BIODIVERSITAS
Volume 25, Number 2, February 2024
Pages: 644-653

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d250223

Mangrove distribution to support biodiversity management in Teluk Bintuni District, West Papua, Indonesia

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Manuscript received: 22 October 2023. Revision accepted: 16 February 2024.

Abstract. *Kasihiw P, Bawole R, Marwa J, Murdjoko A, Wihyawari A, Heipon Y, Cabuy RL, Benu NMH, Hematang F, Leftungun NY. 2024. Mangrove distribution to support biodiversity management in Teluk Bintuni District, West Papua, Indonesia. Biodiversitas 25: 644-653.* Mangroves play an important role in coastal ecosystems, but the areas of mangroves are decreasing globally. Understanding the ecological and geographical distribution of mangroves will be useful to develop sustainable management and policy. Thus, this study aimed to analyze the ecological and geographical distribution of mangroves in Teluk Bintuni, West Papua, Indonesia. The distribution of mangroves was investigated to see the relationships between elevation and the number of individual mangroves at the family level. Vegetation data were collected by setting 180 circular plots and geographical data were obtained from secondary sources. Our study revealed that Rhizophoraceae family was found in all plots with 97.78% presence, whereas Acanthaceae and Meliaceae families were found in half of the plots with 65% and 60.56% presence, respectively. Lythraceae, Primulaceae, Malvaceae, and Arecaceae were only found in 15% of the plots. Elevation affected significantly the presence of mangroves which there mainly occurred in elevation between 10-30 m asl, while they were lower in below 10 m asl and above 30 m asl. Species belonging to Acanthaceae and Lythraceae, such as those from the genera of *Avicennia* and *Sonneratia*, were found more abundant in the low elevation (seaward zone) than in the higher elevation (landward zone). In contrast, species belonging to Meliaceae and Rhizophoraceae were more abundant in the landward zone with the presence of genera *Xylocarpus*, *Bruguiera*, *Ceriops*, and *Rhizophora*. The distribution of Arecaceae, Malvaceae, and Primulaceae did not show a significant pattern where they appeared randomly in mangrove forests. Geographically, 12.43% area of Teluk Bintuni District was mangroves which mainly occurred in the eastern and southern parts. Based on forest status, 2.23%, 35.60%, 10.46%, and 51.71% of mangroves in Teluk Bintuni occur in non-forestry use areas (*Area Penggunaan Lain/APL*), conservation forest (*Hutan Konservasi*) in the form of nature reserve, protected forest (*Hutan Lindung*), and production forest (*Hutan Produksi*), respectively. As the mangrove ecosystem has been part of local people, the specific management to support biodiversity in mangrove forests must be put officially in the development program.

Keywords: New Guinea Rhizophoraceae, shoreline, sustainable management, Tanah Papua

INTRODUCTION

Mangroves are unique vegetation that grows in transitional zones between terrestrial and marine realms. Mangrove ecosystem can be found primarily in tropical and subtropical regions with the largest extent being in Southeast Asia, followed by South America, Africa, and Australia (Giri et al. 2011). Mangrove vegetation can tolerate high salinity and water inundation, thus it develops various adaptation strategies to cope with unique environmental conditions such as the presence of pneumatophores (Kathiresan and Bingham 2001; Feller et al. 2010). Mangrove ecosystems are characterized by high biodiversity levels and complex ecological interactions both under and above the water surface.

Mangrove plays an important role in providing habitat for a wide range of organisms, coastal protection, carbon sequestration, and numerous ecological services (Field et al. 1998; Sarker et al. 2019a). Furthermore, mangrove ecosystems provide numerous benefits to both the environment and local communities in economic aspects. They act as natural barriers against coastal erosion and storm surges, protect shorelines, provide habitats for diverse marine life, and support local livelihoods through fishing and ecotourism. On the other side, many coastal communities depend on mangrove ecosystems for their livelihoods. Fishing, crabbing, and collecting shellfish are common activities that sustain local economies. Additionally, mangroves often serve as a source of traditional medicine and construction materials for these communities (Hagger et al. 2022; Islam et al. 2022).

Notwithstanding the ecological and socio-economic functions, mangrove ecosystems are being threatened by a

variety of human activities. Deforestation and degradation of mangrove forests for the development of aquaculture, agriculture, and urban settlement, are the major contributors to global mangrove loss. Pollution from industrial activities and oil spills are also major threats to this vulnerable ecosystem. Furthermore, climate change, including increasing sea levels and an increase in the frequency of extreme weather events, exacerbates mangrove vulnerability (Polidoro et al. 2010; Worthington et al. 2020).

Indonesia has the largest extent of mangroves in which one-fifth of the global mangrove area occurs in this country (Giri et al. 2011). One region in Indonesia where mangrove forests are still in good condition is Indonesian New Guinea (a.k.a. Tanah Papua). The percentage of mangrove loss in this region is still the lowest compared to other islands with only three percent in the last two centuries (Ilman et al. 2016; Sasmito et al. 2023). However, mangrove forest in Tanah Papua is increasingly threatened since this region is prioritized for regional development especially infrastructural facilities such as roads (Gaveau et al. 2021). To minimize the adverse impacts of development on mangrove forests, the Indonesian government has set forest restoration programs including in mangrove areas. Among the nine targeted provinces for mangrove restoration is Tanah Papua (Sasmito et al. 2023).

