Mangrove Community Structure and Healthiness in Rote Ndao, East Nusa Tenggara

Fakhrurrozi[1*], *Z.* Yuniar[2], *T. R.* Alam[3], *M. A.* Asriadi[4], Idris[1], *S.* Yusri[1], *R. A.* Dewi[5]

[1]TERANGI Foundation, Jl. Asyibaniyah No. 105-106 Pondok Jaya, 16438 Depok, Indonesia
[2]Padjajaran University, Jl. Raya Bandung-Sumedang KM.21 Jatinangor, 45363 Sumedang, Indonesia
[3]Sunan Ampel State Islamic University, Jl. Ahmad Yani No.117 Jemur Wonosari, 60237 Surabaya, Indonesia
[4]Marine and Fisheries Polytechnic of Pangandaran, Jl. Raya Babakan KM 2, 46396 Pangandaran, Indonesia
[5]BKKPN Kupang, Jl. Yos Sudarso, 85231 Kupang, Indonesia

Abstract. Mangroves in Rote Ndao play an important role in protecting and preserving 65% of fish and marine biota in this surrounding area. Unfortunately, the data and information about the condition of the mangrove ecosystem are limited and less published. This study aimed to determine the mangrove community structure and spatial distribution of mangrove healthiness in Rote Ndao District. Mangrove distribution was investigated using the k-means algorithm classification method by Sentinel 2A Surface Reflectance. Mangrove community structure and condition were studied in 39 observation plots spread around Rote Ndao Regency. The Healthiness distribution of the mangrove ecosystem was analyzed using the MHI Algorithm produced by Dharmawan. A total of 13 mangrove species have been identified, with the highest Important Value Index (IVI) *Rizhophora apiculata* and *Sonneratia alba*. The average canopy cover shows a medium value of 63.48±16.34%, density of 21.55±9.31 stand/plot, Diameter Breast Height (DBH) 15.93±5.25 cm, and height 12.05±4.54 m. Mangrove Health Index (MHI) shows a moderate to excellent category with an average of 64.01±13.18 %. The distribution of mangrove areas in Rote Ndao is 2,081.44 ha, and 6% or 124 ha areas are in the poor category.

1 Introduction

Mangroves in Indonesia are spread from the West of Sumatra Island to the South of Papua Island, with a total area 2021 of 3,364,080 Ha [17]. From this, Indonesia is the largest mangrove area in the world [7]. Rote Ndao Island is located in the East Nusa Tenggara province, the southernmost region of Indonesia, bordering directly with the Indian Ocean. So the area is vulnerable to waves or high waves and strong winds. Therefore, a protective measure for its coastal area is required.

The mangrove ecosystem is essential for both humans and the surrounding environment. Mangroves serve as protective barriers for coastal areas against erosion, wind, tsunami, and

* Corresponding author: fakhrurrozi@terangi.or.id

prevent seawater intrusion [5], [7], [18]. Ecologically, mangrove ecosystems play as habitats, breeding grounds, and feeding sites for diverse species including fish, shrimp, and birds [20]. Economically, the mangrove tree trunks can be utilized for fuel and infrastructure. Besides, mangrove ecosystems provide a place for sourcing food such as fish and shrimp and can be prominent tourism destinations [7], [19].

Indonesia has a diversity of mangrove species totaling up to 202 different species. Mangrove species are most commonly found on Java Island with 166 species, Sumatra with 157 species, and Kalimantan with 150 species [18], [9]. The mangrove species in East Nusa Tenggara, particularly in Rote Ndao, remain largely unknown and unexplored. The lack of available data is one of this research aims to provide information regarding the condition, species, and distribution of mangroves in Rote Ndao, East Nusa Tenggara. This data will serve as a valuable information source and reference material for both government and non-government to develop the Rote Ndao mangrove ecosystem.

