SEBARAN MANGROVE DAN ESTIMASI KONDISI *Canopy Closure* DENGAN METODE *Hemispherical photography* SEDERHANA PADA KOMUNITAS MANGROVE DESA WAIHERU

Mangrove Distribution and Estimation of Canopy Closure Condition: Employing the Simple Hemispherical Photography Method within the Mangrove Community of Waiheru Village

Janson Hans Pietersz*, Reinhardus Pentury
Department of Water Resource Management, Faculty of Fisheries and Marine Science, Universitas Pattimura
Jl. Mr. Chr. Soplanit, Poka, Ambon, Maluku 97233 Indonesia
*correspondence: jansonpietersz.1301@gmail.com, *rpentury0508@gmail.com*

ABSTRAK

Penutupan kanopi pada komunitas mangrove Desa Waiheru memiliki peranan yang sangat penting dalam melindungi area pemukiman dari terpaan angin kencang dan juga dapat menaungi organisme perairan yang berasosiasi untuk dapat terhindar dari terpaan sinar matahari secara langsung, naungan kanopi mangrove juga dapat menjadi daya dukung dalam pengembangan ekowisata mangrove di area tersebut. Penelitian ini bertujuan untuk mengetahui bagaimana sebaran jenis mangrove, sebaran substrat dan bagaimana kondisi penutupan kanopi mangrove. Metode yang digunakan dalam pengambilan data mangrove dan substrat yaitu *Stratified Random Sampling*. Sedangkan untuk pengambilan data penutupan kanopi dilakukan dengan menggunakan metode *Hemispherical Photography*. Hasil analisa dapat menjelaskan bahwa ditemukannya 11 jenis mangrove yang terdiri dari 7 famili. Jenis *Rhizophora mucronata* merupakan jenis yang memiliki sebaran pertumbuhan yang lebih luas bila dibandingkan dengan jenis lainnya. Terdapat juga 2 tipe substrat yaitu substrat lumpur berpasir dan berpasir. Kondisi penutupan kanopi mangrove di Desa Waiheru masih dalam kondisi baik dimana sebagian besar stasiun pengamatan memiliki persentase penutupan kanopi yang tergolong padat dan sedang.

Kata kunci: Sebaran mangrove; Substrat; Penutupan kanopi

ABSTRACT

The canopy closure within Waiheru Village's mangrove community is crucial in shielding residential areas from robust winds and providing shade for associated aquatic organisms, thereby mitigating the effects of direct sunlight. Furthermore, the shading provided by the mangrove canopy contributes to the area's carrying capacity for developing mangrove-based ecotourism. This study aims to investigate the distribution of mangrove species, substrate distribution, and the condition of the mangrove canopy closure. Stratified Random Sampling was employed for the data collection on mangroves and substrates, while the Hemispherical Photography method was utilized to gather canopy cover data. The analysis revealed the presence of 11 mangrove species from seven different families, with Rhizophora mucronata exhibiting the most extensive growth distribution compared to other species. Two substrate types, sandy and sandy mud, were also identified. The mangrove canopy closure in Waiheru Village *remains in favorable condition, as most observation stations demonstrate a high proportion of dense and moderate canopy closure.*

Keywords: *Mangrove distribution; substrate; Canopy closure*

Introduction

Mangroves are specialized plants that thrive and reproduce effectively in sheltered coastal areas with an adequate freshwater supply. Typically, they inhabit regions between the highest tidal level and areas around or above the average sea level (Suapriharyono, 2017). Waiheru Village's coastal area provides an ideal environment for the presence and growth of mangroves. Mangrove communities are vital in supporting coastal populations and associated aquatic organisms (Mardhotillah et al., 2021; Pietersz et al., 2022).

Mangrove ecosystems contribute to the balance of coastal environments and support the livelihoods of nearby communities by functioning as producers of organic material, habitats for mangrove fauna, protectors and barriers for coastlines, and areas for tourism and conservation (Saparinto, 2007). Waiheru Village's mangrove community plays a significant role in meeting the needs of neighboring communities, who rely on associated aquatic organisms for consumption and sale. Nanlohy (2013) reported that the direct benefits derived from Waiheru's mangrove ecosystem by surrounding communities include firewood, fish, clams, crabs, shrimp, and eels. Additionally, the mangrove community serves as an ecotourism and educational area, further bolstering the local economy (Mardhotillah et al., 2021).

Canopy closure is a critical component of mangroves that supports these benefits. In Waiheru Village, the mangrove canopy provides shade for associated aquatic organisms and contributes to environmental support for the area's development of mangrove ecotourism. Canopy closure is a barrier, limiting light penetration within a plant ecosystem (Kumala et al., 2021). The condition of mangrove canopy closure is also essential as an environmental support component in developing mangrove ecotourism, particularly for tracking activities and determining the area's carrying capacity to accommodate visitors (Pratiwi et al., 2022).

Excessive exploitation of mangroves by local communities in Waiheru village's coastal area can negatively impact canopy closure. This finding aligns with Nurdiansha and Dharmawan's (2018) study, which revealed moderate and rare (damaged) mangrove canopy closures could result from local community activities. Consequently, management measures, including monitoring the mangrove ecosystem's condition, are necessary to preserve mangroves' distribution and canopy closure in Waiheru village's coastal area.

