Life form, diversity, and spatial distribution of macroalgae in Komodo National Park waters, East Nusa Tenggara

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Abstract. Komodo National Park is one of the favorite destinations for both domestic and international marine tourism. Marine tourism activities have caused environmental changes and impact on fisheries and marine resources. Macroalgae were also affected by the environmental changes, so management of macroalgae was required. Ecological data of macroalgae can be used as baseline data for coastal area management. The study aimed to determine the life form, species composition, spatial distribution, and ecological aspects of macroalgae assemblages in Komodo National Park waters. The study was conducted in September 2013, in eight locations, namely Setuga, Komodo Karang Makasar, Padar Kecil, Padar, Papagarang, Mangaitan, and Muntia island. Macroalgae samples were collected by the quadratic transect method. The data analyzed were Sorensen’s similarities. A total of 42 species of macroalgae were recorded, consisting of three Phylum: Chlorophyta (19 species), Ochrophyta (8 species), and Rhodophyta (15 species). Epilithic was the dominant life form of macroalgae. In general, macroalgae can be stably attached to hard substrates. The highest macroalgae diversity was found on Mangaitan Island (22 species). Halimeda and Amphiroa were macroalgae that can be found in almost all locations. Setuga Island had similar macroalgae with both Mangaitan and Muntia islands. The differences in the number of macroalgae species were influenced by environmental pressure, topography, and substrate profile. Management of macroalgae resources was needed to maintain the sustainability of the macroalgae ecosystem.

Keywords: diversity, Komodo National Park, macroalgae, marine resource

1. Introduction
Indonesia is an archipelagic country that has thousands of islands surrounded by exotic oceans. Geographical location and natural conditions make several islands in Indonesia become marine tourism destinations [1]. The Indonesian government has designated Komodo National Park (KNP) as a super-premium and exclusive destination [2]. The KNP is one of the seven wonders of the world [3]. Currently, KNP is one of the favorite destinations for both domestic and international marine tourism. The number of tourists visiting KNP increases every year. Even on eight months in 2018, the number of tourists reached 126,599 people [3]. However, the development of marine tourism can cause problems of environmental damage due to the construction of buildings, yacht crossing, and tourism activities [1]. Tourism activities (snorkeling, diving, fishing, daily trips, reef-walking), land-based pollution, and sedimentation contribute to the degradation of coastal waters. Yacht and cruises also contribute to water and air pollution (due to waste disposal and gas emission) [1, 4, 5]. Marine tourism activities have caused...
environmental changes and impact on fisheries and marine resources. Macroalgae were one of the marine resources; it was also affected by environmental changes.

Macroalgae are important elements in coastal ecosystems. The role of macroalgae in coastal ecosystems are as primary producers, nursery ground (for juvenile of sea urchins, crabs, prawns, mollusk), provide shelter (for fish, sea urchins, crabs, prawns, mollusk), and food source for other marine organisms (herbivorous fish, sea urchins, mollusk) [6, 7]. Macroalgae were also as CO$_2$ sink, it related to their role in climate change mitigation [8-13]. The important of the study, so management of macroalgae and other marine resources were required.

There was no information on the diversity and distribution of macroalgae in KNP waters. The important role of macroalgae in the coastal ecosystem and the limited data and information of macroalgae in KNP and its surroundings, so this research was conducted as baseline data for more complex ecological studies in the future. This study was also for the proper management of macroalgae resources. This study aimed to determine the diversity, distribution, and life forms of macroalgae in KNP waters.

2. Materials and methods

2.1. Study site

KNP waters had three ecosystems, namely mangroves, seagrasses, and coral reefs. Mangroves were still good and dominated by *Rhizophora* sp. Seagrass was dominated by *Enhalus* sp. The lowest tide was 50 cm. Komodo National Park had three main islands, namely Rinca, Padar, and Komodo Island. Furthermore, there were many small islands surrounding the main islands. The research was carried out on both the main and small islands. The research was conducted using the research vessel Baruna Jaya VIII. The research was conducted in September 2013 at eight island (Figure 1), namely Setuga (S:08°32'22,7"; E: 119°34'62"), Komodo (S:08°52'30,0"; E:119°56'97,9"), Karang Makasar (S:08°31’0,71”; E:119°35’1,32”), Padar Kecil (S:08°39’1,4”; E:119°34’11”), Padar, Papagarang (S:08°34’41,6”; E:119°43’0,1”), Mangaitan, dan Muntia (S:08°33’5,7”; E:119°49’29,6”).

