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Study of Biomass in Two Mangrove Ecosystems

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Abstract: This study aims to determine the storage of biomass in the mangrove ecosystem of Jakarta Bay compared to Ambon Bay. This research used descriptive quantitative method. Sampling technique using the Point Center Quarter Method (PCQM) which was measured around the chest height of mangrove trees (DBH). Data analysis was performed using an allometric equation where each mangrove plant has a specific gravity. The results of this study indicated that the composition of mangrove species in Ambon Bay consists of 6 mangrove species, namely: *Bruguiera cylindrica* (L.) *Bl*, *Rhizophora apiculata Bl*, *Sonneratia alba Smith*, *Aegiceras corniculatum* (L.) *Blanco*, *Avicennia officinalis* L, *Ceriops tagal*. In the ecosystem, *Rhizophora apiculata Bl* and *Sonneratia alba Smith* had higher biomass values compared to the other four species. Meanwhile, in Jakarta Bay, the composition of mangrove plants is dominated by *Sonneratia alba Smith*. The subsurface biomass in the Jakarta Bay and Ambon region is lower than the aboveground biomass.

Keywords: Ambon Bay; Carbon; Biomass; Mangrove ecosystem; Muara Angke

Introduction

Greenhouse gas emissions (GHG) can be formed naturally or as a result of human activities (anthropogenic). Based on the Kyoto Protocol, anthropogenic greenhouse gases consist of six types of gases, namely CO_2 (carbon dioxide), CH4 (methane), N2O (nitrous oxide), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons), and SF6 (sulfur hexafluoride).

The concentration of GHGs in the atmosphere will continue to increase along with the rate of increase in the use of fossil fuels and agricultural activities, as well as waste and land management that are not appropriate. In addition, the process of burning forest vegetation on a large scale and draining peatlands in the process of converting land use into agricultural land also has an effect on increasing greenhouse gas emissions in the atmosphere. Forest and land fires as well as deforestation and land forest conversion into agricultural land have placed Indonesia in the 5th largest CO_2 emitting country in the world. In this case, Indonesia is below the United States, China, Russia and Brazil, covering 4% of the world's total carbon emissions (Simons, 2021).

The global environmental temperature is getting hotter day by day which is caused by the high concentration of Greenhouse Gases (GHG) in the atmosphere. This condition should be minimized if the quality of the forest, soil and sea (active carbon pool) is maintained. But the current reality is the opposite, the concentration of GHG in the air continues to increase mainly due to the uncontrolled process of burning fossil fuels, deforestation and forest degradation.

Realizing the high CO_2 emissions in Indonesia, the government through Presidential Decree 61 of 2001 (National Action Plan for Reducing Greenhouse Gas Emissions), issued policies to mitigate GHG emissions in the fields of agriculture, forestry and peat lands, energy and transportation, industry and waste management. Mitigation in the forestry sector is carried out by increasing the quality of CO_2 absorption bags (carbon pools). As one of the pockets of CO_2 absorption, mangrove ecosystems have an average absorption capacity about 8 tons of CO_2/ha/year and play an important role in the global carbon cycle (Murray et al., 2011). Mangrove ecosystems in Indonesia are very important in the global carbon cycle because they have an area of 22.6% of the world's mangroves or the first highest in the world (Giri et al., 2011). Out of a total of

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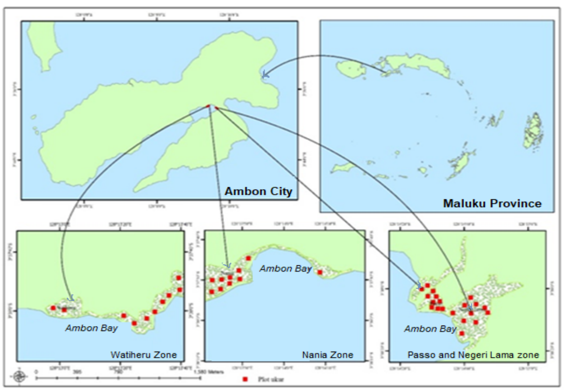
22.6%, it was recorded that around 25.02 ha were in the Muara Angke Wildlife Reserve Area and around 39 ha were spread across Ambon Bay (Belseran, 2022).

