International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 5
ISSN: 2088-5334

Rhizopora apiculata (Blume) Density, NDVI, and Utilization by Fishermen Community in Muara Angke Wildlife Reserve, Penjaringan District, Jakarta, Indonesia

Noverita Dian Takarina [a], Agung Suwanto [b], Raldi H Koestoer [b], Evi Frimawatya [b]

[a] *Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok, 16424, Indonesia*
[b] *School of Environmental Science, Universitas Indonesia, Jakarta, 10430, Indonesia*
*Corresponding author: *noverita.dian@sci.ui.ac.id*

***Abstract*—*Rhizopora apiculata* is a common mangrove species found in tropical Asia, and it is also widely used by communities living near mangrove forests, including in Indonesia, due to its wood durability. This study aims to assess the status and utilization of *R. apiculata*, primarily by the fishermen community living near Muara Angke Wildlife Reserve in Jakarta Bay, Indonesia. The density of *R. apiculata* was determined by placing 100-meter-long transects from west to East in Muara Angke. While the normalized difference vegetation index (NDVI) of *R. apiculata* was studied using Landsat 8 satellite images with specific near-infrared and red wavelengths. The utilization of *R. apiculata* was assessed through interviews with 108 fishermen. The results showed that the west parts of Muara Angke had higher density, NDVI values, and canopy covers, with the *R. apiculata* density, NDVI, and canopy cover ranges being 3339.5-2856.3 Ha^{-1} trees, 0.79-0.99 percent, and 90-100 percent. There was a positive relationship between *R. apiculata* density, NDVI, and cover and the distance to the fishermen's village, decreasing NDVI trends toward villages. NDVI values in *R. apiculata* populations located far (> 1 km) from villages were higher, while NDVI values in *R. apiculata* populations located close (1 km) to villages were lower. Low density and NDVI values near the village were linked to fishermen's understanding and use of *R. apiculata*. This research can help to conserve and sustainably use the remaining mangrove community, primarily in Jakarta Bay.**

***Keywords*—Bay; fishermen; mangrove; NDVI; utilization.**

Manuscript received 22 Jun. 2021; revised 18 Nov. 2021; accepted 13 Dec. 2021. Date of publication 31 Oct. 2022.

I. INTRODUCTION

Rhizopora apiculata is a mangrove species commonly found in most mangrove forests in tropical Asia, from the brackish delta of the Indus in Pakistan to Vietnam and Hainan [1]. It occurs throughout the Malesian region and reaches southwards to the Tropic of Capricorn in Queensland and eastwards as far as New Caledonia and Ponape in Micronesia. As a most common mangrove species, *R. apiculata* grows gregariously in brackish swamps flooded by normal high tide, on deep soft mud of estuaries, and often consolidated and sheltered from waves and currents by pioneer mangroves including *Avicennia* and *Sonneratia* [2]. *R. apiculata* avoids hard soils and develops well in per-humid regions where it can form almost pure stands, sometimes in association with other mangrove species including *Bruguiera* sp. and *R. mucronata*. This species does not occur in freshwater swamps.

Jakarta Bay is an important marine ecosystem since it is located in the capital city of Indonesia, Jakarta City. Mangrove trees still inhabit several coastal locations in Jakarta Bay. Those locations were in Muara Angke Wildlife Reserve, Angke Kapuk Nature Park, and Kapuk Angke-Kapuk forest Conservation and Muara Angke Wildlife Reserve [3]. Mangrove ecosystems play important roles in biological, ecological, and economic aspects. Mangrove ecosystems provide natural resources [4] for people living nearby in the forms of fishes, crabs, shellfish, shrimps, wood for houses, and nipa leaf (*Nypa fruticans*) for house roofs. Mangroves also preserve coastal environments and maintain the habitat of marine animals along the bay [5]. In the context of land uses, mangrove ecosystems provide Green Open Space that protects the northern part of Jakarta City lands.

Currently, the condition of mangrove ecosystems at the national scale and regional scale in Jakarta Bay continues to experience pressures, both from land caused by pollution, destruction and encroachment, and pressures from the sea,

including abrasion and pollution [6]. On a national scale, the degradation rate of mangrove forests reaches 52,000 ha/year or 6% [7]. Consequently, particular mangrove species like *R. apiculata* have experienced more threats due to anthropogenic activities nearby. Those activities have reduced *R. apiculata* habitat due to the conversion of mangrove forest into coastal fish farming settlements, combined with the extraction and utilization of *R. apiculata* woods [8]. *R. apiculata* is preferred more over other mangrove species due to its durability, stability [9], and resistance to marine borer, termite, and fungal attacks [10].

Studies on mangrove ecosystems, particularly Jakarta Bay, have been conducted by previous studies [11], [12]. Despite large numbers of literature on mangroves, a study focusing on how local communities, mainly fishermen, utilize the mangrove ecosystems is still limited. Fishermen communities were selected because their livelihood and fishing activity relied mainly on mangrove ecosystems [13]. Considering these conditions, this research aims to analyze the current conditions of *R. apiculata* populations and evaluate the utilization of *R. apiculata* by fishermen communities living in a nearby village adjacent to the *R. apiculata* in Muara Angke Wildlife Reserve. This research's contribution is expected to provide an update of baseline information for the conservation, management, and sustainable utilization of particular *R. apiculata* species in Jakarta.