![Figure 1. Map of the study of macroalgae in Komodo National Park waters.](image-url)
2.2. Sampling of macroalgae

Macroalgae were collected by the quadrat transect method. Quadrat transects were carried perpendicular to the coastline toward to edge. The length of the transect was 100-150 m according to the width of the beach. Each research location was conducted in three transects with a distance of 100 m. Each transect consists of 10 transect points (frame) so that each research location consists of 30 transect points (frames). Macroalgae in the frame (1 m²) was taken to examine biomass and species macroalgae [14, 15]. Macroalgae collection was also done outside the transect frame. Macroalgae collections outside the transects frame were carried out to identify macroalgae that grow in the study site but were not found in the transect frame. Macroalgae samples were weighed and sorted based on species of macroalgae.

2.3. Sampling of substrate

Substrate samples, especially sediments, were taken at each transect. Sediment was dried using an oven at a temperature of 80°C for 48 hours. After drying, the sediment was be strained using a mesh filter with 35, 120, and 230 mesh sizes. The filter size of 35 mesh was for silt (mud), while the filter size of 120 and 230 mesh was for sand [16]. While observing basal substrate (rock, rubble, coral, and dead coral) was carried out visually in the transect frame.

2.4. Identification of macroalgae

Macroalgae were identified according to the guide for identification of macroalgae [17-23, 24]. The nomenclature of macroalgae was matched by the algaebase.org [25]. Collections of macroalgae were preserved in 70% alcohol. Samples were stored in the Reference Collection of Research Center for Oceanography-National Research and Innovation Agency (BRIN) in Jakarta. The grouping of macroalgae life forms was based on the substrate [26]. They were able to grow on a wide variety of substrates (soft and hard substrates).

2.5. Data analysis

Species list of macroalgae was grouped according to their taxonomic group: green macroalgae (Chlorophyta), brown macroalgae (Ochrophyta), and red macroalgae (Rhodophyta) [25]. Macroalgae were also grouped according to their life form group [26]. Sorensen similarity index analyzes were performed to visualize differences in macroalgae species from the different Islands.

3. Results and discussion

3.1. Diversity and distribution of macroalgae

A total of 42 macroalgae species were collected from KNP waters. The macroalgae consist of three divisions: Chlorophyta (19 species and 10 genera), Ochrophyta (eight species and six genera), and Rhodophyta (15 species and 12 genera) (Table 1). The proportion of brown macroalgae (Ochrophyta) was lower than red macroalgae (Rhodophyta) and green macroalgae (Chlorophyta). The proportion of brown macroalgae was 10%, while red and green macroalgae proportions were 36 % and 45 %, respectively (Figure 2). This phenomenon was common in Indonesian waters. In Indonesian waters, brown macroalgae had lower diversity than red and green macroalgae [27-28].

No predominance of macroalgae species was found. However, several genera of macroalgae were found in almost all locations, namely Halimeda (Figure 3) and Amphiroa (Figure 4). Halimeda and Amphiroa were common macroalgae [27-28]. They have had an excellent tolerance for tides. They were also able to grow on various substrates (soft and hard substrates) [29]. Halimeda and Amphiroa can be found in rocks, dead coral, coral, and sand. They can also be found attached to the shells of mollusk, seagrass, and other macroalgae.
### Table 1. The diversity of macroalgae on each location in Komodo National Park waters, East Nusa Tenggara.