2 Method

2.1 Site description

This study focuses on the mangrove forests in the Rote Ndao Regency, East Nusa Tenggara. It is bordered directly by Timor and Southern waters to the south and the Sawu Marine National Park to the north. Observations have been conducted at 7 stations, covering 33 plots (10x10 m) from the west to the east of Rote Ndao. The community structure was collected for classification analysis, and the Mangrove Health Index (MHI).

2.2 Community structure assesment

The community structure assessed using a vegetation analysis approach and aided by observation plots measuring 10x10 m. The mangrove community structure data are species diversity, DBH (diameter at breast height), canopy cover, tree height, and Global Positioning System (GPS) location. The data were inputted into the Monmang application [1]. The IVI (Importance Value Index) was subsequently calculated based on the summation of Density, Frequency, and Dominance values. Hereupon, the data were analyzed using the MHI (Mangrove Health Index) algorithm, yielding information regarding the health condition of the mangroves in each observation plot [2].

2.3 Spatial analysis

The spatial distribution of mangroves was processed to obtain a cloud-free image collection using Sentinel 2 SR imagery data acquired in 2021. The image data analysis was entirely conducted on a cloud-based platform called Google Earth Engine [3]. The steps undertaken included cloud-free masking, elevation masking, water masking, unsupervised classification (k-means algorithm), accuracy assessment, and applying the MHI (Mangrove Health Index) algorithm. Overall accuracy assessment was done using GPS data of mangrove presence obtained from field observations. Mangrove healthiness distribution was analyzed based on the spatial model of the Mangrove Health Index developed by Nurdiansyah and Dharmawan [4]. This model used a combination of four vegetation indices: NBR, GCI, SIPI, and ARVI. MHI values were divided into three ranges of forest such as poor (0-33%), moderate (33-66%), and excellent (66-100%).