Most mangroves in Tanah Papua grow and regenerate naturally with the distribution of mangroves varies depending on environmental factors. The geographical condition of coastal areas in Tanah Papua affects the presence of various types of mangrove vegetation (Kartikasari et al. 2012). Some mangroves grow in shorelines and bay areas, for example, mangroves in Teluk Bintuni, which have a unique geographical shape. Teluk Bintuni is a bay but the shoreline has a shape with a narrower curve in the mouth, making it often called a gulf rather than a bay. Studies of mangroves have been performed in Teluk Bintuni mainly focusing on vegetation on logging concession, diversity, secondary succession, and carbon stock (Sillanpää et al. 2017; Yudha et al. 2021; Sraun et al. 2022; Yudha et al. 2022; Kasihiw et al. 2023).

The community in Teluk Bintuni has paid great attention to the mangrove forest in their area they assign a special name for the mangrove ecosystem which is called "Tanah Sisar Matiti" or water with high turbidity. The presence of a large extent of mangroves in Teluk Bintuni is due to many rivers and estuaries with the occurrence of mangroves. Mangroves play a crucial role in Teluk Bintuni not only in terms of economic and ecological aspects but also from a cultural perspective. Hence, the government pays full attention to mangrove management as an integrated part of regional development. However, the information on the distribution of mangrove forests in general is poorly known in Teluk Bintuni. Thus, the goals of this study were to analyze the ecological and geographical distribution of mangroves in Teluk Bintuni and to investigate geographical factors that affect mangrove distribution. The distribution of mangroves was investigated to see the relationship between altitudinal conditions and the density of individual mangroves that were grouped taxonomically as a family. We expected the results of this study might serve as a reference when designing a regional development plan by incorporating biodiversity management of mangroves.

MATERIALS AND METHODS

Study area and period

This study was carried out in Teluk Bintuni District (E133°35'73" S2°31'25") located in Bird's Head Peninsula of West Papua, Indonesia which is part of New Guinea Island (Figure 1).

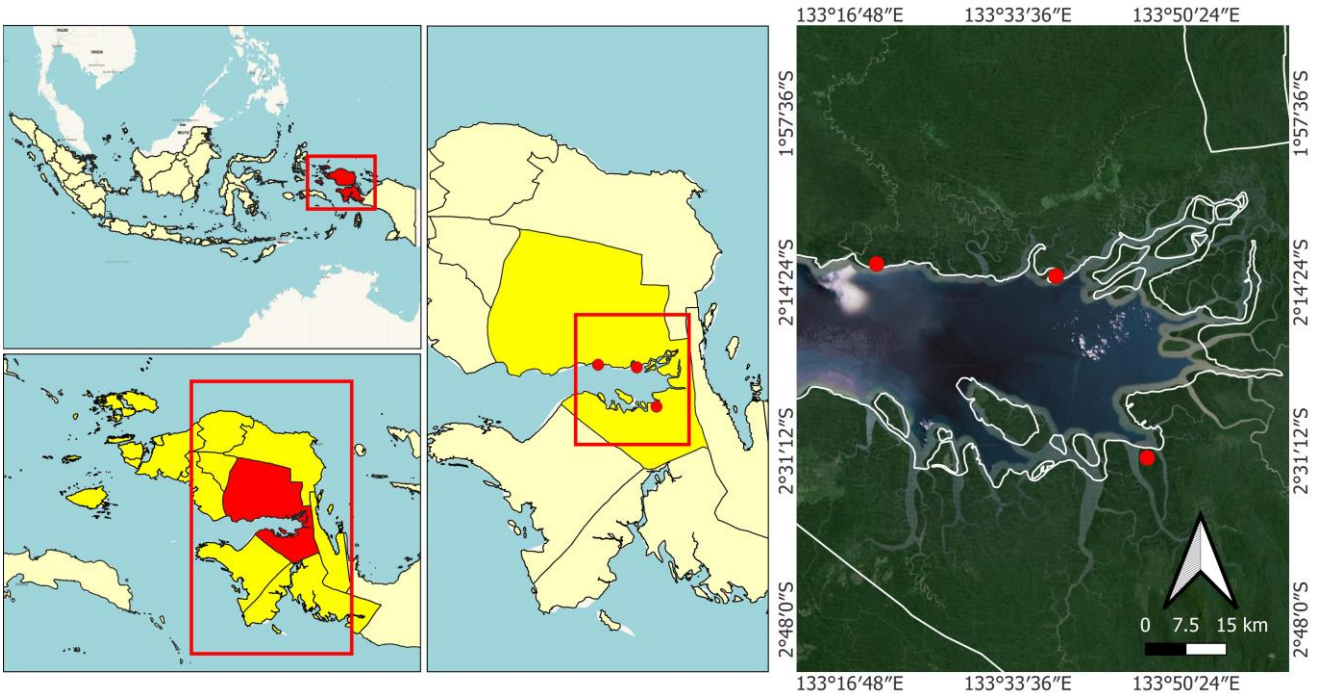

Figure 1. Map of the study area in Teluk Bintuni District (red line as borderline) and three observation plots (red dots)

Administratively, Teluk Bintuni is part of West Papua Province and assigned as a district since 2002 by the issuance of Law Number 26/2002 by the central government. Based on the land cover condition, the district is mainly still composed of forest cover with various types. The focus of this study is the areas with mangrove forests in Teluk Bintuni District. Mangrove in this area is mainly dominated by species belonging to family of Rhizophoraceae. The previous study of species richness revealed that the mangrove forest consisted of 57 species grouped into 9 lifeforms viz. bamboo (1 species), climber (6 species), epiphyte (7 species), fern (3 species), orchid (2 species), palm (3 species), pandanus (1 species), shrub (2 species), and tree (32 species). Moreover, this study also classified the mangrove as true mangrove with 17 species and mangrove associated with 40 species. Another study also mentioned that the vegetation of mangroves was dominated by genera of *Rhizophora* and *Bruguiera* belonging to Rhizophoraceae family (Kasihiw et al. 2023). The tide-dominated deltas are shaped in coastal areas, particularly in the eastern and southern parts. The data collection in the field was carried out from February to March 2023.