| No. | Species                          | St.1 | St.2 | St.3 | St.4 | St.5 | St.6 | St.7 | St.8 |
|-----|----------------------------------|------|------|------|------|------|------|------|------|
| 1   | *Boergesenia forbesii*           | -    | -    | -    | -    | -    | +    | -    | +    |
| 2   | *Boodea composita*               | -    | -    | -    | -    | +    | -    | -    | +    |
| 3   | *Caulerpa racemosa*              | +    | -    | -    | -    | -    | +    | -    | -    |
| 4   | *Caulerpa serrulata*             | -    | -    | -    | -    | -    | +    | -    | -    |
| 5   | *Chromomorpha crassa*            | -    | -    | -    | -    | +    | -    | -    | -    |
| 6   | *Codium arabicum*                | +    | -    | -    | -    | -    | +    | -    | +    |
| 7   | *Codium decorticatum*            | -    | -    | -    | -    | +    | -    | -    | -    |
| 8   | *Codium edule*                   | +    | +    | -    | +    | -    | +    | -    | -    |
| 9   | *Codium sp.*                     | -    | -    | -    | -    | -    | +    | -    | +    |
| 10  | *Dictyosphaerla cavernosa*       | +    | -    | +    | -    | +    | -    | +    | -    |
| 11  | *Halimeda incrassata*            | -    | -    | -    | -    | +    | -    | -    | -    |
| 12  | *Halimeda macroloba*             | +    | -    | -    | +    | -    | +    | -    | +    |
| 13  | *Halimeda opuntia*               | +    | -    | -    | +    | -    | +    | -    | +    |
| 14  | *Microdictyos japonicum*         | -    | -    | -    | -    | +    | -    | -    | -    |
| 15  | *Ulva clathrata*                 | -    | -    | +    | -    | -    | -    | -    | -    |
| 16  | *Ulva lactuca*                   | -    | +    | -    | -    | -    | -    | -    | -    |
| 17  | *Ulva reticulata*                | -    | -    | -    | +    | -    | -    | -    | -    |
| 18  | *Valonia aegagropila*            | -    | -    | -    | +    | +    | -    | +    | -    |
| 19  | *Valonia ventricosa*             | -    | -    | -    | -    | -    | +    | -    | +    |
| 20  | *Ochrophyla*                     | -    | -    | +    | -    | -    | +    | -    | +    |
| 21  | *Hormophysa cuneiformis*         | -    | -    | -    | -    | -    | -    | -    | -    |
| 22  | *Hydroclathrus clathratus*       | +    | -    | -    | -    | -    | -    | -    | -    |
| 23  | *Padina australis*               | +    | -    | -    | -    | -    | +    | +    | +    |
| 24  | *Sargassum sp.*                  | +    | -    | -    | -    | -    | -    | +    | +    |
| 25  | *Sargassum polyctum*             | -    | -    | -    | +    | -    | -    | -    | -    |
| 26  | *Turbinaria conoides*            | +    | -    | -    | +    | -    | +    | +    | +    |
| 27  | *Turbinaria ornata*              | -    | -    | -    | -    | -    | +    | -    | +    |
| 28  | *Rhodophyta*                     | -    | -    | -    | +    | -    | -    | -    | -    |
| 29  | *Acanthophora muscoides*         | -    | -    | -    | -    | +    | -    | -    | -    |
| 30  | *Acanthophora spicifera*         | -    | +    | -    | -    | +    | -    | +    | +    |
| 31  | *Aman sia glomerata*             | +    | -    | -    | +    | -    | -    | -    | -    |
| 32  | *Amphiroa fragilissima*          | +    | -    | +    | -    | +    | +    | +    | +    |
| 33  | *Cymathia sp.*                   | -    | -    | -    | +    | -    | -    | -    | +    |
| 34  | *Portiera hornemani*             | -    | -    | -    | -    | -    | -    | +    | +    |
| 35  | *Gracilaria salicornia*          | +    | -    | -    | -    | -    | +    | +    | +    |
| 36  | *Eucheuma sp.*                   | -    | -    | -    | -    | +    | -    | -    | -    |
| 37  | *Gelidi ella acerosa*            | +    | -    | +    | -    | -    | -    | -    | -    |
| 38  | *Gracilaria sp.*                 | +    | -    | -    | -    | -    | +    | -    | -    |
| 39  | *Gracilaripsis longissima*       | -    | -    | -    | -    | -    | +    | +    | +    |
| 40  | *Hypnea sp.*                     | -    | -    | -    | -    | -    | -    | +    | +    |
| 41  | *Hypnea asperi*                  | -    | -    | -    | +    | -    | -    | +    | +    |
| 42  | *Laurencia obtusa*               | -    | -    | -    | +    | -    | -    | +    | +    |
| 43  | *Palmaria palmata*               | -    | -    | -    | -    | -    | -    | +    | -    |

**Total of species**: 15 1 7 7 15 5 22 15

Note: + was found, − was not found, St 1 Setuga, St 2 Komodo, St 3 Karang Makasar, St 4 Padar Kecil, St 5 Padar, St 6 Papagarang Besar, St 7 Mangaitan, and St 8 Muntia Island.
Figure 2. Composition of macroalgae (Chlorophyta, Ochrophyta, and Rhodophyta) in Komodo National Park.

Figure 3. *Halimeda* was a green macroalga (Chlorophyta) commonly found in Komodo National Park.

Figure 4. *Amphiroa* was a red macroalga (Rhodophyta) commonly found in Komodo National Park.

Figure 5. Macroalgae distribution on each location in Komodo National Park.
The highest macroalgae diversity was found on Mangaitan Island (22 species), followed by Setuga Island (15 species), Padar Island (15 species), Muntia Island (15 species) (Figure 5). At the same time, Komodo Island had the lowest macroalgae diversity (one species). The presence of macroalgae was influenced by the type and complexity of the substrate. They had a variety of substrates (soft and hard substrates), while the Komodo waters only had soft substrates. According to Imchen [30] and Norashikin [31], substrate complexity affected the diversity and abundance of macroalgae.

