawan et al., 2020).

**Table 4. Abundance and diversity of reef fish at observation stations**

| Station | Genus Richness | Abundance (ind/500m²) | Dominant Family |
|---|---|---|---|
| 1 | 18 | 88 | Pomacentridae |
| 2 | 24 | 135 | Labridae |
| 3 | 28 | 165 | Chaetodontidae |

Station 3 showed the highest fish abundance (165 individuals/500 m²) and genus richness (28 genera), with the Chaetodontidae family (butterflyfish) dominating the community composition. Chaetodontidae species function as excellent coral reef health indicators due to their obligate dependence on live coral for feeding. The presence of these indicator fish such as Chaetodontidae demonstrates healthy ecosystem conditions, as also observed in successful coral transplantation areas in Bunaken (Karauwan et al., 2022).

The progressive increase in fish abundance and diversity with depth parallels the pattern of increasing coral cover and structural complexity, demonstrating the fundamental importance of coral habitat quality for supporting diverse fish assemblages (Mahendrajaya et al., 2025).

**Figure 2. Reef Fish Community Structure in Darunu Waters**

**Tourism Suitability Assessment**

Tourism Suitability Index (TSI) analysis revealed differential suitability across stations, reflecting variations in depth, coral conditions, and fish abundance (Table 5). All stations achieved S2 (Suitable) or S1 (Highly Suitable) suitability ratings, indicating strong overall tourism potential for the study area, as also found at various dive points in the Bunaken area (Karauwan and Gumolili, 2023; Marasabessy et al., 2021).

**Table 5. Tourism Suitability Index values for diving and snorkeling activities**

| Station | Activity | TSI (%) | Category |
|---|---|---|---|
| 1 | Snorkeling | 74,2 | S2 |
| 2 | Snorkeling | 81,7 | S1 |
| 3 | Diving | 84,5 | S1 |

Station 3 achieved the highest TSI value (84.5%), classified as Highly Suitable (S1) for diving activities. This high rating reflects excellent coral cover (83%), high fish abundance (165 ind/500 m²), optimal depth range (12-18 m), and diverse coral morphology providing visual interest. The combination of vertical wall formations and high biodiversity creates an outstanding diving experience comparable to renowned dive destinations such as Lekuan 2 and Fukui dive points in Bunaken Island (Karauwan and Solang, 2023; Karauwan et al., 2025; Suryanti et al., 2020).

These TSI values demonstrate that Darunu Village possesses substantial marine tourism assets suitable for development as a diving and snorkeling destination. The presence of multiple suitable sites with varying characteristics allows for tourist segmentation and activity diversification, enhancing destination appeal and economic potential (Yulianda, 2019).

**Area Carrying Capacity Analysis**

Carrying capacity calculations establish maximum visitor limits that are essential for maintaining ecosystem integrity and visitor experience quality (Table 6). These values provide critical guidance for tourism management planning and regulation development.

**Table 6. Carrying capacity for diving and snorkeling activities**

| Activity | Effective Area (m²) | PCC (people/day) | RCC (people/day) |
|---|---|---|---|
| Diving | 12,800 | 51 | 5 |
| Snorkeling | 145,600 | 582 | 58 |

Diving activities demonstrate a Real Carrying Capacity (RCC) of 5 people/day across the effective diving area of 12,800 m². This relatively low capacity reflects several correction factors including ecosystem fragility, safety considerations, and environmental limitations.

**Figure 3. Diving in Darunu Waters**

## 4. CONCLUSION

- This comprehensive assessment demonstrates that Darunu Village possesses exceptional marine tourism potential, with coral reef ecosystems showing good to very good health status comparable to high-quality reef areas in North Sulawesi such as Bunaken National Park (Karauwan and Gumolili, 2023). Physical-chemical water quality parameters meet international standards for recreational diving activities. Live coral cover ranging from 72% to 83% supports diverse fish assemblages of 88-165 individuals/500 m², creating highly attractive underwater environments for tourism development.
- Tourism Suitability Index analysis classified Station 2 and 3 as Highly Suitable (S1) for snorkeling and diving respectively, while Station 1 achieved Suitable (S2) status for snorkeling activities. Carrying capacity calculations established sustainable visitor limits of 5 people/day for diving and 58 people/day for snorkeling.
- Marine tourism development in Darunu Village must follow ecotourism principles, incorporating environmental education, local community participation, and sustainable ecological monitoring, as has been implemented in the Bunaken National Park area (Karauwan, 2023). Implementation of carrying capacity limits through reservation systems and visitor management protocols will be critical for long-term sustainability.
- Future research priorities should include seasonal monitoring of coral health and fish populations, assessment of tourism impacts after development initiation, and studies on coral reef restoration techniques such as coral transplantation that have proven successful at other locations in North Sulawesi (Karauwan et al., 2024). These research directions will support an adaptive management approach that is essential for maintaining both ecological integrity and economic viability over extended time frames.

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