Ecological characteristics of mangroves and coral reefs at Central Weda Sub-District, North Maluku

M R Lessy¹, J Bemba¹, N Wahiddin², Supyan², I Taeran³, Z Galitan⁴
¹Program Studi Ilmu Kelautan- Universitas Khairun, Ternate – Indonesia
²Manajemen Sumberdaya Perairan– Universitas Khairun, Ternate-Indonesia
³Pemanfaatan Sumberdaya Perikanan - Universitas Khairun, Ternate-Indonesia
⁴Sekolah Tinggi Ilmu Maritim Indonesia, Ternate – Maluku Utara

*Corresponding Author: mrlessy8375@gmail.com

Abstract: Increase of human activities on coastal area in Central Weda Sub-District has caused degradation of coastal ecosystems. Even though coastal ecosystems have an essential role in marine ecology, such as coral reefs and mangrove forests, they are sometimes undermined by economic or commercial interests. This study aimed to determine density and cover percentage of mangrove forests and coral reefs in Central Weda Sub-district, North Maluku. Data collection on coral reef ecosystem components was carried out by applying georeferenced photo-transect and line transect quadrat techniques. While for mangroves, data collection included species diversity and tree/canopy cover percentage. Study result showed that based on lifeform percentage of coral reefs, most of the study areas were in a good category with 23.95% coverage, moderate condition 39.5%, and poor condition 36.6%. The coral reefs in good and moderate conditions were found at location having relatively low human activities. Whereas percentage of mangrove cover from all stations ranged from 78.39 to 78.76% with Important Value Index ranging from 106.79% to 158.32%.

1. Introduction
Coastal ecosystems have an important ecological functions in marine environment. For example, coral reefs and mangrove forests are sanctuary and feeding ground for almost all marine organisms. Mangroves and coral reefs also provide many benefits to people, particularly those who live in coastal areas. They provide livelihoods for fishers. They also provide indirect benefits for the coastal and marine ecosystem. They protect coastal areas from erosions, cyclones, sea-level rise, and also tsunami.

Unfortunately, increase of human activities in coastal areas has caused degradation of the coastal ecosystems. For example, tin mining in Bangka Belitung decreased mangrove areas from 2,807.79 hectares in 1997 to 1,596.38 ha in 2014. Commercial mangrove timber exploitation during at last 30 years has been increased from 11,000 ha to 36,000 ha. Other activities that decline area and quality of mangrove forests and coral reefs are development of brackish-water fish ponds, land use conversion, and natural disaster.

Research about coastal ecosystems, particularly mangrove forests and coral reefs in the central Weda sub-district, North Maluku, is still limited to date. Several research had been conducted such as by [1] on identification of mangrove species and community structure evaluation in Weda Bay; [2] on density and diversity of seaweed in Weda Bay, and [3] focused on distribution patterns and abundance of Halmahera walking shark in Weda Bay. The research focused on mangrove forests, and coral reefs...
in Central Weda Sub-district are essential due to increasing pressure from mining activities, land-use conversion, and other human activities. By conducting research continuously, changing of coastal ecosystems or habitats could be well understood. Therefore, this study aimed to determine density and cover percentage of mangrove forests and coral reefs in Central Weda Sub-district, North Maluku. This study would provide data and information that was critical for better coastal management in the future.

2. Materials and methods

2.1 Study areas

Geographically, study areas were a part of Weda Bay which was located in Central Halmahera Regency. Since Weda bay has very large area, the study were focused on mangrove forests and coral reefs ecosystem located at Lelilef Sawai, Lelilef Woibulen, and Gemaf villages (Figure. 1). Those three villages are close to mining activity area.

![Figure 1. Study location in Central Weda Sub-District – North Maluku](image)

2.2 Data collection and analysis

Coral reefs data collection and analysis

A total of 14 observation points were selected as coral reef sampling locations. Data collection on coral reef ecosystem components was carried out by applying georeferenced photo-transect and line transect quadrat techniques [4],[5]. Georeferenced photo-transect is a survey technique where data is collected by snorkeling method. Then, recording of basic habitat was done by used of underwater camera equipped with GPS placed on a buoy or carried by a swimmer. This technique is good to apply for shallow areas such as large reef flats and area where data collection by diving is not possible.

The Underwater Photo Transect technique is a data collection technique by placing a 1x1 m quadrant on a 30 m long transect with a quadrant placement distance of 1 meter on each left and right side of the transect, so the total number of quadrant placements is 31 times per transect. Coral and benthic data at each quadrant was recorded using an underwater digital camera with approximately distance of 120 cm between camera and benthic objects. This technique is applied to deeper areas such as slope area of coral reefs.

The data was then analyzed to find information about coral species (or genus), condition of coral reefs, and total area of coral reefs at study site. All those data and information would be processed
geographically and presented on maps. All quadratic photos were analyzed using the Coral Point Count with Excel extensions-CPCe application [6]. This application is a standalone application developed for automatic and quick random point counts analysis. Data analysis included percentage of coral cover which was calculated based on the comparison of number of points of each object and total number of points with equation developed by [4].