II. Material and Methods

A. Study Area

The study was conducted in the wildlife reserve and fishermen's village of Muara Angke located in the North of Jakarta Province, Indonesia. (Figure 1). The geographical coordinates of wildlife reserve and fishermen's village were from 106.7510 E, 6.1024 S to 106.7659 E, 6.1161 S. This wildlife reserve was established on June 17, 1939, by Dutch Colonial with an initial size of 15.04 Ha. On February 28, 1988, the area was declared a wildlife reserve with an area of 25.4 Ha. Based on the recent measurement the size of Muara Angke was 135 Ha. Due to its location near the coast, Muara Angke was dominated by saline tolerant vegetations. There are about 30 species of plants and 11 of them are tree species in the mangrove forest. The mangrove trees include *Rhizophora mucronata*, *R. apiculata*, *Avicennia* spp., *Sonneratia caseolaris*, and *Excoecaria agallocha*. Several species of mangrove plant associates can also be found in this area include *Terminalia catappa* and *Nypa fruticans*. In addition to the above species, several types of terestrial plants include *Tamarindus indica*, *Cerbera manghas*, *Acacia auriculiformis*, *Calophyllum inophyllum*, *Bruguiera gymnorrhiza*, and *Hibiscus tiliaceus*. The South of Muara Angke was bordered by settlement and commercial areas. To the East, it is bordered by fishermen village, a fish landing center, and fishery port. Jakarta Bay and the Java Sea bordered the North of Muara Angke [14] [15].

The climate of Muara Angke was under type A, according to Schmidt and Fergusson's classification. The rainfall here is high in January, reaching 294 mm, and the lowest rainfall is recorded in Juli with a value of 58 mm. The lowest daily temperature range is 21-24ºC and the highest range is 29-33,5ºC with an average of 26-28ºC.

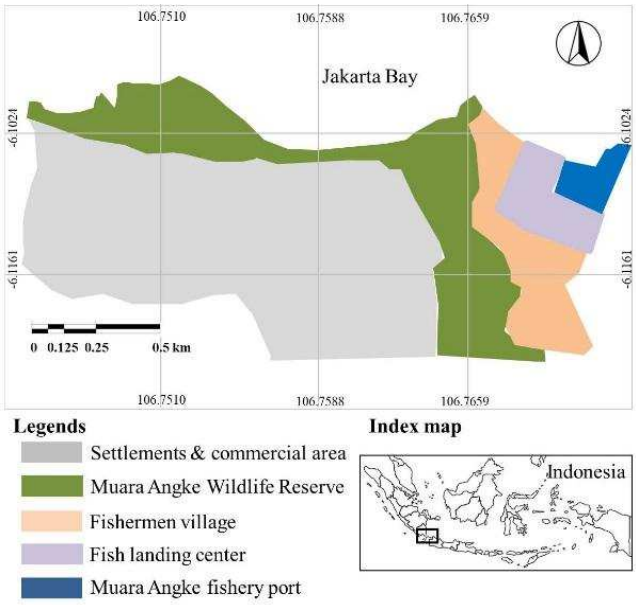

Fig. 1 Map of wildlife reserve and fishermen's village in Muara Angke, Jakarta Bay, Indonesia

B. Procedures

1) Rhizopora apiculata density: Rhizopora apiculata density samplings were conducted based on direct observation in designated sampling stations. The observations were conducted using transect methods modified from the following [16] [17]. In 6 stations in Muara Angke Wildlife Reserve (Figure 2), a 100 m transect was positioned perpendicular from the coast to the mainland. Stations a, b, and c were represented stations far from fishermen village and stations d, e, and f were represented stations closed to fishermen village in East and South parts of the reserve. In every 10 m distances along the transect, a 10 x 10 meters tree sampling plot was located. In total there were 60 sampling plots representing 6 stations. Inside the plots, numbers of Rhizopora apiculata-1 (trees with a trunk diameter of $\geqslant$ 10 cm and a height of $\geqslant$ 1,5 meters were recorded. The Rhizopora apiculata density was denoted as trees Ha^{-1})

2) *Rhizopora apiculata NDVI:* Besides measuring the density of R. apiculata, NDVI (normalized difference vegetation index) analysis on this mangrove species was also included. The method to measure R. apiculata NDVI was the following [18]–[20]. The NDVI is described as a simple graphical indicator that can be used to analyze remote sensing measurements, often from a space satellite platform, assessing whether or not the target being observed contains live green vegetation. The NDVI was measured by analyzing wavelength of satellite images retrieved from Landsat 8 containing vegetation images. This measurement is possible since cell structure of the vegetation leaves strongly reflects near-infrared light wavelength ranges from 0.7 to 1.1 µm. The calculation of NDVI for each pixel of vegetation pixel was as follows:

$$\text{NDVI} = \frac{\delta\text{near infraed} - \delta\text{ red}}{\delta\text{near infrared} + \delta\text{red}} \quad (1)$$

where δ =wavelength. The NDVI was denoted as a range from 0 (no vegetation) to 1(high vegetation density). The NDVI

values then were overlayed and mapped into Muara Angke Wildlife Reserve using ArcView. The mangrove covers are then categorized and classified by using NDVI values as follows [10]:

- if 0 < NDVI < 0.3 then mangrove covers < 50%
- if 0.31 < NDVI < 0.4 then mangrove covers are 50 – 69%
- if 0.41 < NDVI < 1.0 then mangrove covers are 70 – 100%

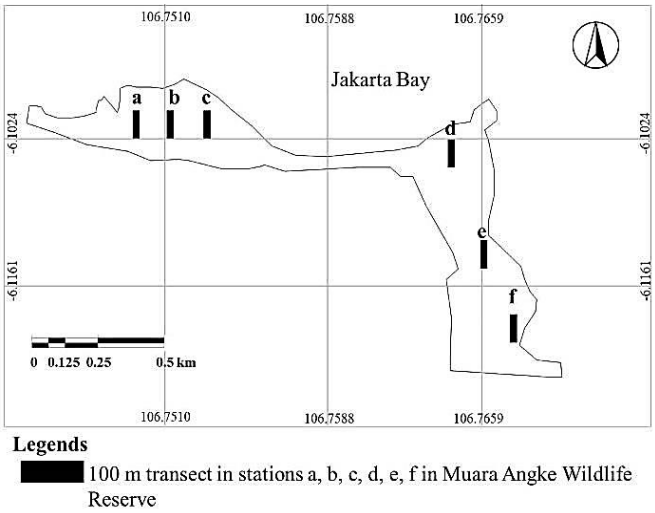

Fig. 2 Sampling station (a, b, c, d, e, f with d-f are close to the fishermen village) and 100 m transect locations to measure *Rhizophora apiculata* density in Muara Angke, Jakarta Bay, Indonesia.