$$MHI = 102.12 * NBR - 4.64 * GCI + 178.15 * SIPI + 159.53 * ARVI - 252.39 \quad (1)$$

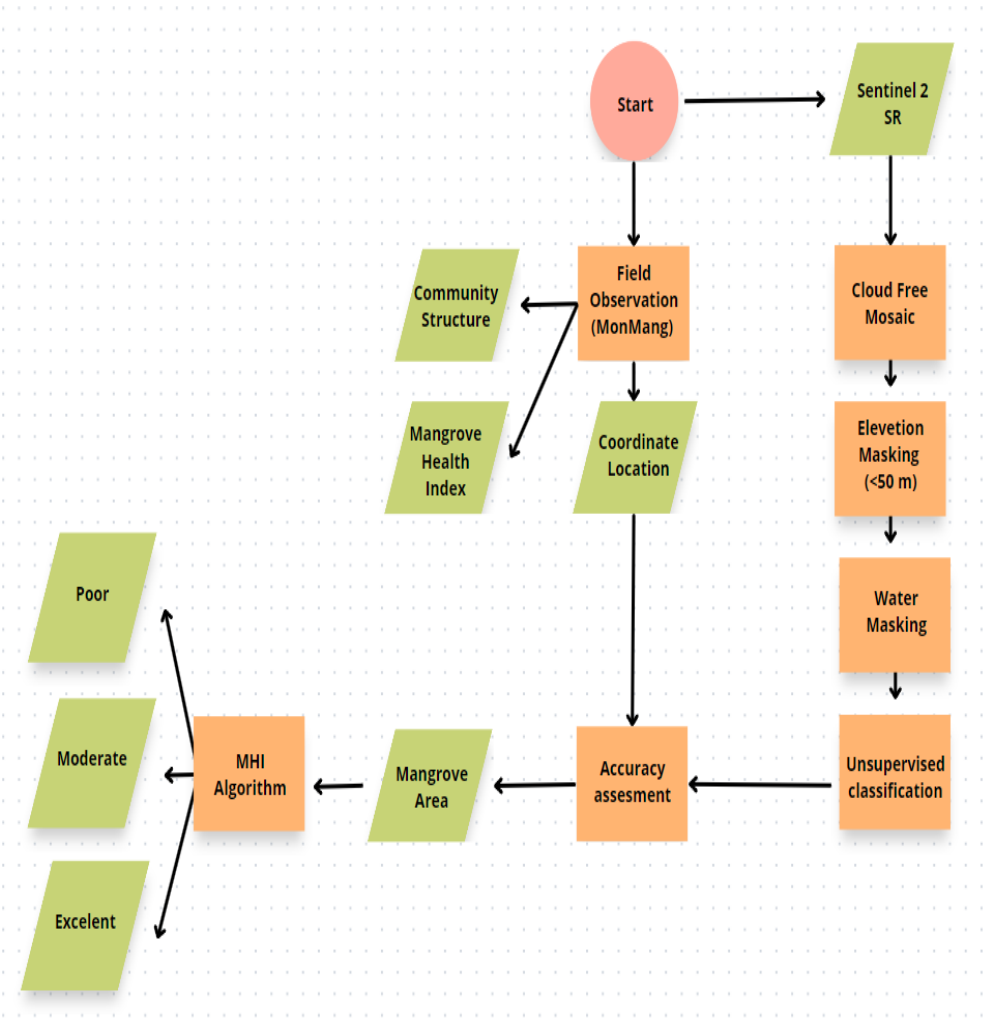

Fig 1. Workflow process of assessment mangrove community structure and spatial analysis.

3 Result and discussion

3.1 Mangrove area distribution

As a district consisting of several small islands around it, mangroves in Rote Ndao predominantly grow on the main land (Figure 2). Based on their habitat characteristics, estuarine mangroves, especially those near rivers, tend to dominate and can be found in the northern part of the island, specifically around the villages of Boni, Tesabela, and Balotena. Oceanic mangroves are found to dominate the southern part of the island, notably in Oeseli, Oebau, and Faifua. Based on the analysis of Sentinel 2 imagery data from 2021, it was found that the total mangrove area in Rote Ndao is approximately 2,081 hectares, with an overall

accuracy result of 92.31%. This expanse of mangrove is considerably larger when compared to the mangrove areas of nearby locations, such as Sabu Raijua, which only covers 82 hectares [5].