Geographical data

Mangrove areas were identified using Google Earth Engine (GEE) (Giri et al. 2011) while more information on global mangroves was gained from published literature. Data on elevation and Teluk Bintuni Area (district and sub-district) were acquired from Badan Informasi Geospasial Republik Indonesia (http://tanahair.indonesia.go.id/portal-web/ accessed on 7 September 2023). Data on roads, rivers, and residential areas were attained from OpenStreetMap Website (https://download.geofabrik.de/asia/indonesia.html accessed on 6 September 2023). The process of grouping and clipping as well as map view to display used QGIS version 3.18.2-Zürich.

Vegetation sampling and data collection

We applied curricular plot method for vegetation sampling of mangroves (Sillanpää et al. 2017; Kasihiw et al. 2023). We established 180 circular plots with a radius of 7 m in the mangrove forest distributed across three forest functions enacted by the central government through SK.783/Menhut-II/2014 dated 22 September 2014 namely nature reserve in the eastern part, protected forest in the northern part, and production forest in the southern part of the sea. Each location consisted of 60 plots and the plotting followed a transect that was perpendicular from beach fringe to landward zones as the representation of mangrove zonation. We only focused the vegetation on true mangroves to analyze the distribution.

The data collection was done during the low tide condition in which the interview with local people was conducted to gain information concerning tidal time and we also re-checked the information using (https://www.tideschart.com/Indonesia/West-Papua/Bintuni/ accessed on 2 February 2023). The vegetation data included the taxonomical information and the number of individuals. Taxonomical information was identified in the plots, otherwise for undescribed species were collected as vouchers and sent to *Herbarium Manokwariense* (*MAN*) *Pusat Penelitian Keanekaragaman Hayati Universitas Papua* (*PPKH-UNIPA*), Manokwari. The taxonomy was described as a family group and the scientific names were standardized using The World Flora Online (http://www.worldfloraonline.org/ accessed on 20 March 2023) and Plants of the World Online (https://powo.science.kew.org/ accessed on 20 March 2023).

Data analysis

The altitude was grouped with intervals of 10 m and then the altitudinal class, forest types, and sub-districts were clipped only for mangrove areas. To analyze the portion of mangrove areas per forest type, elevation, and sub-districts, the percentage of mangrove area (%) was calculated as follows:

$$P_i(\%) = \frac{n_i}{N_i} \times 100\%$$

Where:
P : Percentage (%)
i : Forest types, elevation, or sub-districts
n : Mangrove area (ha)
N : Area (ha)

The result of the percentage was displayed as a bar chart for forest types, elevation, and sub-districts. The distribution of each family was analyzed as follows:

$$F_i(\%) = \frac{n_i}{N_i} \times 100\%$$

Where:
F : Frequency (%)
n : Number of plots containing a family
i : Family name
N : Total of the total (Bray and Curtis 1957)

The nonlinear regression equation was used to analyze the relationship between the density of each family and the altitudinal condition (m). The general model was described as:

$$Y_i = f(x, \beta) + \epsilon$$

Where:
Y : Density of family (n/plot)
f : Regression function
i : Family name
x : Elevation (m)
β : Vector of parameter
ϵ : An error

The models were tested using the F test to obtain the best model of nonlinear regression. Moreover, the coefficient of determination (R^2) was tested as follows:

$$R^2{}_i = 1 - \frac{RSS}{TSS}$$

Where:
i : Family
RSS : Sum of squared residuals
TSS : Total sum of squares

RESULTS AND DISCUSSION

Mangrove distribution and its relationship with altitude

In this study, we applied family-level analysis for mangrove distribution in Teluk Bintuni and focused on true mangroves (Figure 2). The family of Rhizophoraceae was found in all plots with 97.78% presence while the families of Acanthaceae and Meliaceae were distributed in half of the plots accounting for 65% and 60.56% respectively. There were family distributions below 15 % of plots, i.e., Lythraceae, Primulaceae, Malvaceae, and Arecaceae in descending order of frequency (F) value.

Non-linear regression was performed to see the relationship between the abundance of families and altitude. Based on the result of non-linear regression, of the seven families, four families showed a significant relationship with elevation (Figure 3). We found both positive and negative relationships between the two variables. Firstly, the negative relationship was shown by Acanthaceae and Lythraceae which were distributed more in lower altitudes rather than in higher altitudes. Second, a positive relationship was shown between Meliaceae and Rhizophoraceae, suggesting that these mangroves were found to be more abundant at higher altitudes (i.e., close to land). The rest of the families, namely Arecaceae, Malvaceae, and Primulaceae, had no relationships with altitude.