3) Fishermen demography and Rhizopora apiculata uses assessment: This part was conducted in fishermen villages located 500 m in the East and South parts of mangrove reserves. For the assessments, there were 108 fishermen selected as respondents to be interviewed and provided with questionnaires. The research's background and purpose were explained before each interview. The interview method was modified following [13], [21]–[24]. The interview activities were divided into two parts. The first part of the interviews aimed to collect fishermen's demographic data, including age, gender, education level, monthly income, and working experiences as fishermen. While the second interview part focused on explaining the social interactions that influence *Rhizopora apiculata* resource management. It focused on local fishermen's knowledge systems that inform the traditional concepts in utilizing and conserving the *R. apiculata*. In this second part, the interviews aimed to evaluate fishermen's understanding of *R. apiculata* community, functions and benefits of *R. apiculata*, and utilization frequencies of *R. apiculata* trees.

C. Data Analysis

The results of *Rhizopora apiculata* density sampling and fishermen interviews were tabulated. In the table are the data of age, gender, education level, income, working experiences as fishermen, fishermen's understanding of *R. apiculata* community, functions and benefits of *R. apiculata*, and utilization frequencies on *R. apiculata* trees were recorded. The data then were visualized as the percentage and composition in the form of the pie chart.

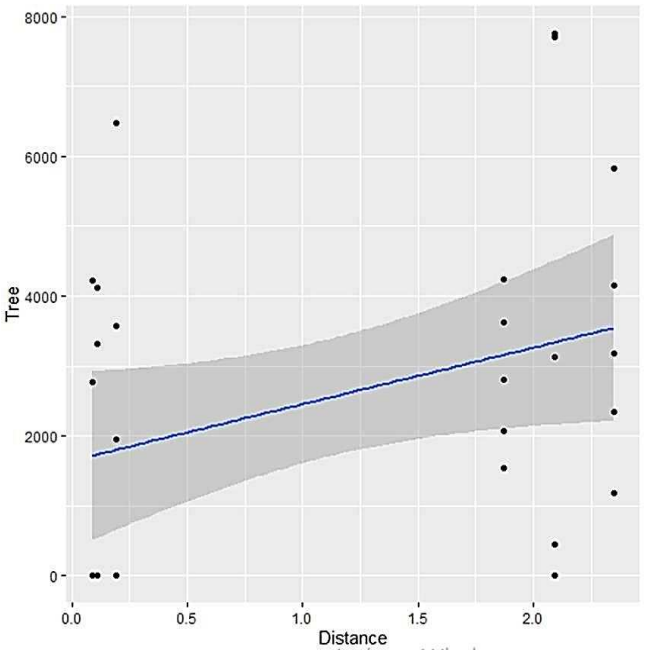

Fig. 3 Correlations (shaded areas for 95%CI) of distance to fishermen village (km) with *Rhizopora apiculata* density (trees Ha-1) in Muara Angke Wildlife Reserve, Jakarta Bay, Indonesia

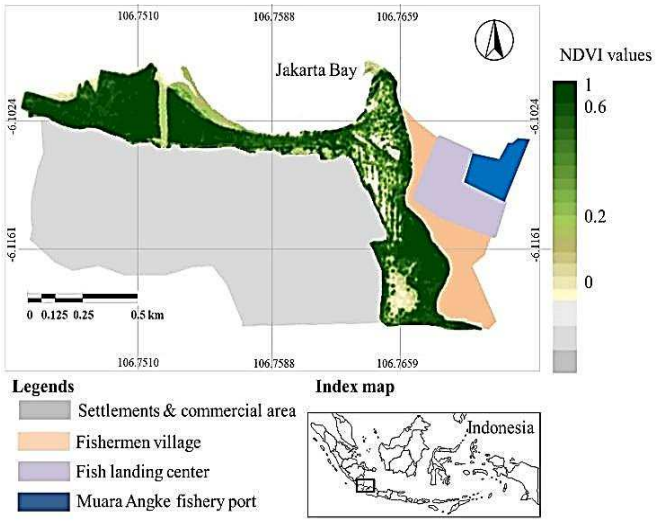

Fig. 4 NDVI values of *Rhizopora apiculata* in Muara Angke Wildlife Reserve, Jakarta Bay, Indonesia

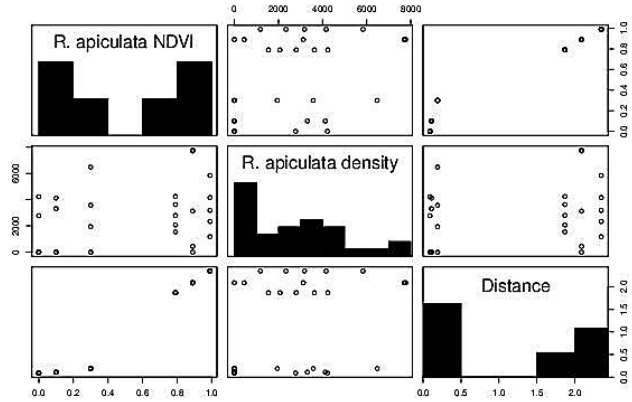

Fig. 5 Trivariate correlations of distance to fishermen village (km) with *Rhizopora apiculata* density (trees ha^{-1}) and NDVI in Muara Angke Wildlife Reserve, Jakarta Bay, Indonesia

III. Result and Discussion

A. *Rhizopora apiculata density and NDVI*

Rhizopora apiculata density (trees Ha^{-1}) from 6 stations in Muara Angke Wildlife Reserve was presented in Table I. The orders of stations according tree density are stations b > a > c > d > e > f. Station b was having the highest density (3807.2 trees ha-1 95% CI: 497, 7120) followed by the station a (3339.5 trees ha-1 95% CI: 1790, 4890). The lowest *R. apiculata* density was observed in station f with 1399.5 trees ha-1 (95% CI: 341, 3140). Statistical analysis shows the tree densities among stations were significantly different (P<0.05, F = 2.62). The differences were related to the distance to the fishermen's village (Figure 3). Stations a, b, and c were known to have high tree density among other stations and were located within a distance of more than 1 km from the fishermen's village. While several stations including stations d, e, f that located near the village and within the distance of less than 1 km were having lower *R. apiculata* density in comparison to stations a, b, and c. The increment of mangrove ecosystem distance to fishermen's village, it will increase the *R. apiculata* density. Figure 4 presents the NDVI values of mangroves in Muara Angke. The NDVI informed that mangrove forests located far from fishermen's village have higher and maximum NDVI values closed to 1. Whereas the NDVI values were decreasing toward mangrove forests with proximity close to the village. Figure 5 describes the correlations of proximity to fishermen's village with density and NDVI of *R. apiculata*. It also confirms that density and NDVI of *R. apiculata* were having positive correlations.