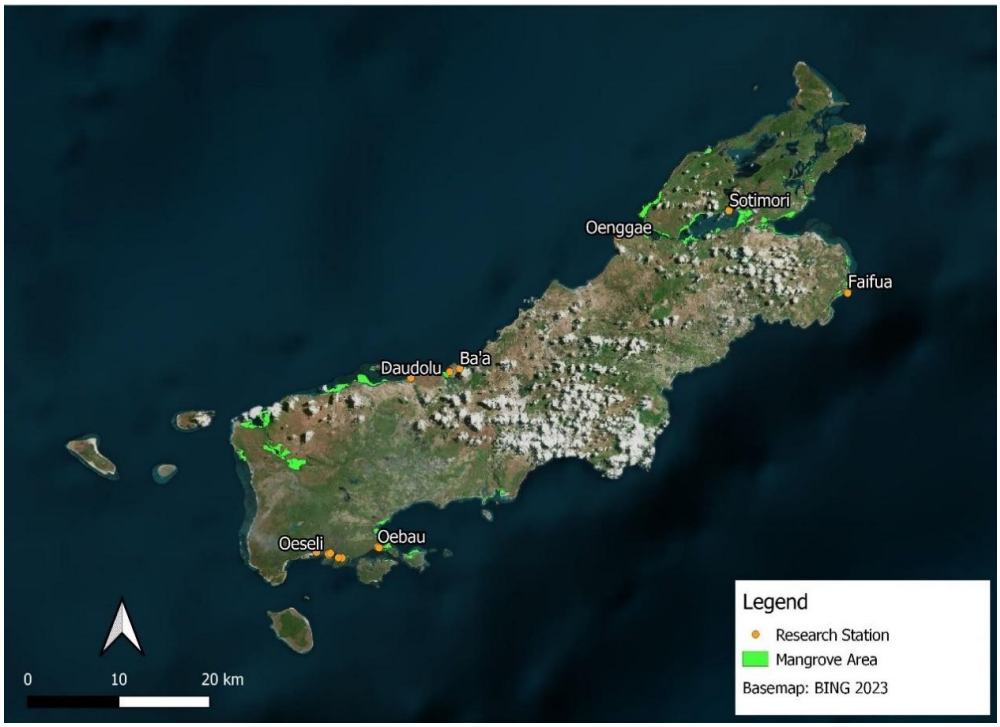

Fig 2. Distribution of mangrove area in Rote Ndao.

3.2 Mangrove community structure

Thirteen species of mangroves found in Rote Ndao. This abundance is relatively high when compared to locations such as Tanjung Benoa in Bali, which only has 9 species, Sabu Raijua with only 8 species, and the Biak Islands in Papua which consist of only 11 species [5]-[7]. Reviewing the data from each station, the location with the most variety is Faifua (9 species), while the locations with the least variety are Oenggae and Daudolu (each 2 species). For the stations at Faifua and Sotimori, only presence data was collected, leaving only 5 stations with complete data regarding community structure information (Table 1).

Overall, the highest IVI (Importance Value Index) values are held by *Rhizophora apiculata* and *Sonneratia alba*, each at 102%. The Baa station stands out as one location dominated by *R. apiculata*, followed by species *S. alba* and *R. mucronata*. This is also supported by the characteristics of the location of Baa Station which is protected, located at the mouth of a river and has a muddy substrate. Dominance of *R. apiculata* is also observed in several mangrove forests in Indonesia, such as in Karimunjawa and Padaidori Island, Biak Papua [7] and [8]. Noor et al. [9] also stated that mangrove habitats dominated by river flows and located in protected areas are preferable for *R. apiculata*. Pramujdi [10] further revealed that locations with a soft muddy substrate, forests, large rivers, and protected bays are suitable for supporting mangrove growth.

The canopy cover of the mangrove community indicates favorable results (seen in Figure 3 on the top left), exceeding 50%, ranging from the lowest at Daudolu, being 55±3%, to the

highest at Oenggae, which is 78±3%. According to the Decree of the Ministry of Environment No. 201 of 2004, the average percentage of mangrove canopy cover in Rote Ndao is Good/Moderate category (50-75%). This aligns with observational data from COREMAP CTI from 2015-2020, which states that the canopy cover of mangroves in East Nusa Tenggara and its surroundings ranges between 50-75% [11]. The canopy cover value in this study, on average, is still lower compared to other mangrove areas with more natural conditions, such as in Sawalati, West Papua, which is 84.73% [12].

Tabel 1. IVI Value and species distribution.

No	Species	IVI	Baa	Daudolu	Oebau	Oeselli	Oenggae	Faifua*	Sotimori*
1	*Aegilitis annulata*	4				1		1	1
2	*Avicennia eucalyptifolia*	7			1				
3	*Bruguiera gymnorhiza*	2			1				
4	*Bruguiera parviflora*	*						1	1
5	*Ceriops decandra*	22					1	1	
6	*Ceriops tagal*	2			1				1
7	*Lumnitzera racemosa*	9				1			
8	*Phempis acidula*	*						1	
9	*Rhizopora apiculata*	102	1		1		1	1	
10	*Rhizopora mucronata*	48	1	1	1	1		1	1
11	*Sonneratia alba*	102	1	1	1	1			1
12	*Sonneratia caseolaris*	*						1	
13	*Xylocarpus moluccensis*	*						1	
	Total	300	3	2	6	4	2	9	5

The density values at all observation stations are in the very dense category exceeding 15 stems per 100 square meters (seen in Figure 3 on the top right). These values are higher when compared to other locations in Indonesia such as the Thousand Islands, Pontianak, Ternate, Aru, Tual, Miossu, and Buton [7]. Canopy cover and density clearly determine the health condition of the mangrove community. The Oenggae station has the highest canopy cover and density values, but the lowest DBH. This indicates that the Oenggae station has a dense leaf canopy structure and high stem density, but not particularly large DBH or tree height. On the other hand, Baa station has high DBH and canopy cover but low density, this indicates that the station has large tree trunks, a dense canopy but grows at a distance.