In addition to external factors, biological factors can also influence the canopy closure of individual mangrove species, such as the distinct growth characteristics and leaf sizes. Dharmaji and Lestarina's (2019) research supports this, showing that the percentage of canopy closure in mangrove ecosystems, analyzed using the hemispherical photography method, is significantly influenced by the leaf size of each encountered mangrove species. The distribution or zonation of mangroves in various locations is highly diverse and affected by factors such as substrate. Rahmadhani et al. (2021) noted that substrate conditions, salinity, and water levels influence the mangrove forest zone.

Given the scarcity of information on the distribution of mangrove species, substrate distribution, and canopy closure conditions as essential data for managing and preserving Waiheru village's mangrove ecosystem—particularly in supporting the community-managed mangrove ecotourism program—this study aims to ascertain the distribution of mangrove species in Waiheru village's coastal area, the distribution of substrate as a limiting factor in mangrove distribution, and the canopy closure condition of each mangrove population, analyzed using a straightforward hemispherical photography method.

Methodology

Time and Location

This study occurred between September and October 2022 and was situated in the mangrove ecosystem of Waiheru Village in Teluk Ambon Dalam, Ambon City, Maluku Province (Figure 1). Astronomically, the research area encompassing the mangrove community in Waiheru Village lies between 128°13'18.08" and 128°13'47.87" E and 3°38'1.36" and 3°37'49.87" S (Figure 1).

Drawing on Odum's (1993) concept of the ecological niche, it can be deduced that the growth of individual mangrove species exhibits various distributions based on their respective niches, with certain limiting factors affecting mangrove growth in a particular area. These limiting factors in mangrove distribution create a characteristic zonation pattern (Ruslia et al., 1999). The stratified random sampling method (Vries, 1986; Dharmawan et al., 2020) determined observation stations or quadrants based on mangrove growth or zonation patterns. This method involved randomly selecting observation stations according to the growth patterns of various mangrove species. Subsequently, a 10x10 meter quadrant was established at each observation station to gather data on mangrove canopy closure percentages and substrate data as one of the limiting factors of mangrove distribution (Dharmawan et al., 2020).

The quadrants established in this study were tailored to the research objectives, with quadrants set up for each population of the identified species. As a result, each quadrant was expected to interpret the canopy closure of the population of each encountered mangrove species. This method was also employed to determine substrate sampling points, which were analyzed as limiting factors influencing mangrove distribution.

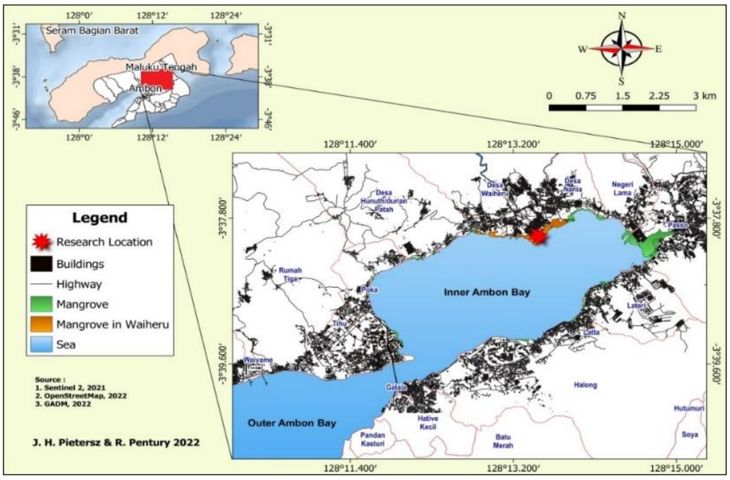

Figure 1. Map of the Research Study Area

Tools and Material

The tools and materials used in this study are as follows:

Table 1. Tools and Materials

Tools and Materials	Purpose
Smartphone (Samsung A7 2018, Selfie camera: 24 MP, f/2.0, 26mm (wide), 1/2.8", 0.9µm)	Collecting canopy closure data and recording each mangrove species and their surrounding conditions within quadrats
GPS (Garmin 78s)	Recording coordinates at each station
Nylon rope (40 m in length	Establishing 10x10 m observation quadrats
Cat spray (Suzuka SF-4, Pink)	Labeling each observation station/quadrat
Modified sediment core *(PVC 2)*	Collecting substrate samples
Sieve shaker machine (Made in China)	Separating substrates according to grain size
Mangrove identification book	Identifying each discovered mangrove species

Data Collection

At each observation station/quadrant, herbarium samples, including leaves, flowers, and fruits, were collected and documented to capture the roots, stems, leaves, flowers, and fruits essential for accurately identifying the mangrove species encountered.

Canopy closure data at each observation station/quadrant were collected using a simplified hemispherical photography method specifically designed for monitoring mangrove cover in COREMAP CTI (Dharmawan & Pramudji, 2014; Dharmawan et al., 2020). This technique involved capturing images of the canopy facing the sky using a smartphone's front camera, held at the height of 1.3 meters above the sediment surface or an adult's chest height (Jennings et al., 1999; Korhonen et al., 2006; Paletto & Tosi, 2009; Dharmawan et al., 2020). Canopy photographs were taken within the established observation quadrants with five repetitions. The camera was positioned vertically between individual trees to ensure that the analyzed canopy closure solely represented the coverage of the mangrove canopy and leaves (Figure 2). The substrate sampling used a sediment core device to maintain the mangrove environment's integrity (English et al., 1997). Substrate samples were collected randomly within the 10x10 quadrant without repetitions at a hole depth of 30 cm.