TABLE I
RHIZOPORA APICULATA DENSITY (TREES HA-1) IN MUARA ANGKE WILDLIFE RESERVE, JAKARTA BAY, INDONESIA

	a	b	c	d	e	f
Mean	3339.5	3807.2	2856.3	2399.7	1486	1399.5
STD	1773.2	3777.9	1100.5	2726.4	2054.8	1982.8
95%	1790, 4890	497, 7120	890, 3820	9.7, 4790	314, 3290	341, 3140

P <0.05, F = 2.62

B. *Fishermen demography*

Most of the 108 respondents as many as 98.15 percent were male and only 1.85 percent were female. More male than female fishermen because in the survey, the interviewed respondents were the head of the family (Figure 6). Interviews with respondents (Figure 7) in Muara Angke showed that the numbers of the fishermen with age between 25-35 years old were 43 people (39.81%), the age of the fishermen between 36-45 years old was as many as 31 people (28.70%), and the age between 46-60 years old was 34 people (31.48%). This fishermen's age composition indicates that the fishing activities in Muara Angke were mostly carried out by young people. Based on the survey of the education level of respondents, it shows that 87.96% of fishermen were graduated from elementary school, 11.11% were graduated from junior high school, and only 0.93% were graduated from high school (Figure 8).

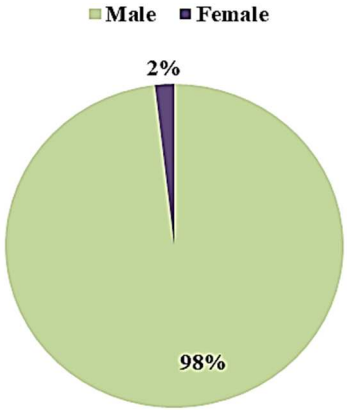

Fig. 6 Male and female (n = 108 respondents) fishermen composition in Muara Angke Wildlife Reserve, Jakarta Province, Indonesia

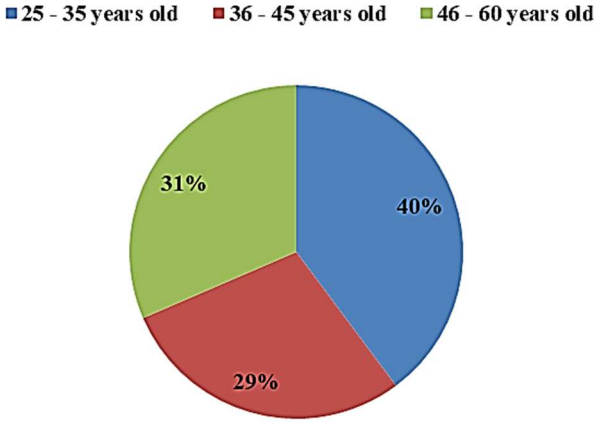

Fig. 7 Fishermen (n = 108 respondents) compositions based on age (years) in Muara Angke Wildlife Reserve, Jakarta Province, Indonesia

Most fishermen (38%) earned incomes from fishing were equal to 6-10 million IDR and followed by 2-4 million IDR (32%) (Figure 9). About 15% of fishermen have low incomes less than 2 million IDR per month. Most fishermen (42%) have worked for 11-20 years and 31-40 years (30%). While small populations either have less experience (3%) or having worked for more than 40 years as fishermen (1%) (Figure 10).

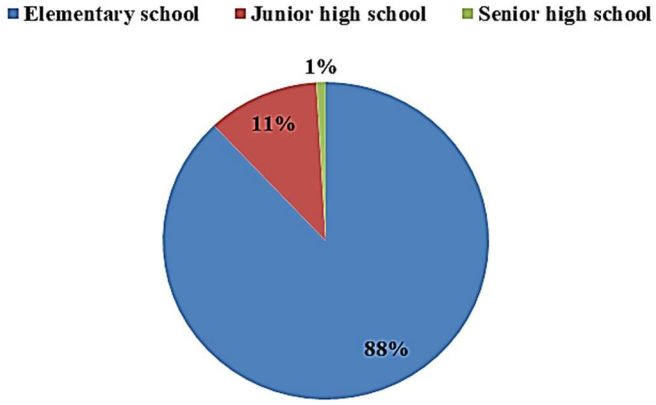

Fig. 8 Fishermen (n = 108 respondents) compositions based on education level in Muara Angke Wildlife Reserve, Jakarta Province, Indonesia

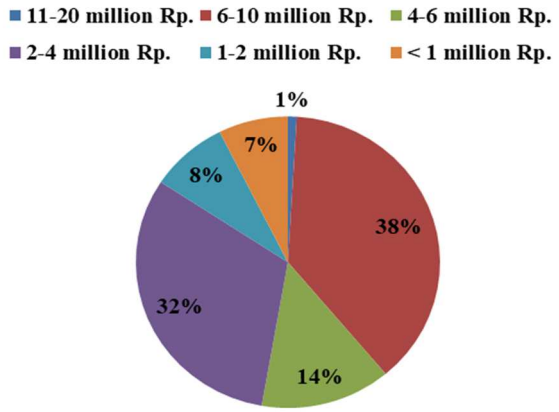

Fig. 9 Fishermen (n = 108 respondents) compositions based on income per month (million IDR month-1 or Rp. month-1) in Muara Angke Wildlife Reserve, Jakarta Province, Indonesia