The ecological condition of mangrove forests can be analyzed through the distribution of vegetation. In this study, we focused on the family distribution as some publications mentioned that Rhizophoraceae was the dominant vegetation in Teluk Bintuni. It is important to note that mangroves in Teluk Bintuni grow in gulf areas and the distribution of vegetation can be used to describe the vegetation assemblage or cohort. The zonation of mangroves especially in the gulf area can vary depending on regional environmental conditions, anthropogenic activity, and other factors (Sillanpää et al. 2017; Yudha et al. 2022). Nonetheless, mangrove zonation is also dynamic and can be different over a long time mainly owing to natural processes including erosion, sedimentation, and sea-level rise.

We applied elevation as an independent variable to explain its relationship with the distribution of mangroves (Matthijs et al. 1999; Fu et al. 2018; Baloloy et al. 2021). We found that the distribution of some mangrove families is likely affected by altitude which grows dominantly either in the sea fringing zone or the landward zone, while other families grow randomly in terms of elevation. Species belonging to Acanthaceae and Lythraceae were found abundantly in the sea fringing zone. Genera from these families, such as *Avicennia* and *Sonneratia*, were more diverse and dominant in the sea fringing zone as other studies also mentioned the same result (Liu et al. 2018; Nasrin et al. 2020; Baloloy et al. 2021). The areas are characterized as having high saline levels and exposed to waves. Hence, the majority of the mangrove species belonging to families of Acanthaceae and Lythraceae in this region are salt-tolerant and have adaptations to deal with frequent flooding and high salinity. Moreover, species like *Avicennia marina* have pneumatophores (aerial roots) to help facilitate oxygen exchange in waterlogged soils (Canty et al. 2022).

In contrast, the distribution of Meliaceae and Rhizophoraceae was more abundant in the landward zone with the presence of genera *Xylocarpus*, *Bruguiera*, *Ceriops*, and *Rhizophora*. This area is located between the high tides and low tides that are periodically submerged under the sea during high tides and exposed to the air during low tides. Some areas lay further inland and are not immediately impacted by tidal changes and freshwater conditions are often present mainly from rivers with ocean inundation occurring less frequently. Rhizophoraceae seemed to be more frequently found in mangrove forests according to some studies (Sillanpää et al. 2017; Sraun et al. 2022; Kasihiw et al. 2023). This area comprised the tide-dominated deltas shaped by many rivers which might explain the dominance of Rhizophoraceae. Additionally, their ability to tolerate high salinity gives them a competitive advantage over other plant species in these environments supported by various physiological and anatomical adaptations. The ecological function of Rhizophoraceae is crucial to stabilize coastal sediments which is the result of the extensive root systems which trap sediments and organic matter, preventing erosion and promoting sediment accretion. This process helps in building up landmasses and contributes to the formation of mangrove forests. Moreover, the dense network of roots also provides a habitat for various organisms and also serves as a natural filtration system by removing pollutants and excessive nutrients from the water (Sreelekshmi et al. 2018).

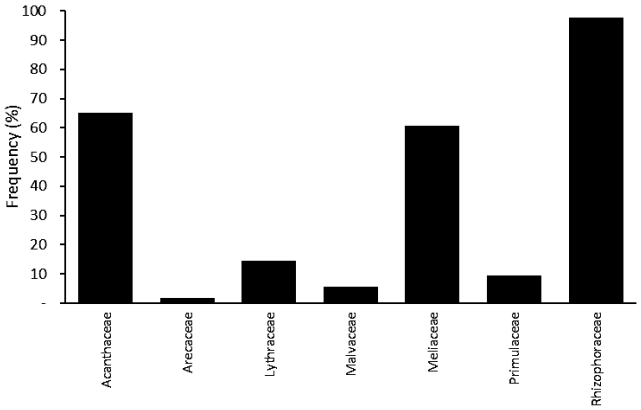

Figure 2. The frequency of each mangrove (%) is measured as the presence of individuals belonging to each family per total plot