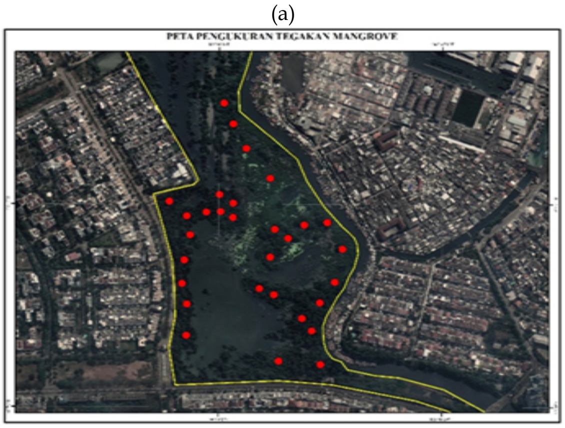
Mangrove ecosystems in Ambon Bay and Jakarta Bay are currently showing severe damage due to land conversion into settlements, roads and agricultural land (Sofian et al., 2020; Suyadi, 2022). This level of damage which is categorized as severe, makes the biomass and carbon stock of mangrove ecosystems allegedly decrease. Therefore, it is necessary to carry out research related to biomass storage and carbon stock in the mangrove ecosystem in Muara Angke, North Jakarta compared to the mangrove ecosystem in Ambon Bay. This will be very useful for projecting the ability of biomass and carbon accumulation in these two ecosystems.

Method

The purpose of this study was to calculate the storage of biomass and carbon in the Jakarta Bay mangrove ecosystem compared to Ambon Bay. Data collection starts from February to March 2022.



(a)



(b)

Figure 1. Research locations: (a) Ambon Bay, and (b) Muara Bay

Information on the extent of the Ambon Bay mangrove ecosystem, obtained from the Land Cover Map of the Ministry of Environment and Forestry/KLHK (2021). This information is used as the basis for dividing the research zone into West, Central and East Zones (Figure 1). These zones are the main part, within which there are several measuring plots. The plot placement technique uses random sampling (Howard et al., 2014), with a total of 40 plots (10 plots per zone) measuring 10 m x 10 m each.

Data collection in each measuring plot includes: (1) Mangrove plant species. Mangrove vegetation in each measuring plot is identified and the local name and Latin name are recorded on the tally sheet; (2) Diameter of mangrove plants. Measurement of the diameter of mangrove vegetation stems in measuring plots is only carried out for mangrove vegetation at a height of 1.3 m from the stilt roots boundary which is called breast height diameter (DBH) ≥ 10 cm (Figure 2).

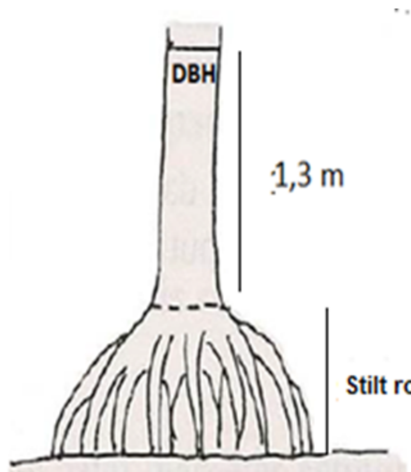


Figure 2. DBH of Mangrove Plants is measured at a Height of 1.3 m from the Stilt Roots Boundary

Calculation of mangrove plant biomass in this study, using non-destructive sampling method and analyzed with the equation developed by Komiyama et al. (2005):

Estimation of aboveground biomass: $W_{top} = 0.251\rho D^{2.46}$,

Estimation of subsurface biomass: $WR = 0.199\rho^{0.899}D^{2.22}$.

Note: ρ is the specific gravity of mangrove vegetation obtained from the World Agroforestry Database (Chave et al., 2009), and D is the diameter of the mangrove trunk

Result and Discussion

Mangrove Ecosystem of Ambon Bay

General Condition

Geographically, the mangrove ecosystem in Ambon Bay is located at position 3°37'56.3850" S and 128°13'33.4591" E, on the coast of Ambon City. Its existence in urban coastal areas makes the area surrounded by various human activities, such as agriculture, settlement and other physical development. Development and physical activity that continues around the area has put pressure on the mangrove ecosystem. These activities include illegal logging, pollution and increasing domestic waste and industrial waste.

Realizing that there is damage to the mangrove ecosystem in Ambon Bay, the Ambon Provincial Government is trying to optimize monitoring activities for the remaining mangrove areas. The latest data states that the mangrove area in Ambon Bay is around 58.80 ha, with a primary land cover type (KLHK, 2021).

The Ambon Bay Mangrove Ecosystem is classified as a primary mangrove area, with a mature mangrove stand type. This can be seen from the results of measuring the tree dimensions (trunk circumference and tree height). The composition of mangrove species in Ambon Bay includes *Bruguiera cylindrica (L.) Bl., Rhizophora apiculata Bl., Sonneratia alba Smith., Aegiceras corniculatum (L.) Blanco, Avicennia officinalis L., Ceriops tagal.*

The recorded mangrove species were found in four monitoring zones, namely the Waiheru Zone, the Nania Zone, the Negeri Lama Zone, and the Passo Zone. In each zone there are variations in structure and species composition. Further description is as follows.