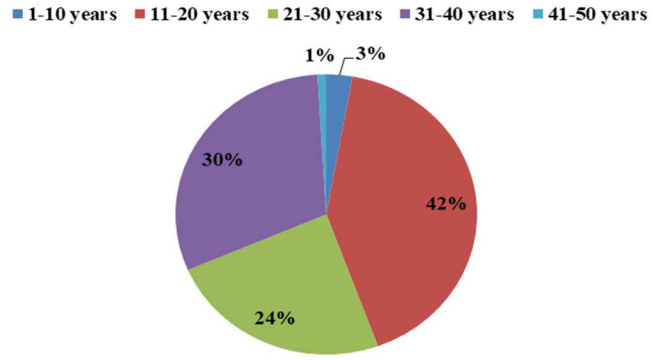

Fig. 10 Fishermen (n = 108 respondents) compositions based on working experiences (years) in Muara Angke Wildlife Reserve, Jakarta Province, Indonesia

C. *Rhizopora apiculata utilizations*

Interview (Figure 11) with fishermen shows that as many as 66.67% of fishermen do not completely understand the mangrove ecosystem, 28.70% said they did not understand, 2.78% said they understand, and only 1.85% has good understanding of the *Rhizopora apiculata* community. Regarding the fishermen understanding on functions and benefits of the *R. apiculata* in Muara Angke (Figure 12), 47.22% of respondents said they understood, 41.67% did not completely understand, 9.26% did not understand, and no fishermen (0%) that have a good understanding on the functions and the benefits of the *R. apiculata*.

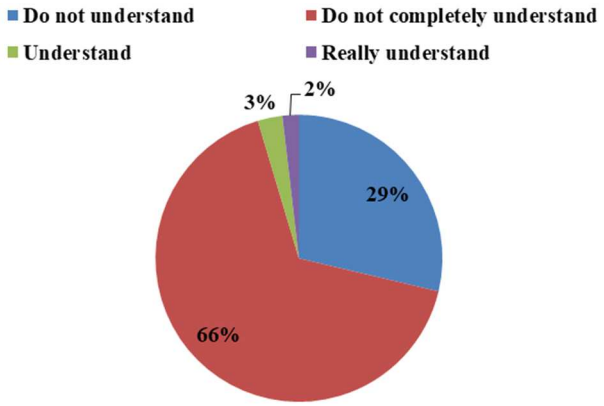

Fig. 11 Fishermen (n = 108 respondents) compositions based on fishermen's understanding on R. apiculata community in Muara Angke Wildlife Reserve, Jakarta Province, Indonesia

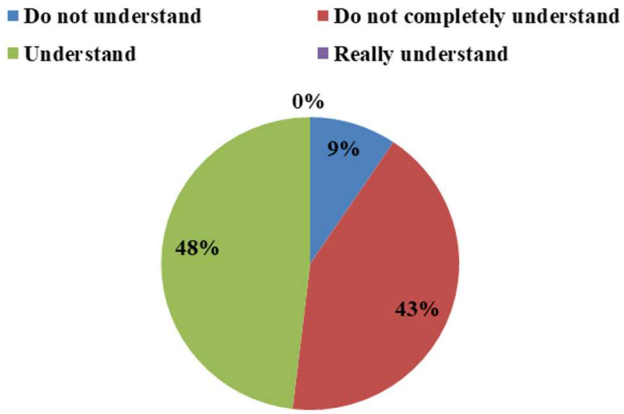

Fig. 12 Fishermen (n = 108 respondents) compositions based on fishermen's understanding on functions and benefits of R. apiculata community in Muara Angke Wildlife Reserve, Jakarta Province, Indonesia

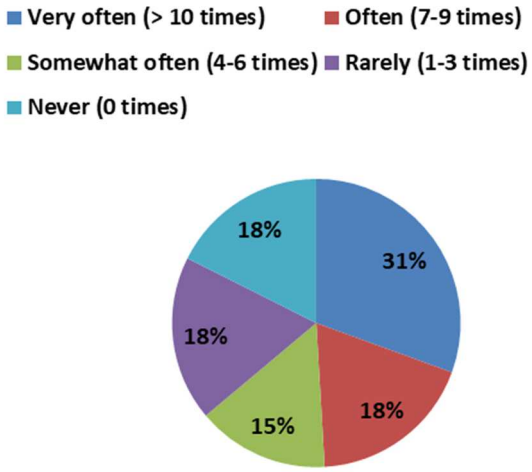

Fig. 13 Fishermen (n = 108 respondents) compositions based on utilization frequencies on R. apiculata trees in Muara Angke Wildlife Reserve, Jakarta Province, Indonesia

The results of the interview regarding utilization frequencies (Figure 13) showed that 30.56% of fishermen used *R. apiculata* as fuelwood, building, and charcoal more than 10 times a month, 18.52% stated often (7-9 times), 14.81%t said somewhat often (4-6 times), 18.52% stated rarely (1-3 times), and as much as 17.59% said never used *R. apiculata*.

D. *Discussion*

Recently mangrove species population in Indonesia has been studied whether a national scale [1], [25], [26] and on at regional scale in Jakarta Bay [3], [11]. Information on the density and NDVI values of R. apiculata from those studies is still limited. In this study, 2 important variables to measure *R. apiculata* including tree density and NDVI were measured, and those variables were positively correlated. NDVI values of *R. apiculata* obtained in this study with lower values were observed near fishermen village were in corroboration with a previous study [27]. The study estimated that from 135 Ha of mangrove forest in Muara Angke, only 19 Ha was considered in the intact conditions. Table II informs the comparisons of NDVI in Muara Angke with NDVI values from other locations. The wide range of NDVI values in Muara Angke are representing both intact and degraded mangrove forest conditions. High NDVI values found in the West parts of

Muara Angke far from fishermen's village were similar to the NDVI of intact mangrove forest in Arakan Bay, North Sulawesi, and Pangpang Bay, East Java. High NDVI values of mangrove forests in Arakan, and Pangpang Bay were related to the intactness of those locations that were isolated and located far from anthropogenic activities. This intactness condition was similar to the conditions of mangrove forest in West of Muara Angke in particular stations a, b, and c. In those stations, *R. apiculata* was observed to have high density since it was located far from nearby fishermen's villages anthropogenic activities. The Southern parts of Muara Angke in particular stations d, e, and f had low NDVI, and this condition is comparable to Surabaya Bay, which also has low NDVI values. The mangrove forest in Surabaya Bay is similar to the condition in the South parts of Muara Angke, since the forest in Surabaya Bay is closed to the settlements and fishermen village [7].