In its pristine condition, the mangroves in Rote Ndao have a relatively large DBH and tree height (seen in Figure 3 on the bottom), measuring at 16±5 cm and 12±5 m respectively. However, this DBH is still smaller compared to the data from mangroves in Wondama, Papua, which stands at 20 cm, and is greater when compared to that in Komodo National

Park, which is 13 cm [13] and [14]. The difference in optimal stem diameter and height values in a mangrove community is highly influenced by species dominance. The Oebou station with high species abundance produces the lowest average dbh value among the other stations. In contrast, the Baa station, which tends to be dominated by a single species, *R. apiculata*, produces larger dbh values compared to other stations.

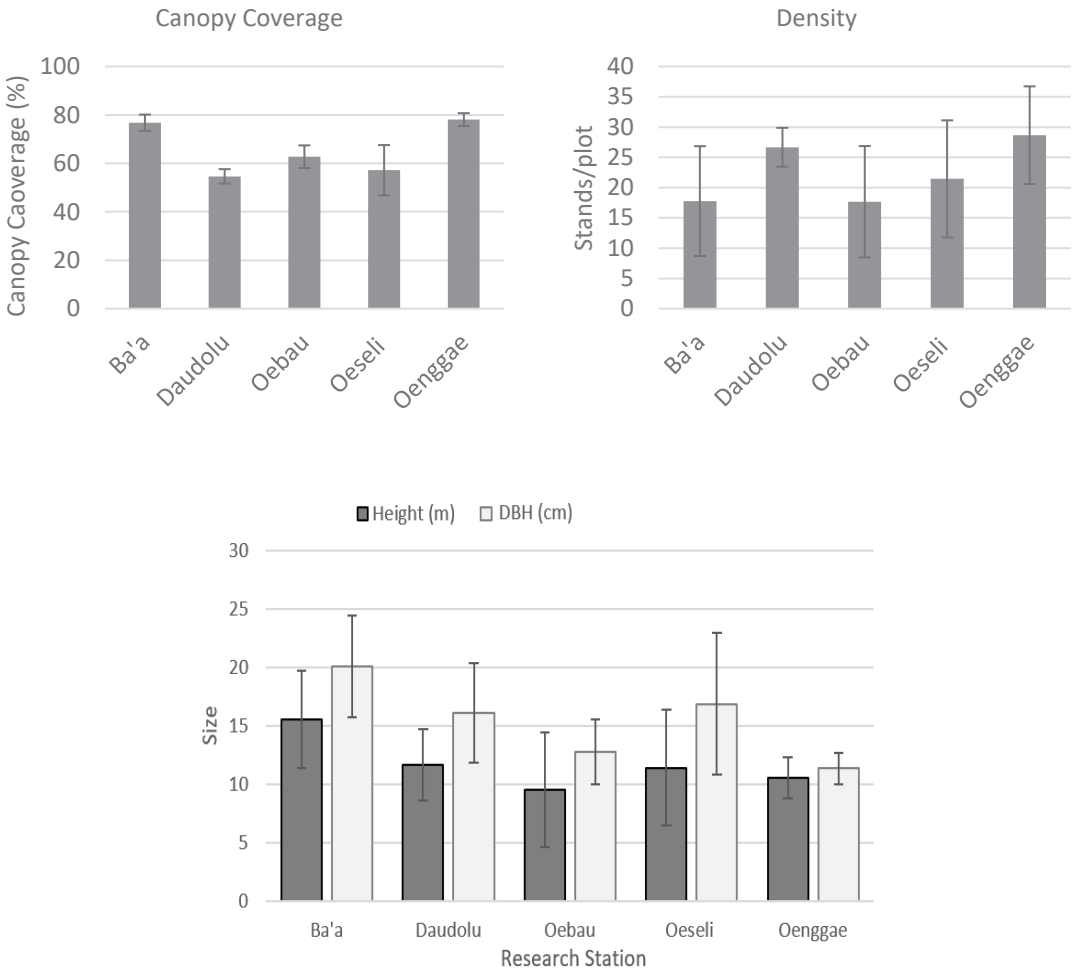

Fig 3. Canopy cover (top left), Density (top right), Height and Diameter Breast Height (DBH) of mangroves (bottom).

3.3 Mangrove health index distribution

The MHI in Rote Ndao displays an average value of 64±13%, indicating that the mangroves in this location are in the 'Moderate' category. The moderate category have also been found in various locations throughout Indonesia, including Sabu Raijua, Biak and Liki Island [5], [15], [16]. The highest value is observed at the Baa station with 77±6%, categorized as 'Excellent,' while the lowest is at the Oebau station with 53±8% in the moderate category (seen in Figure 4 on the left).