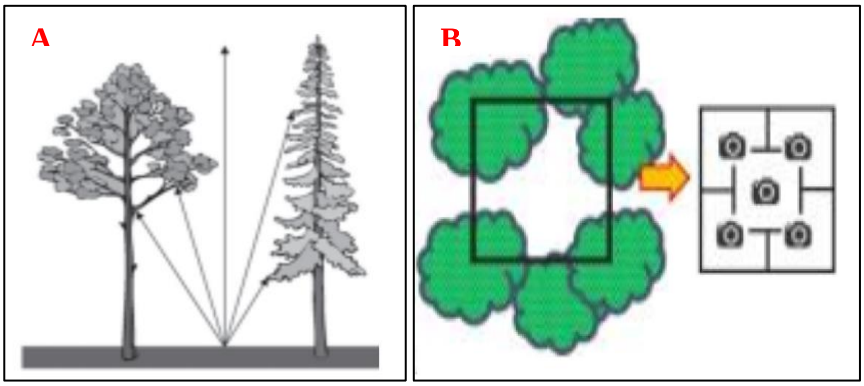

Figure 2. Illustration of Mangrove Canopy Closure Photo Collection (A: Korhonen et al., 2006, B: Dharmawan et al., 2020)

Data Analysis

The acquired mangrove vegetation data were identified and classified according to Tomlinson (1986); Rusila et al. (1999); Kitamura et al. (1999); Giesen et al. (2002); and Spalding et al. (2010). Mangrove canopy closure data from photographs were analyzed using Image-J and Microsoft Excel 2010 (Dharmawan et al., 2020). The canopy closure images were assessed to determine the percentage of canopy closure pixels relative to sky pixels. Subsequently, the canopy closure analysis results were interpreted based on the Mangrove Damage Standard (Table 2). The hemisphere photo processing using the Image-J application involved several steps: converting RGB photos to 8-bit, executing threshold processes to separate pixels representing canopy closure and sky, performing canopy matrix calculations or determining the number of each pixel group in the histogram display, and ultimately exporting and saving the resulting threshold photo in various formats (Beckschäfer, 2015; Dharmawan et al., 2020).

The collected substrate samples were dried and analyzed using a Sieve Shaker Machine, and the substrate analysis results were interpreted based on the Wentworth scale (English et al., 1997). The Quantum GIS Bialowieza 3.22.4 application was employed to evaluate the distribution of mangroves and substrates and canopy closure conditions based on observation stations.

Table 2. Mangrove Damage Standard
(Minister of Environment Regulation No. 201 the Year 2004)

Criteria		Canopy Closure (%)
Excellent	Very dense	≥ 75
	Moderate	≥ 50 - < 75
Degraded	Sparse	< 50

RESULTS AND DISCUSSION

Composition and Distribution of Mangrove Species

Observations and identification revealed the presence of 11 mangrove species belonging to 7 families in the study area, with the Rhizophoraceae family being the most dominant, comprising seven species (Table 3). The total area of mangroves along the Waiheru Village coastline is approximately 16.22 hectares. However, the area investigated in this study only covered 77.13% of the total mangrove area in Waiheru Village, amounting to around 12.52 hectares. Overlapping interests in several coastal areas of Waiheru Village posed challenges in accessing or studying the entire mangrove area. The mangrove area in Waiheru Village has increased since nine years ago when it covered approximately 11.39 hectares in 2013 (Nanlohy, 2013).

Table 3. Composition of Mangrove Species along the Waiheru Village Coast

Family	Species	Local Name	Initial
Arecaceae	*Nypa fruticans* Wurmb.	Daun atap	NF
Avicenniaceae	*Avicennia lanata* Ridley.	Api-api	AL
Bombacaceae	*Camptostemon schultzii* Master	Batang putih	CS
Myrsinaceae	*Aegiceras corniculatum* (L.) Blanco	Cili laut	AC
Rhizophoraceae	*Bruguiera parviflora* (Roxb.) W. & A. ex Griff.	Tongke perempuan	BP
	Ceriops tagal (Perr.) C. B. Rob.	Tongke	CT
	Rhizophora apiculata Bl.	Tongke laki-laki	RA
	Rhizophora mucronata Lmk.	Tongke laki-laki	RM
	Rhizophora stylosa Griff.	Tongke-tongke	RS
Rubiaceae	*Scyphiphora hydrophyllacea* Gaertn. F.	Cengkeh laut	SH
Sonneratiaceae	*Sonneratia alba* J. E. Smith	Mange-mange	SA

Figure 3. Identified Mangrove Species

Considering the distribution of each mangrove species, it becomes evident that the species found exhibit diverse distributions. The extensive distribution of *Rhizophora mucronata* can be observed by establishing 31 observation stations, where this species was found at seven observation stations, indicating its dominance in the study area. Following this, *Camptostemon schultzii* and *Sonneratia alba* were found in four observation stations, while *Bruguiera parviflora* was present in three.

Meanwhile, *Scyphiphora hydrophyllacea* and *Avicennia lanata* had the lowest population distributions at only one observation station (Figure 4). The dominant distribution of *Rhizophora mucronata* in the study area can be attributed to substrate conditions that strongly support the growth of this species (Figure 5). According to Prinasti et al. (2020), *Rhizophora mucronata* can be found on sandy clay and sandy clay loam substrates in Ngurah Rai Forest Park, Bali. In the coastal waters of Negeri Ihamahu Saparua Island, *Rhizophora mucronata* can be found on muddy and fine sand substrates (Lewerisa et al., 2018).