TABLE II
RHIZOPORA APICULATA NDVI RANGES IN MUARA ANGKE WILDLIFE RESERVE, JAKARTA BAY, INDONESIA IN COMPARISON TO OTHER LOCATIONS

Locations	NDVI ranges	References
Gresik, East Java	0.5 – 0.7	[26]
Perancak Estuary, Bali	0.70 – 0.84	[28]
Surabaya Coast, East Java	0.70 – 0.75	[29]
Muara Angke, Jakarta Bay	0.1 – 0.99	This study

This study has confirmed that the lowest of the *R. apiculata canopy* covers, tree density, and NDVI values in the South parts of Muara Angke. This result agrees with the results obtained from a previous study [30]. According to their results, the areas with high mangrove covers in South parts were only 37%. The remaining mangrove forest ranges from 16 to 47% with low mangrove covers. In South parts of Muara Angke, bushes and *Nypa fruticans* have dominated and outnumbered the mangrove species. Low *R. apiculata* covers, tree density, and NDVI values were related to the mangrove forests' proximity to the adjacent fishermen villages. The proximity of the mangrove forest to the nearby village can provide a readily accessible mangrove and increase the dependency, utilization, and even exploitation of mangrove forest products. As a result, mangrove wood is logged and commonly used for making fishing traps and canoes, processing the prawn and fish catch, and for domestic use, including fencing, housing, and fuel for cooking. The uses of *R. apiculata* in Muara Angke are comparable to the other locations (Table III). Mostly *R. apiculata* species were used as firewood, charcoal, and limited uses as medical resources. Despite extensive uses of *R. apiculata*, some fishermen already sustainably use this species by developing nursery and plantations.

Low *R. apiculata* density, NDVI, and canopy cover near fishermen village are related to the fishermen's understanding of *R. apiculata* ecosystems, benefits, and utilization frequencies. The results from the interview indicate that there are still many fishermen around the Muara Angke mangrove forest who are logging the *R. apiculata* for its wood, firewood, building materials, and charcoal. The wood of *R. apiculata* was used as firewood for self-need or to be sold. The woods are cut into pieces with sizes about 50-60 cm long, tied up, and then sold for 15000 IDR per bundle. The wood of *R. apiculata* is solid, sturdy, and durable and it is appropriate to be utilized as building materials, firewood, and charcoal materials. Mangrove wood is usually cut using a cutting machine to produce wood chips [1]. Using *R. apiculata* as firewood is considered very efficient because using *R. apiculata* woods with a diameter of 8 cm and 50 cm in length can cook for 5 people. Then *R. apiculata* firewood is most preferred by fishermen especially when the fuel price is high.

TABLE III
RHIZOPORA APICULATA USES IN MUARA ANGKE WILDLIFE RESERVE, JAKARTA BAY, INDONESIA IN COMPARISON TO OTHER LOCATIONS

Locations	**Uses**	**References**
Muara Angke, Jakarta Bay	Firewood, building materials, and charcoal	This study
Balikpapan Bay	Wood production	[9]
Samut Songkhram Province, Central Thailand	Plantation, charcoal	[31]
Mempawah	Medicine	[32]

The utilization of *R. apiculata* by the fishermen was related both to a low understanding of *R. apiculata* and the socioeconomic conditions of the fishermen community. The fishermen community in this study was characterized by gender bias; most fishermen were male, had low education level, and had low incomes. Their study regarding mangrove utilization by coastal communities in Unguja Island, Zanzibar, Tanzania [33] revealed that all socioeconomic conditions influenced the exploitation and degradation of mangroves, and household income and education level significantly influenced the exploitation of mangrove forests. A person dominated most fishermen in Muara Angke with low education levels and an understanding of *R. apiculata*. This finding is in line with a previous study [34] that education has become an important aspect of the community to manage natural resources better. Low education levels among fishermen will also prevent them from securing knowledge and opportunities on other livelihood activities such as owning small shops, food vending, and casual labor, reducing pressure on mangrove resource extraction. Currently low education level combined with low understanding on *R. apiculata* will force the local fishermen to rely on mangrove resources as an alternative source of income generation through the selling of building poles, making charcoal, fuelwood, fish traps, and poles for boats [35].

IV. CONCLUSION

To conclude, the *R. apiculata* conditions in 135 Ha of Muara Angke Wildlife Reserve were divided into first the populations with high density, NDVI values, and canopy covers, as can be seen in West parts of reserve. While *R. apiculata* conditions in East and South parts of reserve adjacent to fishermen village had lower tree density, NDVI values, and covers. Most fishermen in the village had low understanding of *R. apiculata* and frequently logged the *R. apiculata* to be used as firewood, building material, and charcoal. This *R. apiculata* utilization is alarming due to economic dependency, lack of knowledge, and alternative source of income and energy for fishermen's daily use that can impose significant pressure on the *R. apiculata* species in Jakarta Bay

REFERENCES

[1] R. P. Yudha, Y. S. Sugito, M. Sillanpää, and S. Nurvianto, "Impact of logging on the biodiversity and composition of flora and fauna in the mangrove forests of Bintuni Bay, West Papua, Indonesia," *For. Ecol. Manage.*, vol. 488, p. 119038, 2021, [Online]. Available: https://doi.org/10.1016/j.foreco.2021.119038.

[2] S. Amaliyah, S. Hariyanto, and H. Purnobasuki, "Growth responses of Rhizophora apiculata Blume in different soil and sediment conditions," *AACL Bioflux*, vol. 11, no. 2, pp. 379–386, 2018, [Online]. Available: http://www.bioflux.com.ro/docs/2018.379-386.pdf.