The percentage cover analysis was then used to determine condition of coral reefs referring to the category of percentage cover as established by the Indonesian Ministry of Environment with following criteria: Very good: 75-100%; Good: 50-74.5%; Moderate: 25-49.5%; and Poor: 0-24.5% [7].

**Mangrove forest data collections and analysis**

Total five data sampling stations were chosen for mangrove study. Data collected included species diversity and tree/canopy cover percentage. Species diversity data collected included: 1) Seedlings, all sprout to young plants up to 1.5 m high; 2) Saplings, all plants higher than 1.5 m with a DBH of less than 10 cm; 3) Trees, all plants with a DBH of more than 10 cm. The data collecting through the multiple quadrats in the belt transect method [8]. In this method, the sampling plots were constructed in various sizes of quadrats where sampling plot for seedlings was 2 x 2 m, for saplings 5 x 5 m, and for trees 10 x 10 m. Vegetation structures of mangroves were analyzed by calculating relative density, relative frequency, relative coverage, and importance value index (IVI). Water quality was analyzed by measuring pH, Dissolved Oxygen (DO), Total Suspended Solid (TSS), salinity, and temperature.

Percentage of mangrove canopy cover was calculated using hemispherical photography method. Canopy cover data was collected by using a camera equipped with a fish-eye lens having an angle of view of 180° at one point of taking photos [9],[10]. Captured photos were then analyzed using ImageJ software. This analysis aimed to separate sky pixels and mangrove canopy cover so that the percentage of mangrove canopy cover pixels could be calculated in binary image analysis [11]. The photos from the field measurements were then converted into an 8-bit format so that the value format is 0 to 255. The 8-bit formatted photo were then separated between canopy cover and sky using threshold tools on the ImageJ software. The value 0 was sky pixel and the value 255 was canopy cover pixel. The percentage of canopy cover was calculated using the formula:

\[
\% \text{ Mangrove Cover} = \frac{P_{255}}{P} \times 100\%
\]

The criteria for mangrove forests condition was determined based on the Ministry of Environment regulation with the following criteria: good: >75%; Moderate: 50-75%; Poor: 0-50% [7].

**3. Result and discussion**

**3.1 Coral reefs covers**

Study results found that total area of coral reefs over the study area was about 270.2 hectares. Types of coral reefs consisted of fringing reefs and patch reefs. The fringing reefs dominated study areas, while patch reefs were only found around Tanjung Ulie and west of Gemaf village (at locality called Batepo Cape). Geomorphologically, most coral reefs in study areas grew in reef flat areas and front reefs (sloping areas). The fringing reef grew at depth of 8 - 10 m, while the patch reefs were mostly found at depth of 20 - 25 m.

Based on coral lifeform percentage, most coral reef over the study areas was in a good category (23.95%), moderate condition 39.5%, and poor condition 36.6%. Coral reefs with good and moderate conditions were found in areas with relatively low human activities pressure. Vice versa, poor coral reefs were found close to coastline that affected by high intensity of human activities and mining area (Figure 2). Percentages of coral reefs cover from each station are shown in Figure 3. Study results on composition of coral reef ecosystem at all observation stations at a depth of 5 meters showed that components of hard coral *Acropora* were about 29.1%; hard coral non-*Acropora* were around 21.1%; algae 16.8%; other fauna 13.9%; sand 9.3%; and rubble 9.8%. Meanwhile, at a depth of 10 meters, the
composition of coral reef ecosystem consists of hard coral *Acropora* 18.3%; hard coral non-*Acropora* 26.2%; algae 16.2%; other fauna 21.6%; sand 8.7%, and rubble 9.0%.

**Figure 2.** Map of coral reefs condition in study areas

![Figure 2](image)

**Figure 3.** The percentages of coral reefs cover on each station

![Figure 3](image)

3.2 Composition and density of mangrove forest

Ground survey was carried out at 4 stations inside study area at Central Weda sub-district. Field studies results indicated that three species of mangroves dominated study area. The three mangrove species were *Sonneratia sp*, *Rhizophora sp*, and *Bruguiera sp*. Mangroves found in these areas grew on argillaceous, sandy soil land and sand, with a high salinity range and typical rooting system which resistant to strong waves.
Overall, based on imaginary satellite analysis, total area of mangrove forests in the study area was about 19.92 ha, around 3.8 ha in the 1st station, 7.04 ha in the 2nd station, 7.64 ha in the 3rd station and 1.44 ha in the 4th station.

Tree species with the highest density in the study area was *Rhizophora sp* with 400 trees/ha, followed by *Bruguiera sp* 240 trees/ha, and *Sonnetaria sp* 100 trees/ha. *Rhizophora sp* had the highest density because this mangrove type had good regeneration ability and was supported by appropriate circumstances to grow. Mangrove forests in this location were relatively less than other sub-districts in Central Halmahera Regency. [12] found that mangrove forests in Loleo village, South Weda Sub-district was 170 ha.