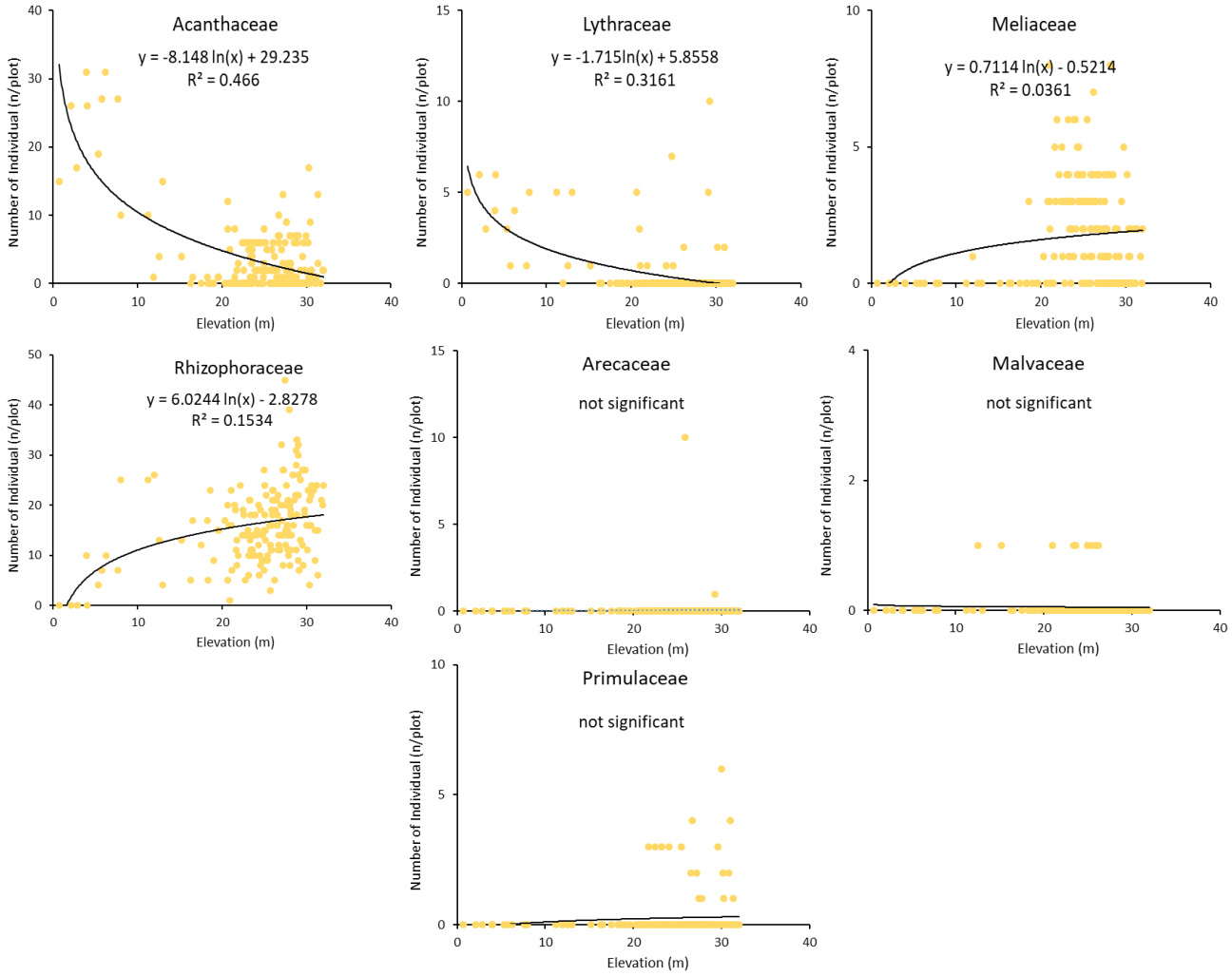

Figure 3. Non-linear regression to see the relationship between the abundance of mangroves of each family and altitude

The distribution of Arecaceae, Malvaceae, and Primulaceae did not show a significant pattern where they appeared randomly in mangrove forests. The species belonging to genera *Nypa*, *Heritiera*, and *Aegiceras* contributed to the density of mangroves. These families are able to tolerate high salt concentrations, but in these mangrove areas, they were ecologically outcompeted. In particular, *Nypa* can be found inside mangrove habitats and is not always consistent with the surrounding environmental factors predominating in areas with lower salinity and greater freshwater input (Baloloy et al. 2021). Local people in Teluk Bintuni have utilized this species for generations, implying the importance of this species in terms of socio-economic aspects.

Status and geographical location of mangroves

Mangrove vegetation in Teluk Bintuni mainly occurs in the eastern and southern parts where many deltas are formed. Our spatial analysis revealed that 12.43% area of Teluk Bintuni District is a mangrove forest (Figure 4A). According to the Ministerial Decree of Forestry through SK.783/Menhut-II/2014 dated 22 September 2014, the mangrove forest in Teluk Bintuni is divided into four statuses, namely non-forestry use areas (*Area Penggunaan Lain/APL*), conservation forest (*Hutan Konservasi*) in form of nature reserve, protected forest (*Hutan Lindung*), and production forest (*Hutan Produksi*) with proportion to total mangrove areas were 2.23%, 35.60%, 10.46%, and 51.71% respectively (Figure 5). The nature reserve is located in the eastern part of the gulf characterized by tide-dominated deltas which were created by the accumulation of sediments in the river's mouth. In the western part of the gulf, there is a protected forest of mangroves. Some areas of the production forest of mangroves have been managed as forest concessions for decades in the southern part of the gulf.

Teluk Bintuni District consists of 24 sub-districts where 14 of them have mangrove areas (Figure 4D). The proportion of mangroves in sub-districts varies with the largest being Wamesa, followed by Babo, Kuri, Bintuni, Aroba, Manimeri, Kaitaro, Tomu, Sumuri, Kamundan, Tembuni, Weriagar, Fafurwar, and Aranday. The five sub-districts mentioned first have at least the areas containing

10 % of mangroves while the last four sub-districts have mangrove areas of less than one percent (Figure 7).

Mangrove forests in Teluk Bintuni occurred from the shoreline to an elevation of 40 m above mean sea level (MSL). The gulf is surrounded by lowland areas, particularly in the western part, but the mangroves did not abundantly grow in this area (Figure 4B). Along the coastal line, mangrove forest has the status of protected forest. Regardless of species, the mangroves were mainly distributed in elevation between 10-30 m accounting for 68.7%, while the elevation above 30 m accounted for 13.75% and elevation below 10 m accounted for 17.54%, which were mostly distributed in coastal zones, especially in deltas (Figure 6).