[3] E. Hilmi, L. K. Sari, T. N. Cahyo, Muslih, A. Mahdiana, and S. R. Samudra, "The affinity of mangrove species using Association and Cluster Index in North Coast of Jakarta and Segara Anakan of Cilacap, Indonesia," *Biodiversitas*, vol. 22, pp. 2907–2920, 2021, [Online]. Available: https://doi.org/10.13057/biodiv/d220743.

[4] M. Hernández-Blanco, R. Costanza, and M. Cifuentes-Jara, "Economic valuation of the ecosystem services provided by the mangroves of the Gulf of Nicoya using a hybrid methodology," *Ecosyst. Serv.*, vol. 49, p. 101258, 2021, [Online]. Available: https://doi.org/10.1016/j.ecoser.2021.101258.

[5] Y.-S. Wang and J.-D. Gu, "Ecological responses, adaptation and mechanisms of mangrove wetland ecosystem to global climate change and anthropogenic activities," *Int. Biodeterior. Biodegradation*, no. 162, p. 105248, 2021, [Online]. Available: https://doi.org/10.1016/j.ibiod.2021.105248.

[6] A. Damar, K.-J. Hesse, F. Colijn, and Y. Vitner, "The eutrophication states of the Indonesian sea large marine ecosystem: Jakarta Bay, 2001–2013," *Deep Sea Res. Part II Top. Stud. Oceanogr.*, vol. 163, pp. 72–86, 2021, [Online]. Available: https://doi.org/10.1016/j.dsr2.2019.05.012.

[7] K. Prasetyo, "The Detection of Environmental Degradation Cause in Mangroves Area: Case in the Surabaya Coast," *J. Hunan Univ. Sci.*, vol. 48, no. 3, pp. 6–12, 2021, [Online]. Available: http://www.jonuns.com/index.php/journal/article/view/532.

[8] A. Azman *et al.*, "Low genetic diversity indicating the threatened status of Rhizophora apiculata (Rhizophoraceae) in Malaysia: declined evolution meets habitat destruction," *Sci. Rep.*, vol. 10, p. 19112, 2020, [Online]. Available: https://doi.org/10.1038/s41598-020-76092-4.

[9] A. M. Lahjie, B. Nouval, A. A. Lahjie, Y. Ruslim, and R. Kristiningrum, "Economic valuation from direct use of mangrove forest restoration in Balikpapan Bay, East Kalimantan, Indonesia [version 2; peer review: 2 approved]," *F1000Research*, vol. 8, p. 9, 2019, [Online]. Available: https://doi.org/10.12688/f1000research.17012.2.

[10] N. Salim, I. Jusoh, and Z. Assim, "Anti-wood-fungal performance of methanol extracts of Rhizophora apiculata and R. mucronata barks," *Bioresources*, vol. 15, no. 2, pp. 4143–4149, 2020, [Online]. Available: https://bioresources.cnr.ncsu.edu/resources/anti-wood-fungal-performance-of-methanol-extracts-of-rhizophora-apiculata-and-r-mucronata-barks/.

[11] N. Sari, M. P. Patria, T. E. B. Soesilo, and iwan G. Tejakusuma, "The structure of mangrove communities in response to water quality in Jakarta Bay, Indonesia," *Biodiversitas*, vol. 20, pp. 1873–1879, 2019, [Online]. Available: https://doi.org/10.13057/biodiv/d200712.

[12] N. S. Slamet, P. Dargusch, A. A. Aziz, and D. Wadley, "Mangrove vulnerability and potential carbon stock loss from land reclamation in Jakarta Bay, Indonesia," *Ocean Coast. Manag.*, vol. 195, p. 105283, 2020, [Online]. Available: https://doi.org/10.1016/j.ocecoaman.2020.105283.

[13] R. Seary, T. Spencer, M. Bithell, and C. McOwen, "Measuring mangrove-fishery benefits in the Peam Krasaop Fishing Community, Cambodia," *Estuar. Coast. Shelf Sci.*, vol. 248, p. 106918, 2021, [Online]. Available: https://doi.org/10.1016/j.ecss.2020.106918.

[14] M. Rumanta, "The potential of Rhizophora mucronata and Sonneratia caseolaris for phytoremediation of lead pollution in Muara Angke, North Jakarta, Indonesia," *Biodiversitas*, vol. 20, pp. 2151–2158, 2019, [Online]. Available: https://doi.org/10.13057/biodiv/d200808.

[15] A. K. Nasution, N. D. Takarina, and H. Thoha, "The presence and abundance of harmful dinoflagellate algae related to water quality in Jakarta Bay, Indonesia," *Biodiversitas*, vol. 22, pp. 2909–2917, 2021, [Online]. Available: https://doi.org/10.13057/biodiv/d220556.

[16] R. Suwa *et al.*, "Mangrove biomass estimation using canopy height and wood density in the South East and East Asian regions," *Estuar. Coast. Shelf Sci.*, vol. 248, p. 106937, 2021, [Online]. Available: https://doi.org/10.1016/j.ecss.2020.106937.

[17] B. B. Hanggara, D. Mudiyarso, Y. R. Ginting, Y. Widha, G. Panjaitan, and A. Lubis, "Effects of diverse mangrove management practices on forest structure, carbon dynamics and sedimentation in North Sumatra, Indonesia," *Estuar. Coast. Shelf Sci.*, vol. 259, p. 107467, 2021, [Online]. Available: https://doi.org/10.1016/j.ecss.2021.107467.

[18] S. Thakur, I. Mondal, P. B. Ghosh, P. Das, and T. K. De, "A review of the application of multispectral remote sensing in the study of mangrove ecosystems with special emphasis on image processing techniques," *Spat. Inf. Res.*, vol. 28, pp. 39–51, 2020, [Online]. Available: https://doi.org/10.1007/s41324-019-00268-y.