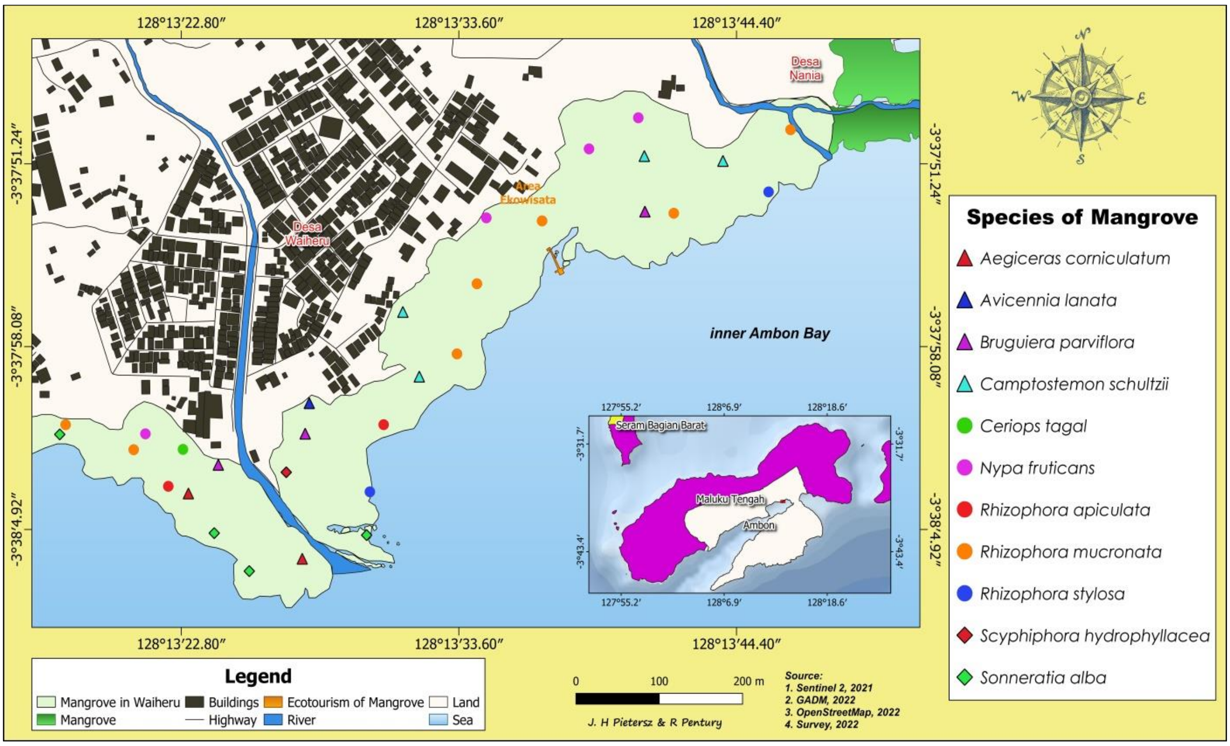

Figure 4. Distribution Map of Mangrove Species

Substrate Distribution

The substrate analysis conducted at all research stations revealed two types of substrates in the study area: sandy mud and sandy substrates. Among these, sandy mud substrate had a more extensive distribution, as demonstrated by its presence at 17 observation stations, while the remaining 14 stations had sandy substrate (Figure 5). The substrate conditions observed at the research location significantly contribute to the presence and growth of mangroves. The highest number of mangrove species was found on sandy mud substrate, with eight species identified: *Rhizophora mucronata*, *Rhizophora apiculata*, *Nypa fruticans*, *Scyphiphora hydrophyllacea*, *Sonneratia alba*, *Aegiceras corniculatum*, *Ceriops tagal*, and *Bruguiera parviflora*. On sandy substrate, seven mangrove species were found: *Camptostemon schultzii*, *Nypa fruticans*, *Rhizophora stylosa*, *Rhizophora mucronata*, *Sonneratia alba*, *Avicennia lanata*, and *Bruguiera parviflora*.

Similarly, Japa and Santoso (2018) reported that muddy substrate mixed with sand significantly supports mangrove species, as evidenced by the eight mangrove species found in Sekotong District, West Lombok, Indonesia. In the mangrove ecosystem of Pagatan Besar Village, robust growth was observed in areas with muddy substrates. Suyadi (2009) reported that the coastal area of Waiheru Village features a flat topography with muddy substrate, which is highly conducive to mangrove growth.