Based on the image analysis and the implementation of the MHI algorithm, it was determined that the mangrove area is predominantly within the 'Excellent' category, with the proportion reaching over 81%. Based on this categorization, mangroves in Rote Ndao can be considered as still being in a pristine state. This is also evident from the small mangrove area categorized as 'Poor,' which is less than 6% or 125 hectares, represented in the right side of Figure 4 in red. The 'Poor' category doesn't always indicate that the mangroves are in a degraded state, but can also suggest that the mangroves are in a seedling stage. This is evidenced by the red areas (seen in Figure 4 on the right) that are often found at the outer boundaries of the mangrove community areas, which usually serve as habitats for mangrove seedling.

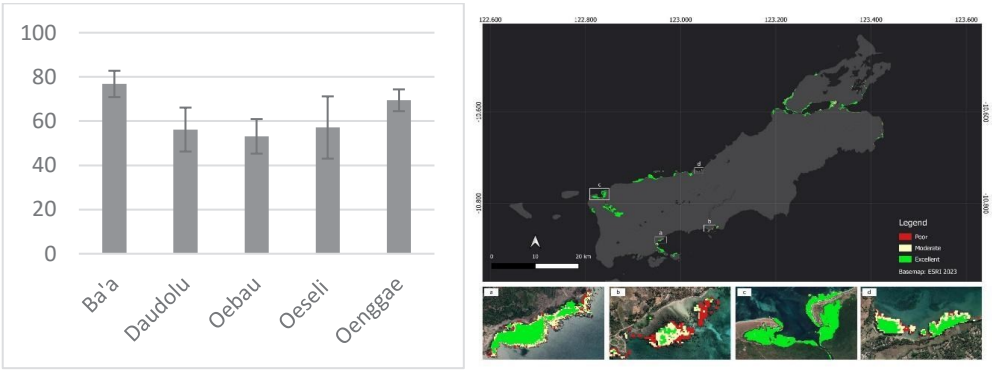

Fig. 4. MH calculated from field observations (left) and MHI derived from remote sensing calculations (right).

4 Conclusion

The mangroves in Rote Ndao are in a highly natural condition, characterized by very high canopy cover and density values at all observation locations. The dominant mangrove species are *R. apiculata* and *S. alba*. The MHI values derived from field data indicate a 'Moderate' category, while the analysis of the imagery data shows that the 'Excellent' category predominates spatially. Since the mangrove ecosystem is still in its pristine condition, establishing long-term monitoring programs is needed to protect the diversity and size of the area. On the other hand, the extensive area mangrove ecosystem in Rote Ndao makes monitoring programs in the field periodically difficult. Remote sensing analysis in Cloud Computing combined with the MHI Algorithm can be powerful enough to detect changes in mangrove conditions rapidly in Rote Ndao.