Most of the residential areas were located in the northern part of the mangrove forest and a few in the southern part of the gulf (Figure 4C). Some infrastructure facilities, such as roads, have been established mainly in the northern part of the mangrove. Teluk Bintuni is a developing district in which many areas are needed for the implementation of development programs. Logging concession began to operate in Teluk Bintuni before this district was definitively established under Law Number 26/2002. Consequently, logging roads have been built in some parts of Teluk Bintuni District which are then used to connect some sub-districts. However, for some sub-districts around the gulf, water transportation plays a fundamental role where the traditional ports have been used.

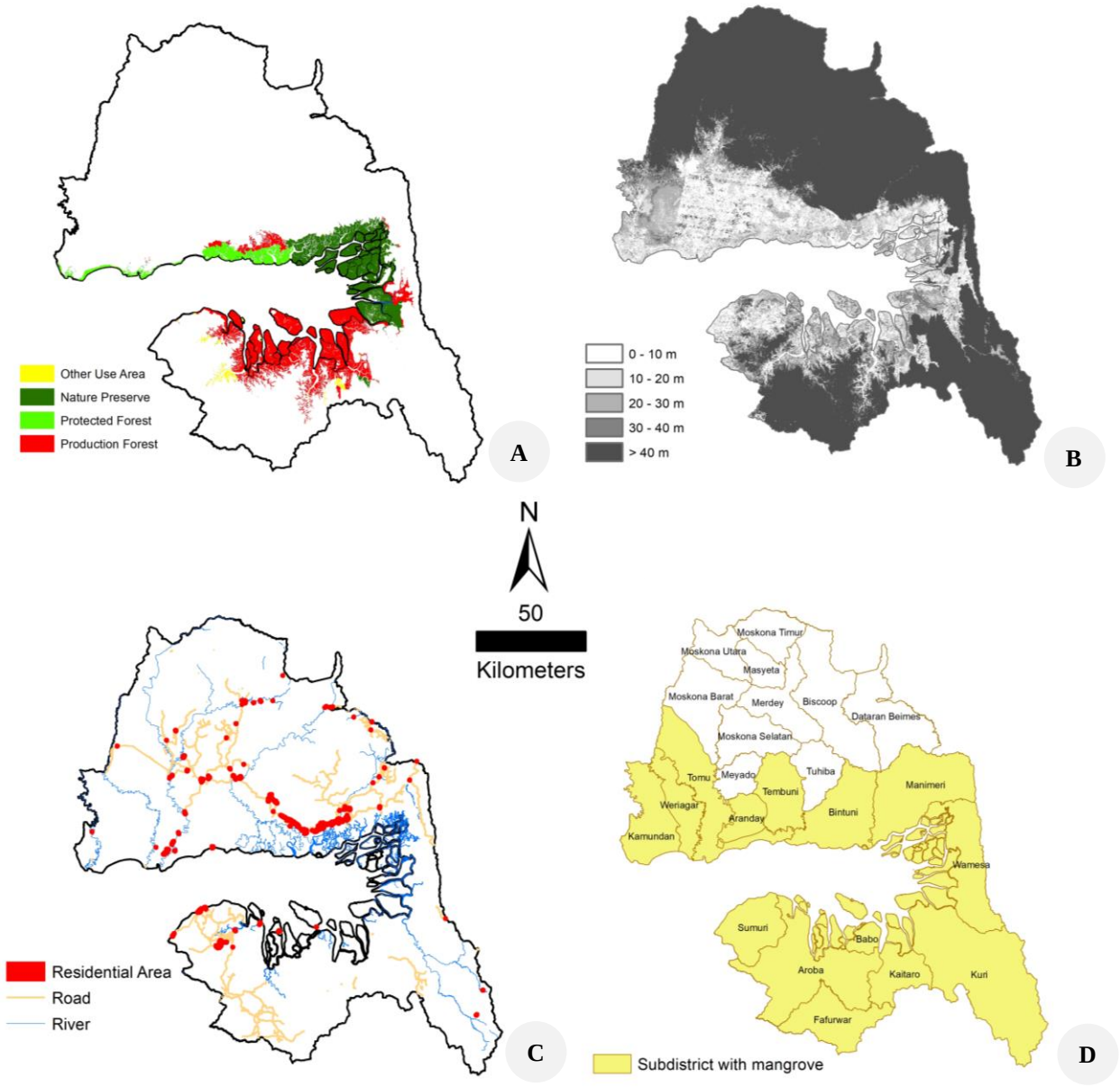

Figure 4. A. Spatial distribution of mangroves based on forest status, B. Elevation with 10 m interval, C. Roads, rivers, and residential areas, D. Maps of sub-districts where yellow color showing sub-districts with mangroves while white color is sub-districts without mangroves