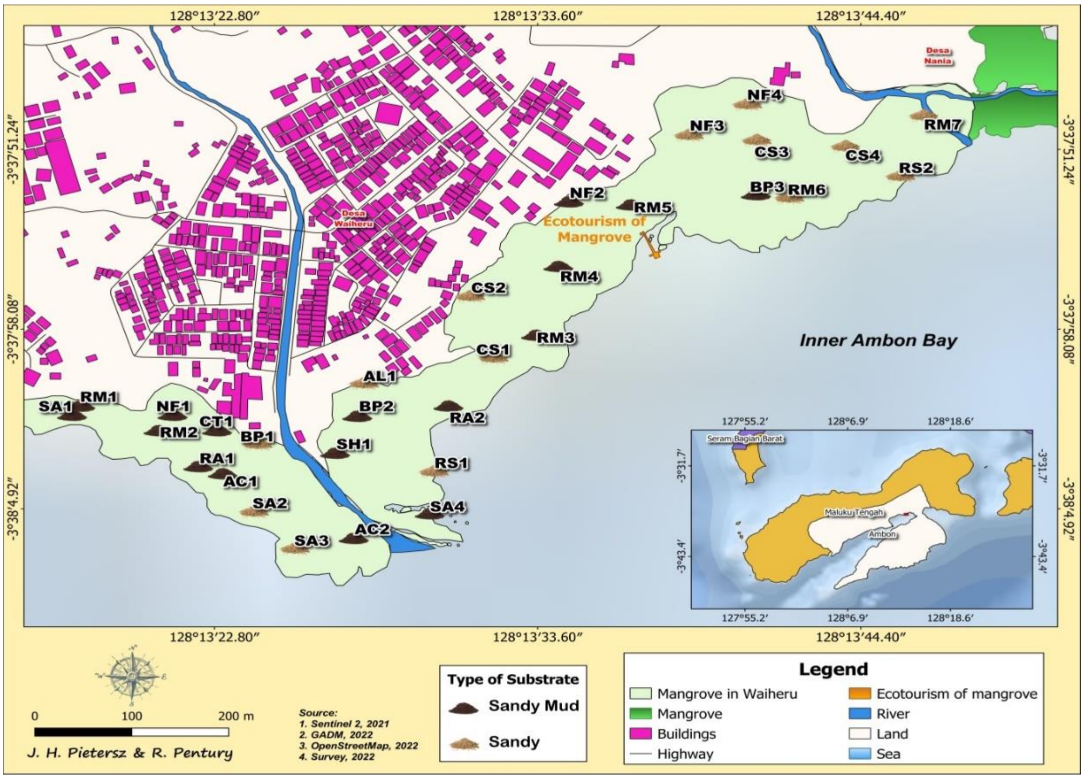

Figure 5. Substrate Distribution Map in Waiheru Village Mangrove Community

Mangrove Canopy Cover

Based on the analysis of mangrove canopy cover and the assessment of canopy cover conditions according to the standard for mangrove damage (Table 1), it is evident that the overall condition of mangrove canopy cover in the coastal waters of Waiheru Village is favorable. Of 31 observation stations, 30 displayed good mangrove canopy cover, with dense canopy cover at 22 stations and moderate canopy cover at eight stations. Sparse canopy cover was observed at only one observation station (Figure 7).

The observation station with sparse mangrove canopy cover is SA4. The low value of canopy cover at SA4 and the moderate canopy cover at RS1 can be attributed to these stations being mangrove rehabilitation areas, with individual trees still in the sapling and seedling stages. Although mature trees were present in other stations, such as SA1, SA2, and SA3, the canopy cover condition of Sonneratia alba was still moderate. This is because the growth characteristics of Sonneratia alba tend to result in moderate to sparse canopy cover, with individual trees having considerable distances between them due to the dominant root growth area of the species. As described by Nurdiansah and Dharmawan (2021), the growth pattern of *Sonneratia alba* populations is unique, characterized by trees spaced at considerable distances, which prevents them from being overshadowed by suckers or seedlings. A similar observation was made in the mangrove community of Teluk Benoa, Bali, where *Sonneratia* sp. exhibited a moderate canopy cover, with a value of 53.00% (Sugiana et al., 2022). *Rhizophora mucronata* populations displayed exceptional canopy cover conditions, featuring dense mangrove coverage percentages from 78.31% to 91.19% across all stations (RM1, RM2, RM3, RM4, RM5, RM6, and RM7). Additionally, *Camptostemon schultzii*, *Bruguiera parviflora*, and *Rhizophora apiculata* exhibited dense canopy cover conditions at four, three, and two stations, respectively (with percentages ranging from 79.93% to

88.26%). This pattern was also evident in Desa Betahwalang, where all observation stations presented dense mangrove coverage. In Teluk Benoa, Bali, mangrove coverage dominated by *Rhizophora* sp. and *Bruguiera* sp. populations also showed dense conditions, with percentages of 75.33% and 78.08%, respectively. The mangrove coverage in the ecosystems of Pulau Batanta and Pulau Salawati in the Raja Ampat district was similarly dense, with percentages ranging from 77.80% to 88.97%. *Rhizophora apiculata* and *Bruguiera gymnorrhiza* emerged as the dominant species at each station.

The high percentage of canopy cover in *Rhizophora* sp. can be attributed to its excellent branch and leaf growth and its larger leaf size compared to other mangrove species. *Rhizophora* sp. is known to have leaves measuring between 9 to 20 cm, resulting in a higher percentage of mangrove canopy cover (Kuncahyo et al., 2020; Purnama et al., 2020). The favorable mangrove cover conditions in the coastal waters of Desa Waiheru are supported by the local community's heightened awareness of the importance of mangroves in daily life. This is evident from the decrease in mangrove felling activities, which indirectly support mangrove growth in the coastal waters. The participation of youth groups and local residents in mangrove planting activities, garbage cleaning actions, and the creation of flora and fauna nameplates, which are aimed at supporting the development of ecotourism-based mangrove attractions, also indicate the high awareness of the importance of mangrove forests in Desa Waiheru (Mardhotillah et al., 2021).