[19] H. Eternadi, J. M. Smoak, and E. Abbasi, "Spatiotemporal pattern of degradation in arid mangrove forests of the Northern Persian Gulf," *Oceanologia*, vol. 63, no. 1, pp. 99–114, 2021, [Online]. Available: https://doi.org/10.1016/j.oceano.2020.10.003.

[20] W. Nardin, I. Vona, and S. Fagherazzi, "Sediment deposition affects mangrove forests in the Mekong delta, Vietnam," *Cont. Shelf Res.*, vol. 213, p. 104319, 2021, [Online]. Available: https://doi.org/10.1016/j.csr.2020.104319.

[21] J. Pearson, K. E. McNamara, and P. D. Nunn, "Gender-specific perspectives of mangrove ecosystem services: Case study from Bua Province, Fiji Islands," *Ecosyst. Serv.*, vol. 38, p. 100970, 2019, [Online]. Available: https://doi.org/10.1016/j.ecoser.2019.100970.

[22] B. Mallick *et al.*, "Livelihoods dependence on mangrove ecosystems: Empirical evidence from the Sundarbans," *Curr. Res. Environ. Sustain.*, vol. 3, p. 100077, 2021, [Online]. Available: https://doi.org/10.1016/j.crsust.2021.100077.

[23] M. Arumugam, R. Niyomugabo, F. Dahdouh-Guebas, and J. Hugé, "The perceptions of stakeholders on current management of mangroves in the Sine-Saloum Delta, Senegal," *Estuar. Coast. Shelf Sci.*, vol. 248, p. 107160, 2021, [Online]. Available: https://doi.org/10.1016/j.ecss.2020.107160.

[24] A. S. M. G. Kibria, R. Costanza, C. Groves, and A. M. Behie, "The interactions between livelihood capitals and access of local communities to the forest provisioning services of the Sundarbans Mangrove Forest, Bangladesh," *Ecosyst. Serv.*, vol. 32 A, pp. 41–49, 2018, [Online]. Available: https://doi.org/10.1016/j.ecoser.2018.05.003.

[25] D. Mudiyarso, S. D. Sasmito, M. Sillanpää, R. MacKenzie, and D. Gaveau, "Mangrove selective logging sustains biomass carbon recovery, soil carbon, and sediment," *Sci. Rep.*, vol. 11, p. 12325, 2021, [Online]. Available: https://doi.org/10.1038/s41598-021-91502-x.

[26] E. Purnamasari, M. Kamal, and P. Wicaksono, "Comparison of vegetation indices for estimating above-ground mangrove carbon stocks using PlanetScope image," *Reg. Stud. Mar. Sci.*, vol. 44, p. 101730, 2021, [Online]. Available: https://doi.org/10.1016/j.rsma.2021.101730.

[27] A. Zaitunah, S. Samsuri, A. G. Ahmad, and R. A. Safitri, "Normalized difference vegetation index (ndvi) analysis for land cover types using landsat 8 oli in besitang watershed, Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 126, no. 1, 2018, doi: 10.1088/1755-1315/126/1/012112.

[28] M. Kamal, F. Sidik, A. R. A. Pranandaa, and S. A. Mahardhikaa, "Mapping Leaf Area Index of restored mangroves using WorldView-2 imagery in Perancak Estuary, Bali, Indonesia," *Remote Sens. Appl. Soc. Environ.*, vol. 23, p. 100567, 2021, [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352938521001038?via%3Dihub.

[29] B. M. Sukojo and Y. N. Arindi, "Study of potentials economic valuation of mangrove ecosystem for coastal communities using satellite imagery (case study: East Coastal Surabaya)," in *Geomatics International Conference 2019 21–22 August 2019, Surabaya, Indonesia*, 2019, p. 012013, [Online]. Available: https://iopscience.iop.org/article/10.1088/1755-1315/389/1/012013.

[30] Y. Mayalanda, F. Yulianda, and I. Setyobudiandi, "Strategy for mangrove ecosystem rehabilitation throughout damaged level analysis at Muara Angke Wildlife Sanctuary, Jakarta," *Bonorowo Wetl.*, vol. 4, pp. 12–36, 2014, [Online]. Available: https://doi.org/10.13057/bonorowo/w040102.

[31] M. K. Hassan, V. Jintana, S. Kuittinen, and A. Pappinen, "Management Practices and Aboveground Biomass Production Patterns of Rhizophora apiculata Plantation: Study from a Mangrove Area in Samut Songkram Province, Thailand," *Bioresources*, vol. 13, pp. 7826–7850, 2018, [Online]. Available: https://ojs.cnr.ncsu.edu/index.php/BioRes/article/view/BioRes_13_4_7826_Hassan_Management_Practices_Aboveground_Biomass.

[32] Y. Arbiastutie, F. Diba, and Masriani, "Ethnobotanical and ecological studies of medicinal plants in a mangrove forest in Mempawah District,

West Kalimantan, Indonesia," *Biodiversitas*, vol. 22, pp. 3164–3170, 2021, [Online]. Available: https://doi.org/10.13057/biodiv/d220619.
[33] A. A. Nchimbi, M. S. Shalli, N. S. Jiddawi, and M. M. Mangora, "Corrigendum to 'Socioeconomic Determinants of Mangrove Exploitation and Seagrass Degradation in Zanzibar: Implications for Sustainable Development,'" *J. Mar. Sci.*, vol. 2020, no. 7635268, 2020, [Online]. Available: https://doi.org/10.1155/2020/7635268.
[34] C. Kusmana and T. Sukwika, "Coastal community preference on the utilization of mangrove ecosystem and channelbar in Indramayu, Indonesia," *AACL Bioflux*, vol. 11, no. 3, pp. 905–918, 2018, [Online]. Available: http://www.bioflux.com.ro/docs/2018.905-918.pdf.
[35] S. C. Gnansounou *et al.*, "Local uses of mangroves and perceived impacts of their degradation in Grand-Popo municipality, a hotspot of mangroves in Benin, West Africa," *Trees, For. People*, vol. 4, p. 100080, 2021, [Online]. Available: https://doi.org/10.1016/j.tfp.2021.100080.