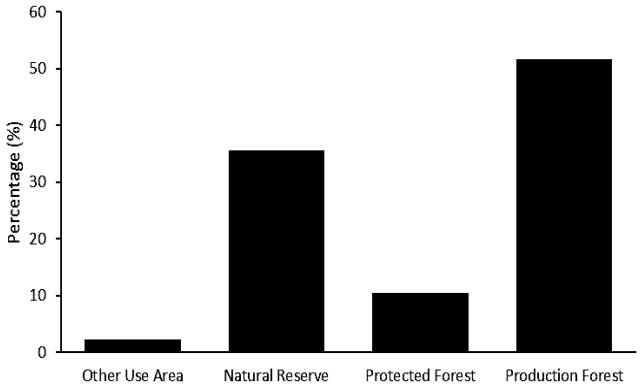

Figure 5. Percentage of mangrove forest in Teluk Bintuni based on forest status

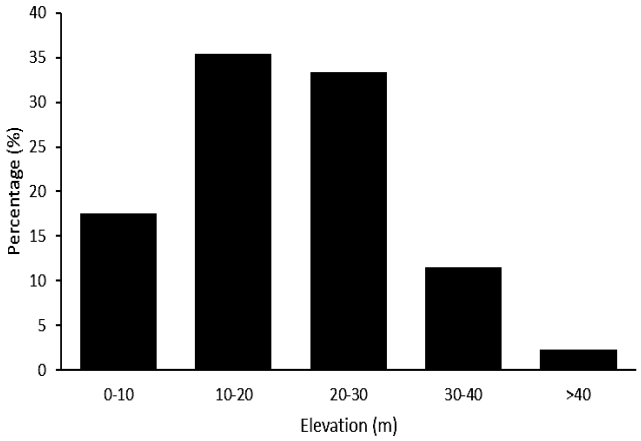

Figure 6. The percentage of mangrove forest in Teluk Bintuni based on elevation (10 m interval)

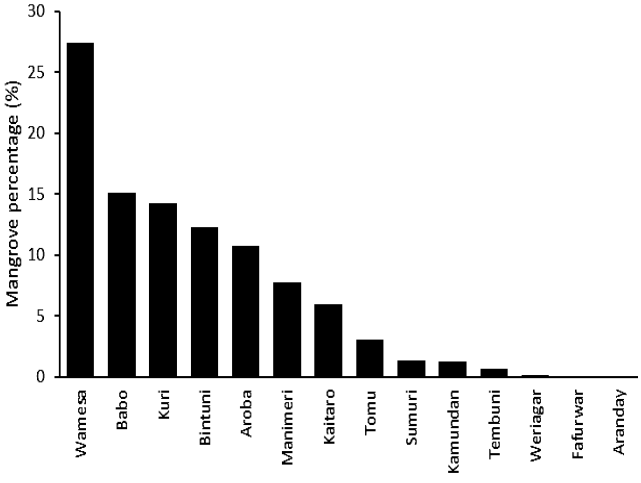

Figure 7. Percentage of mangrove forest in each sub-district that has mangroves in Teluk Bintuni

Teluk Bintuni District is mainly covered by vegetation or forest and some areas of forest have been part of a concession for about three decades since the district was still a sub-district of Manokwari District. As shown in Figure 4C, it can be seen that many roads have been built especially in the northern part and southern part. Teluk Bintuni District contains two conservation areas viz., nature reserve and protected forest some of which include mangrove forests. Hence, the development program must take into account the mangrove area as the main priority. Some studies have revealed the floristic aspect concerning species richness and diversity where the species number was 57 consisting of true mangroves (29.82%) and mangrove associates (70.18%) (Sillanpää et al. 2017; Kasihiw et al. 2023). Mangrove forest is a habitat of not only true mangroves, but also mangrove associates which are important in coastal ecosystems (Wang et al. 2011; Sarker et al. 2019b; Otero et al. 2020). The mangrove forest in Teluk Bintuni also contains species with conservation status of Near Threatened and Vulnerable (Kasihiw et al. 2023). The goal of species management, rare species, and conservation initiatives is to avoid extinction, restore population numbers, and encourage long-term survival for these species. This is accomplished through a variety of approaches, including habitat conservation, captive breeding, reintroduction, and public awareness campaigns. Mangroves are highly productive and diverse ecosystems that provide numerous ecological, economic, and social benefits (Ramdani et al. 2019; Bai et al. 2021; Sasmito et al. 2023). Several studies have discovered the function of the mangrove ecosystem from many aspects where it can serve as essential habitat for a variety of plant and animal species, safeguard against storm and erosive damage to coasts, remove pollutants from water, and support local economies through fisheries and tourists (Bryan-Brown et al. 2020; Sasmito et al. 2020; Gnansounou et al. 2021; Canty et al. 2022; Chamberland-Fontaine et al. 2022; Song et al. 2023).

Teluk Bintuni District is part of the "Sustainable development of West Papua Province" (Cámara-Leret et al. 2019) that has committed to conserving the forest ecosystem including mangroves. Thus, Teluk Bintuni should integrate sustainable mangrove management as part of regional development by preserving and maintaining mangrove biodiversity. As a regional government, Teluk Bintuni plays a crucial role in the management of mangrove biodiversity through the development and implementation of legislation and policy frameworks. It is necessary to have frameworks that aim to protect mangrove ecosystems, regulate human activities within these areas, and promote sustainable use practices. Governments often establish protected areas or reserves to safeguard ecosystems from destructive activities such as deforestation, pollution, and overexploitation (Alamgir et al. 2020; Kim and Kim 2022). These protected areas may have specific regulations regarding fishing, logging, tourism, and other activities to ensure the conservation of biodiversity. The sustainable management programs can also be linked to maintaining the carbon pool as part of the climate change mechanism to mitigate the impacts of climate change such as rising sea levels, increasing storm frequency and severity, and altered precipitation patterns (Azman et al. 2023; Kochoni et al. 2023). Sea-level rise may cause freshwater systems to get contaminated with salt water, which might harm some mangrove species' ability to thrive and survive, so this

situation has been also understood by local people (Ellison et al. 2022; Kochoni et al. 2023). Storms may physically harm mangrove forests, and variations in precipitation patterns may disturb the equilibrium state between freshwater and saltwater required for mangrove existence (Giri 2021; Hagger et al. 2022; Giri et al. 2023).