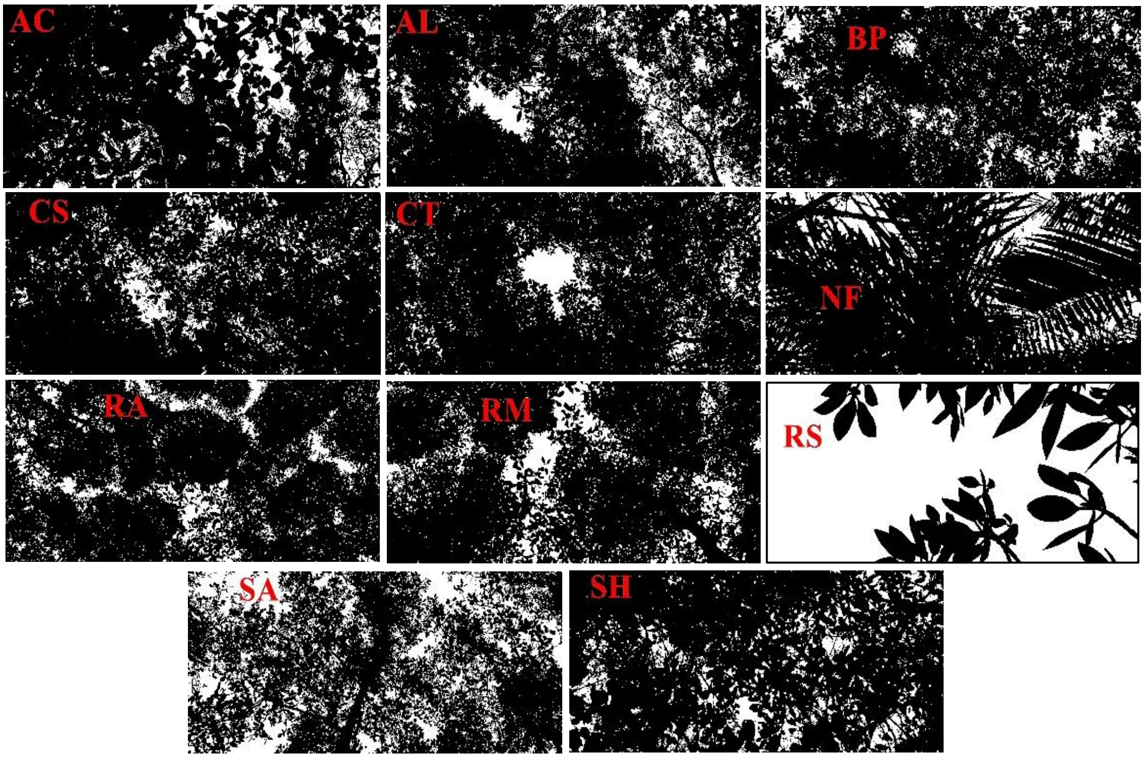

Figure 6. Some Canopy Cover Analysis Results Using Image-J Application

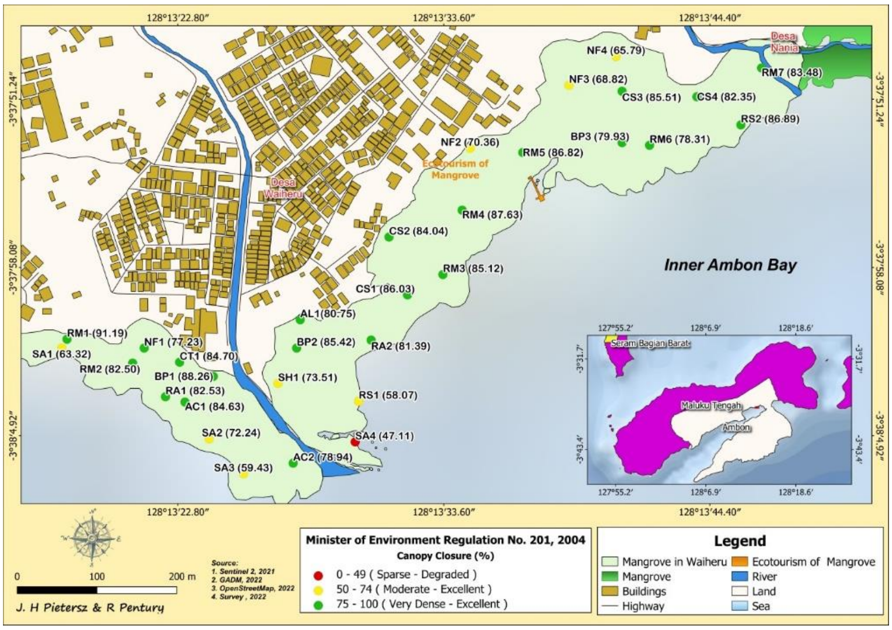

Figure 7. Canopy Cover Condition Map Based on Mangrove Species

Strengths and Weaknesses

The hemispherical photography method employed in this study uses more straightforward equipment compared to other methods utilized in previous studies, such as those by Jennings et al. (1999) and Palletto & Tosi (2009), which involved professional photography equipment like a professional camera with the assistance of a 30º and 60º fisheye camera. This study's straightforward hemispherical photography method utilized a smartphone camera, making it more accessible to various groups (Dharmawan et al., 2020). Although the digital camera measurement method in the field is cost-effective and yields interpretable results, interpreting canopy cover for extended periods can be challenging. Many researchers employ remote sensing methods to estimate canopy cover with greater ease and accuracy. However, hemispherical photography is necessary to test and validate the results obtained from remote sensing methods (Korhonen et al., 2006).