Mangrove community structure in the study area is presented in Table 1. Calculation results of relative density, relative frequency, relative tree cover, and importance value index (IVI) in Table 1 combine all the five stations for each level of life stage (trees, saplings, and seedlings). The highest number of mangrove species frequency in all study sites was *Rhizophora sp*. Frequency data indicated that *Rhizophora sp* grew widely and this species could be found in every sampling location. Importance Value Index showed role of each species in mangrove community. Based on the measurement, the highest Importance Value Index was found on *Rhizophora sp*. The Importance Value Index was related to *Rhizophora sp* wide distribution and it is valuable for the mangrove community. Most of the mangrove genera and families are closely related to each other, but what they have in common is their highly developed morphological, biological, physiological, and ecological adaptability to extreme environmental conditions. Measuring water quality describes mangrove habitat condition in terms of its physical and chemical properties. Parameters data of temperatures, pH, DO, brightness, TSS, salinity indicated that the habitat in the study locations is relatively suitable for mangrove growth (Table 2).

| Level | Relative Density of Species (Rdi) (%) | Relative Frequency species (RFi) (%) | Relative Closure Species (RCi) (%) | Important Value Index (IVI) (%) |
|-------|-------------------------------------|------------------------------------|-----------------------------------|-------------------------------|
| Tree  | 54,89                               | 56,78                              | 46,65                             | 158,32                        |
| Sapling | 32,89                              | 30,23                              | 43,67                             | 106,79                        |
| Seedling | 48,65                             | 47,64                              | 49,23                             | 145,52                        |

Table 2. The environmental parameters in study location

| Parameters | Units | Tools | Stations 1 | Stations 2 | Stations 3 | Stations 4 | *Standart Quality |
|------------|-------|-------|------------|------------|------------|------------|-------------------|
| Temperature | °C    | Thermometer | 29,5       | 29,3       | 29,54      | 29,03      | Natural           |
| pH         | -     | pH Meter   | 7,4        | 7,35       | 7,43       | 7,23       | 7 - 8,5           |
| DO         | mg/L  | DO Meter   | 7,3        | 6,5        | 7,54       | 6,32       | >5                |
| Turbidity  | mg/L  | Secci Dish | 8          | 7          | 6          | 6          | >6                |
| TSS        | mg/L  | Ex-Situ    | 52,32      | 48,65      | 45,65      | 47,54      | 20                |
| Salinity   | %     | Refractometer | 21         | 19         | 25         | 24         | 34                |

Note: * Decree of the Minister of Environment No.51/2004.

The condition of environmental parameters in the study location presented in Table 2 shows that salinity, substrate, and temperature may affect mangrove density and species composition. Salinity affects growth and density of mangroves, which is based on results that area closer towards the sea has higher salinity. Mangrove is not a plant that needed salt, but mangrove is a plant that is tolerant of salt.
According to [13], range of salinity for *Rhizophora mucronata* is 12 - 30 ppt based on research in coastal areas of Torosiaje Jaya Village, 21.5 to 22 ppt for *Bruguiera gymnorrhiza*, and 20 to 21.5 ppt for *Rhizophora stylosa* species. Therefore, the coastal of Torosiaje Jaya Village is a coastal region that can support the growth of those three dominant species.

Various types of mangroves overcome salinity levels in different ways. *Rhizophora*, for instance, secretes excess salt through the glands under its leaves to overcome high salinity. The absorbed water has almost become freshwater, with 90-97% of salt content in seawater were unable to pass through this root filter. Salt from the plant body was accumulated in the old leaves and wasted along with fall leaves. Mangrove vegetation should seek to maintain water because of the difficulty in obtaining fresh water.

Based on observations of air temperature at the study area ranged from 29.03 to 29.54°C. At observation stations, high temperature caused by sunlight was still hindered by mangrove canopy so that temperature becomes lower. Temperatures in the coastal mangrove forests Torosiaje Jaya Village was in range that supported mangroves growth [14]. Further [14] stated that if temperature was higher than 35°C, it would give unfavorable influence on photosynthesis process so that mangrove growth could be hampered.

Results of hemispherical photography analysis conducted on mangrove vegetation at four stations showed that percentage of mangrove canopy cover at all stations ranged from 78.39 to 78.76% (Fig. 4). Based on the Ministry of Environment regulation, mangrove forest cover at study area were in good condition category.

![Histogram of Cover](image1)

![Histogram of St](image2)

**Figure 4.** Mangrove vegetation cover at study locations using image soft rating
4. Conclusion
Overall, the present study informs that mangrove forests and coral reefs in the study area require better attention. It was indicated by cover percentage of coral reefs ranging from moderate to poor categories, while its mangrove forest was in good condition. All stakeholders need to take actions to established an effective sustainable management of these two coastal resources.

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