Sorensen similarity index was shown that macroalgae were different in the study area in KNP (Table 2). Setuga and Muntia island had the highest similarity index (0.53). At the same time, other study areas had a similarity index of less than 0.5. The similarity index value between Komodo and three islands (Karang Makasar, Padar Kecil, and Muntia islands) was zero, indicating that the macroalgae found in these locations were different. Setuga and Muntia islands had a similarity index value of 0.53, which means that the macroalgae in both locations had a similarity of 53%. Macroalgae was found in both locations, namely Halimeda opuntia, Halimeda macroloba, Padina australis, Sargassum sp., Turbinaria conoides, Amphiroa fragilissima, Gracilaria salicornia and Gracilaria sp. The high value of the similarity index at both locations was suspected having similar substrate types, the complexity of the substrate, and topography. The presence and absence of macroalgae were influenced by season, environmental pressure, geographic area, topography, and substrate [30, 31].

| Island | Setuga | Komodo | KarMakasar | Padar Kecil | Padar | Papagarang | Mangaitan | Muntia |
|--------|--------|--------|------------|-------------|-------|------------|-----------|--------|
| Setuga |        |        |            |             |       |            |           |        |
| Komodo | 0.13   |        |            |             |       |            |           |        |
| KrMakasar | 0.27   | 0      |            |             |       |            |           |        |
| Padar Kecil | 0.36   | 0      | 0.14       |             |       |            |           |        |
| Padar | 0.40   | 0.13   | 0.27       | 0.18        |       |            |           |        |
| Papagarang | 0.20   | 0      | 0.33       | 0.17        | 0.10  |            |           |        |
| Mangaitan | 0.49   | 0.09   | 0.28       | 0.21        | 0.43  | 0.07       |           |        |
| Muntia | 0.53   | 0      | 0.27       | 0.36        | 0.33  | 0.30       | 0.32      |        |

### 3.2. Substrate and life form of macroalgae

The substrate was not variable, consisting of sand, mud, sandy mud, rock, and dead coral. The substrate was dominated by sand and a combination of sand and mud. However, macroalgae were dominantly attached to rocks or corals (hard substrate) (Table 2). Macroalgae were attached to the substrate by using holdfast. The attachment of holdfast on hard substrates (rocks and corals) was stronger than on soft substrates (sand, sandy-mud). This phenomenon indicates that the attachment of macroalgae was more stable on hard substrates than soft substrates [32].

There were five categories of life forms of macroalgae, namely epilithic, rhizophitic, epiphytic, epizoic, and drift (Figure 6). The category was grouped by attachment (substrate) [26], the coastal in Indonesia with five types of life form, i.e. Lampung Bay [33], and Kendari [32], while Garut (West Java) had four types of life forms [34]. Epilithic was the most common type of life form, while drift was a rare type of life form. Epilithic was also the most common type of life form at each site (Figure 7). Epilithic type was grown on rock or dead coral (hard substrate), a stable substrate. Drift type was rarely found because only a few macroalgae were able to grow loose-lying [26].

Macroalgae can have one or more types of life form. It can happen because macroalgae can grow on different substrates [26]. Dictyota dichotoma, Padina australis, and Hypnea asperi had three-life forms, namely epiphytic, epilithic, and epizoic. Valonia aegagrophila and Gracilaria Salicornia were drift macroalgae. Dictyota dichotoma, Hormophysa cuneiformis, Hydroclathrus clathratus, Padina australis, Champaia, Hypnea asperi, and Laurencia obtusa were epizoic macroalgae. In general, epizoic macroalgae was attached to mollusk shells [26, 34]. Caulerpa racemosa, Caulerpa serrulata, Halimeda incrassata,
Halimeda macroloba and Halimeda opuntia were rhizophitic macroalgae. Epiphytic macroalgae include Boodlea composita, Chaetomorpha crassa, Microdictyon japonicum, Ulva reticulata, Dictyota dichotoma, Padina australis, Champia, and Hypnea asperi were found attached on seagrass or other macroalgae. Other macroalgae were epilithic macroalgae. Epilithic macroalgae were attached to hard substrates such as rock, rubble, coral, and dead coral [26].

Figure 6. Life form of macroalgae in Komodo National Park.

Figure 7. Distribution of macroalgae life form in Komodo National Park waters.

4. Conclusion
Komodo National Park waters had 42 species of macroalgae, consisting 19 species of Chlorophyta, 8 species of Ochrophyta, and 15 species of Rhodophyta. The highest macroalgae diversity was found on Mangaitan Island, while Komodo Island had the lowest macroalgae diversity. Setuga and Muntia island had the highest similarity index (0.53). At the same time, other study areas had a similarity index of less than 0.5. The distribution of macroalgae in the eight locations was different. Differences in the substrate and environmental conditions most likely cause it. There was five life form of macroalgae, namely epilithic, epiphytic, rhizophytic, epizoic and drift. Epilithic was the dominant life form of macroalgae. Monitoring of macroalgae resources is needed to maintain the sustainability of macroalgae in Komodo National Park waters.
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