Field-based canopy cover measurements using digital cameras offer a cost-effective approach with highly reliable interpretation results. However, this method can be challenging for long-term canopy cover interpretations (Korhonen et al., 2006). Most researchers employ remote sensing methods to estimate long-term canopy cover for easier and more accurate outcomes. Acquiring canopy cover data using digital cameras (hemispherical photography) is essential for testing and validating results obtained through remote sensing methods (Korhonen et al., 2006).

A significant challenge when implementing the simple hemispherical photography method using smartphones is sunlight. Direct sunlight on the camera lens should be avoided when taking canopy photos (Lusk, 2022). Therefore, collecting data using this method is recommended when the sun's position is not vertically aligned with the smartphone lens. Palletto & Tosi (2009) state that overcast skies are crucial for optimal contrast. Dharmawan et al. (2020) suggest adhering to several rules when taking photos using this method, including 1) minimizing direct sunlight penetration on the camera lens, 2) avoiding wet or damp lenses, and 3) preventing the capture of extraneous objects. These factors make determining the appropriate time to take canopy photos in the field challenging. Several environmental conditions are essential for deciding the ideal time to collect mangrove canopy cover data using hemispherical photography, such as data collection during low tide, data acquisition in the morning or late afternoon, and avoiding the rainy season.

Conclusion and Recommendations

Eleven mangrove species were identified, with Rhizophora mucronata being the most widely distributed. Sandy mud substrates predominantly characterize the substrate conditions. The canopy cover (canopy closure) of the Waiheru village mangrove remains in good condition. Consequently, the local community and all stakeholders must prioritize and preserve the Waiheru village mangrove ecosystem. Further research is needed to monitor mangrove canopy cover activities in the coming years. It is also recommended to research canopy cover using remote sensing methods for comparison with hemispherical photography results.

Acknowledgments

We thank the Faculty of Fisheries and Marine Science, Pattimura University, Ambon, for funding this research and the Faculty's leadership for supporting the research implementation. We also thank all parties who assisted us during the research.

References:

Beckschäfer, P. 2015. Hemispherical_2.0 – Batch processing hemispherical and canopy photographs with ImageJ – User Manual. Chair of Forest Inventory and Remote Sensing, GeorgAugust-Universität Göttingen, Germany. www.uni-goettingen.de/en/75936.html

Dharmaji, D., P. M. Lestarina,. 2019. Status Ekosistem mangrove di Kecamatan Takisung, Kabupaten Tanah Laut: Pendekatan *Hemispherical* Photography. Prosiding Seminar Nasional Lingkungan Lahan Basah 4(1):138-142.

Dharmawan, I.W.E., dan Pramudji. 2014. Panduan Monitoring Status Ekosistem Mangrove. Coremap CTI – LIPI, 35-11 pp

Dharmawan, I. W. E., Suyarso, Y. I. Ulumuddin, B. Prayudha, Pramudji,. 2020. Panduan Monitoring Struktur Komunitas Mangrove Indonesia, LIPI (Coremap-CTI). PT Media Sains Nasional. Bogor.

English, S., C. Wilkinson, & V. Baker,. 1997. Survey manual for Tropical Marine Resources 2nd Edition. Australian Institute of Marine Science. Townsville, 390 pp.

Giesen, W., S. Wulffraat, M. Zieren & L. Scholten. 2006. Mangrove Guidebook for Southeast Asia. FAO and Wetlands International. Bangkok.

Japa, L., D. Santoso,. 2018. Analisis Komunitas Mangrove di Kecamatan Sekotong Lombok barat NTB. Jurnal Biologi Tropis 19(1):25-33.

Jennings, S.B., N.D. Brown & D. Sheil. 1999. Assessing forest canopies and understorey illumination: canopy closure, canopy cover and other measures. Forestry 72(1): 59–74.

Keputusan Menteri Negara Lingkungan Hidup Nomor 201 tahun 2004. Tentang Kriteria Baku dan Pedoman Penentuan Kerusakan Mangrove.

Kitamura, S., C. Anwar, A. Chaniago & S. Baba. 1999. Handbook of Mangroves in Indonesia Bali & Lombok. Saritaksu. Denpasar, Indonesia.

Korhonen, L., Korhonen, KT, Rautiainen, M. & Stenberg, P.2006. Estimation of forest canopy cover: a comparison of field measurement techniques. Silva Fennica 40(4): 577–588.

Kumala, K. A., R. Pribadi, R. Ario,. 2021. *Hemispherical photography* Vegetasi Pantai di Perairan Pulau Sintok, Taman Nasional Karimunjawa. Journal of Marine Research 10(2): 313-320.

Kuncahyo, I., R. Pribadi, I., Pratikno,. 2020. Komposisi dan penutupan kanopi Vegetasi Mangrove di Perairan Bakauheni, Kabupaten Lampung Selatan. Journal Of Marine Research 9 (4):444-452.