This study was fully supported and facilitated by the TERANGI Foundation, with funding support from the COREMAP CTI 2022, BAPEENAS, and ICCTF. Our gratitude goes to BKKPN Kupang for their support and for granting the necessary permissions during the data collection in the field.

References

1 I.W.E. Dharmawan, Field survey and data collecton a guidebook for mangrove health index (MHI) training (CV. Nas Media Makassar, 2020)

2 I. W. E. Dharmawan and Y. I. Ulumuddin, Mangrove community structure data analysis, a guidebook for mangrove health index (MHI) training (CV. Nas Media Makassar, 2020)

3 N. Gorelick, M. Hancher, M. Dixon, S. Ilyushchenko, D. Thau, and R. Moore, Remote Sens. Environ. **202**, 18–27 (2017)

4 D. Nurdiansah and I. W. E. Dharmawan, *Jurnal Ilmu dan Teknologi Kelautan Tropis*. **13**, 1 (2021)

5 Fakhrurrozi, Z. Yuniar, M. Harun, W. A. Lestariningsih, and I. Rahman, *Jurnal Biologi Tropis*. **23**, 2 (2023)

6 I. P. Sugiana, A. A. E. Andiani, I.G.A.I.P. Dewi, I.W.G.A.Karang, A.R As-syakur, and I.W.E. Dharmawan, *Biodiversitas*. **23**, 3407–3418 (2022)

7 I. W. E. Dharmawan and Pramudji, *Mangrove community structure in Papuan Small Islands, case study in Biak Regency*, in IOP Conference Series: Earth and Environmental Science, IOP Publishing Ltd, 21-23 Aug 2019, Purwokerto, Indonesia (2020)

8 J. D. Prasetya, Ambariyanto, Supriharyono, and F. Purwanti, Adv. Sci. Lett. **23,** 4, (2017)

9 Y.R. Noor, M. Khazali, and I. N. N. Suryadiputra, Panduan pengenalan mangrove di Indonesia (PHKA/WI-IP, Bogor, 2006)

10 Pramudji, Oseana. **XXV**, 1 (2000)

11 I.W.E. Dharmawan, Field survey and data collecton a guidebook for mangrove health index (MHI) training (CV. Nas Media Makassar, 2020)

12 J. N. W. Schaduw, *Majalah Geografi Indonesia*. **33**,1 (2019)

13 I. W. E. Dharmawan and A. Widyastuti, Marine Research in Indonesia. **42**, 2 (2017)

14 Tri Aryono Hadi et al., Monitoring kesehatan terumbu karang dan ekosistem terkait lainnya di Taman Nasional Komodo dan sekitarnya (Jakarta, 2019)

15 I. W. E. Dharmawan, *Mangrove health index distribution on the restored post-tsunami mangrove area in Biak Island-Indonesia*, in IOP Conference Series: Earth and Environmental Science, IOP Publishing Ltd, 5-6 June 2021, Makassar, Indonesia (2021)

16 D. Nurdiansah and I. W. E. Dharmawan, *Spatial and temporal analysis for mangrove community healthiness in Liki Island, Papua-Indonesia*, in IOP Conference Series: Earth and Environmental Science, IOP Publishing Ltd, 24-25 Aug. 2021 Bogor, Indonesia (2021)

17 Direktorat Konservasi Tanah dan Air, Ditjen PDASRH, Peta mangrove nasional (Jakarta, 2021)

18 Jamaludin, A. Ernawati, Irwan, and Syahribulan, *Keanekaragaman mangrove sejati di Pulau Timor dan Rote Nusa Tenggara Timur*, dalam Proceedings of the Biology National Conference on COVID-19 Pandemic, 19 Sep 2020, Gowa, Indonesia (2020)

19 I. W. E. Dharmawan and N. Akbar, *Prosiding Seminar Nasional Kemaritiman dan Sumberdaya Pulau-Pulau Kecil*. **1**, 1(2017)

20 B.N. Ratna, C.H. Arnold, and B Apriliana, *SIMBIOSA*. **9**, 2 (2020)