Half of the area of Teluk Bintuni is lowlands with elevations more or less 100 m including mangrove forests. Even though about one-eighth of the region is mangrove forest, the conservation program regarding biodiversity is crucial as many studies have shown that mangrove areas decreased globally, so this must be the attention of Teluk Bintuni to take action. The programs should be set in in the roadmap of development ranging from short- to long-term planning. Furthermore, systematic research must be part of the action since the results will provide scientific and valid information. The research helps identify key species, understand ecological processes, evaluate threats to biodiversity, and develop appropriate conservation measures. The government should collaborate with scientific institutions, non-governmental organizations (NGOs), and local communities to conduct studies on mangrove ecosystems. The data collected through these efforts inform decision-making processes related to biodiversity management. Moreover, it is imperative that the government also involves local communities in mangrove biodiversity management. Engaging communities in decision-making processes fosters a sense of ownership and responsibility towards mangrove conservation. The government may establish community-based management initiatives that empower local stakeholders to actively participate in the protection and sustainable use of mangroves. These initiatives often involve capacity-building programs, awareness campaigns, training workshops, and the establishment of community-led monitoring systems. By involving communities, governments can ensure the long-term success of mangrove biodiversity management efforts (Polidoro et al. 2010; Hagger et al. 2022).

Teluk Bintuni District has seven tribes namely Wamesa, Sebyar, Kuri, Irarutu, Moskona, Sumuri, and Sough where some of them have intensively interacted with mangrove forests for generations. More than half of the sub-districts have mangrove areas, so the livelihood of local communities depends on natural resources in mangroves and their cultural activities play an important role in mangrove management and protection. This is due to their extensive knowledge of the local environment, cultural ties to the region, and capacity to influence the behavior of other community members. Moreover, local communities may play an important role in maintaining mangrove ecosystems through community-based projects. These activities may include the founding of local conservation groups, the establishment of community-owned mangrove forests, and the adoption of sustainable land and water management methods. Conservation initiatives may be made more successful and sustainable over time by allowing local people to manage their resources. Hence, cultural conservation may have a positive impact on mangrove conservation because local people perform their cultural activities at the same time they have an understanding concerning the existence of mangroves by keeping the mangrove areas. The cultural factor may be positively correlated to natural resources (Benner et al 2021; Murdjoko et al. 2021; Sonbait et al. 2021; Saiba et al. 2023).

Implication and recommendation for mangrove management in Teluk Bintuni

Mangrove ecosystems play a crucial role by providing a range of ecological, economic, and social benefits. However, globally, these ecosystems are facing many threats by both natural and anthropological factors leading to habitat loss, degradation, and fragmentation. Therefore, effective management of biodiversity is vital to ensure the long-term conservation and sustainable use of mangrove ecosystems including in Teluk Bintuni District. Supporting factors that can be implemented as legal basis in terms of biodiversity protection include the Manokwari Declaration and local regulation of West Papua Province especially Provincial Regulation No. 10/2019 on Sustainable Development in West Papua Province and Provincial Regulation No. 5/2022 on Degree and Management for Ecosystem Mangrove as Essential Area in West Papua Province. Besides, the Teluk Bintuni District also issues the Local Regulation of Teluk Bintuni District No. 1/2019 on Recognition and Protection of Local People in Teluk Bintuni District. The government of Teluk Bintuni District as part of this province has the authority to add biodiversity management of mangroves in regional planning and development, particularly in long-term conditions.

Even though, some areas of mangroves have been legally stated as nature reserves and protected forests, the mangrove management still requires the commitment of Teluk Bintuni as a district under West Papua Province to establish a specific conservation program where one of them could be the mangrove management. Some recommendation programs can be done by having legislation and policy frameworks, research and monitoring programs, community engagement, and international cooperation. Moreover, the government can strive to protect and conserve these valuable ecosystems, particularly in mangrove areas classified as production forests. For instance, Teluk Bintuni government should engage in international cooperation and partnerships to enhance mangrove biodiversity management. This collaboration benefits the government by obtaining knowledge, best practices, and resources during the partnership process and can get access to technical expertise, obtain finance for conservation projects, and create coordinated initiatives to solve transboundary issues.

The specific management to support biodiversity in mangrove forests includes (i) habitat restoration and conservation as some of the mangrove ecosystems are being lost and degraded; (ii) sustainable fishing and aquaculture by implementing catch limits to avoid overfishing, the use of sustainable fishing gear, and the establishment of marine protected areas; (iii) waste management and pollution control since the mangrove is located near residential areas especially in the northern part; (iv) community engagement and education to local communities especially those residing in the 14 sub-districts. Moreover, the understanding of ecological aspects

and geographical distribution is necessary to develop the conservation program along with its management particularly taking into account the local people. For example, as Teluk Bintuni has a slogan of "Tanah Sisar Matiti", it must be legally set as local regulation to have an impact on the development program in this district. Moreover, the biodiversity management of mangroves in Teluk Bintuni could support biodiversity as well as benefit globally as part of carbon sequestration.

ACKNOWLEDGEMENTS

We thank District Government of Teluk Bintuni and PT Bintuni Utama Murni Wood Industries (BUMWI) for the permit and field assistance. In addition, we also thank anonymous reviewers for improving this manuscript.

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