Lewerissa, Y. A. M, M.Sangaji, M. B. Latumahina,. 2018. Pengelolaan Mangrove Berdasarkan Tipe Substrat di Perairan Negeri Ihamahu Pulau Saparua. Jurnal Manajemen Sumberdaya Perairan TRITON 14(1): 1-9.

Mardhotillah, Ach. B. A., A. M. Uar, B. Asran, Z. Seban, M. H. Gani, F. Asran & M. S. Ernas. 2021. Pengembangan Objek Wisata Hutan Mangrove Berbasis Ekowisata. JP2M: Jurnal Pembelajaran Pemberdayaan Masyarakat 2(3): 250-254.

Nanlohy, E. 2013. Valuasi Ekonomi Ekosistem Mangrove Hutan Mangrove Di Desa Waiheru Kota Ambon. Pena Jurnal Ilmu Pengetahuan dan Teknologi 25 (1): 15-21.

Nurdiansah, D., I. W. E. Dharmawan,.2018. Komunitas Mangrove di Wilayah Pesisir Pulau Tidore dan Sekitarnya. Jurnal Oseanologi dan Limnologi di Indonesia 3(1): 1-9.

Nurdiansah, D., I. W. E. Dharmawan,.2021. Struktur Komunitas dan Kesehatan Mangrove di Pulau Middleburg-Miossu, Papua Barat. Jurnal Ilmu dan Teknologi Kelautan Tropis 13(1): 81-96.

Odum, E.P. 1993. *Dasar-dasar Ekologi*. Terjemahan Tjahjono Samingan. Edisi Ketiga. Yogyakarta: Gadjah Mada University Press. Yogyakarta. 697 pp.

Paletto, A & V. Tosi,. 2009. Forest Canopy Cover and Canopy Closure: Comparison of assessment techniques. European Journal of Forest Research 128: 265-272.

Pentury, R., Pietersz, J. H., Tuapattinaja, M. A., Pello, F. S., Huliselan, N. V., Hulopi, M., & Tupan, C. I. Potensi Komunitas Mangrove Pantai Tial Kabupaten Maluku Tengah. *Triton: Jurnal Manajemen Sumberdaya Perairan*, *16*(2), 68-76.

Pietersz, J. H., Pentury, R., & Uneputty, P. A. (2022). Keanekaragaman Gastropoda Berdasarkan Jenis Mangrove Pada Pesisir Pantai Desa Wiheru. TRITON: *Jurnal Manajemen Sumberdaya Perairan*, 18(2), 103-109.

Pratiwi, A.B., A. Darmawan & S. Arsad,. 2022. Analisis Kesesuaian dan Daya Dukung Pengembangan Ekowisata Mangrove Di Rejoso, Pasuruan, Jawa Timur. Jurnal Kebijakan Sosial Ekonomi Kelautan dan Perikanan 12(1): 39-48.

Prinasti, N. K. D., I. G. B. S. Dharma, Y. Suteja,. 2020. Struktur Komunitas Vegetasi Mangrove Berdasarkan Karakteristik Substrat di Taman Hutan Raya Ngurah Rai, Bali. Journal of Marine and Aquatic Science 6(1): 90-99.

Purnama, M., R. Pribadi, N. Soenardjo,. 2020. Analisis penutupan kanopi Mangrove Dengan Metode *Hemispherical photography* di Desa Betahwalang, Kabupaten Demak. Journal Of Marine Research 9(3):317-325.

Rahmadhani, T., Y. F. Rahmawati, R. Qalbi, N. H.P. Fithriyyah & S. N. Husna,. 2021. Zonasi dan Formasi Vegetasi Hutan Mangrove: Studi Kasus di Pantai Baros, Yogyakarta. Jurnal Sains Dasar 10(2): 69-73.

Rusila, N.Y., M. Khazali dan I N. N. Suyadiputra, 1999. Panduan Pengenalan Mangrove Di Indonesia. PHKA/WI-IP, BOGOR.

Saparinto, C. 2007. Pendayagunaan Ekosistem Mangrove. Dahara Prize, Semarang.

Schaduw, J. N. W. 2020. Percentage of mangrove canopy coverage and community structure in Batanta Island and Salawati Island, Raja Ampat District, West Papua Province. Journal Aquatic Science & Management 8(1):28-34.

Spalding, M., F. Blasco, & C. Field,. 2010. World Mangrove Atlas. UNEP-WCMC, Cambridge University Press.

Sugiana, I. P., A. A. E. Andiani, I. G. A. I. P. Dewi, I. W. G. A. Karang, ABD. R. A. Syukur, I. W. E. Dharmawan,. 2022. Spatial distribution of mangrove health index on three genera dominated zones in Benoa Bay, Bali, Indonesia. Biodiversitas 23(7): 3407-3418.

Suyadi,. 2009. Kondisi Hutan Mangrove di Teluk Ambon: Prospek dan Tantangan. Berita Biologi 9 (5): 481-490.

Supriharyono,. 2017. Konservasi Ekosistem Sumber Daya Hayati Di Wilayah Pesisir dan Laut Tropis, Edisi Ketiga. Pustaka Pelajar, Yogyakarta.

Tomlinson, P.B. 1986. The Botany of Mangroves. Cambridge University Press, Cambridge, U.K. 413 pp.

Vries, P. G. de. 1986. Sampling Theory for Forest Inventory. A Teach–Yourself Course. Springer-Verlag. Berlin Heidelberg.