Mangrove Ecosystem in the Waiheru Zone

The Waiheru Main Zone is located at a geographical position of 3°37'56.3850" S and 128°13'33.4591" E (Figure 3).

Figure 3. Mangrove Ecosystem in the Waiheru Zone

In the Waiheru Zone, there were 5 mangrove species that met the measurement criteria (± 10 cm), namely *Sonneratia alba Smith, Rhizophora apiculata Bl, Avicennia officinalis* L, *Ceriops tagal Bruguiera cylindrica* (L.) *Bl*. The composition of each can be explained as follows. *Sonneratia alba Smith* was the most dominant species (44%), followed by *Rhizophora apiculata Bl* (37%), *Avicennia officinalis* L (11%), *Ceriops tagal* (5%), and *Bruguiera cylindrica* L (3%).

In addition to the composition of mangrove species, another parameter that is also considered is the structure of the mangrove stand. The structure of the mangrove stands measured includes height and diameter. The measurement results are presented in Table 1.

Table 1. Results of Measurements of Mangrove Stands in the Waiheru Zone

Species	Diameter (cm)		Heigh (m)	
	Min	Max	Min	Max
Sonneratia alba Smith	10.51	42.99	4	7
Rhizophora apiculata Bl	10.19	38.22	4	7
Avicennia officinalis L	11.78	9.00	5	7
Bruguiera cylindrica (L) Bl	10.83	17.50	4	5
Ceriops tagal	11.00	13.00	3	4

The data in table 1 shows that *Sonneratia alba Smith* and *Rhizophora apiculata Bl* in this zone are included in the large tree category, because their maximum diameter is ≥ 20 cm and the maximum height reaches 7 m. Whereas *Avicennia officinalis* L, *Bruguiera cylindrica* (L.) and *Ceriops tagal* are included in the sapling stage, because they have a maximum diameter of ≤ 20 cm.

Data from measurements of the diameter and height of mangrove stands are then used to calculate the value of the above ground and subsurface biomass. The calculation results are presented in Figure 4.

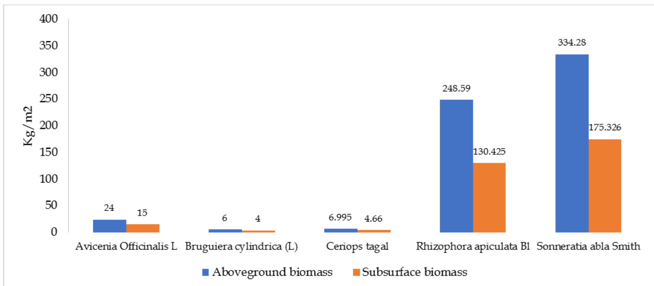


Figure 4. Biomass of Mangrove Plant in the Waiheru Zone

The calculation results show that *Sonneratia alba Smith* and *Rhizophora apiculata Bl* have high biomass values. This is due to the composition and structure of the stands owned by both typese.

Mangrove Ecosystem in the Nania Zone

The Nania Main Zone is located at 3°37'50.2947" S and 128°13'40.1410" E (Figure 5). In the Nania Zone, there were 4 mangrove species that met the measurement criteria (± 10 cm), namely *Rhizophora apiculata Bl., Avicennia officinalis L., Bruguiera cylindrica (L.) Bl., Sonneratia alba Smith.* The composition of each species was as follows: *Rhizophora apiculata Bl* was the most dominant species (63%), *Avicennia officinalis L* (23%), *Sonneratia alba Smith* (11%) and *Bruguiera cylindrica (L.)* (3%).

The results of measurements of the mangrove stand structure (diameter and height) in the zone are presented in Table 2.

Figure 5. Mangrove Ecosytem in the Nania Zone

Table 2. Structure of Mangrove Stands in the Nania Zone

Species	Diameter (cm)		Heigh (m)	
	Min	Max	Min	Max
Rhizophora apiculata Bl.	10.19	32.17	4	9
Avicennia officinalis L.	10.19	29.30	4	10
Bruguiera cylindrica (L.) Bl.	10.83	19.43	8	9
Sonneratia alba Smith.	10.83	15.61	8	12

In Table 2 it is clear that in the Nania Zone, *Rhizophora apiculata Bl. and Avicennia officinalis L.* are categorized as large trees, because the maximum diameter is > 20 cm and the maximum height reaches 7 m. While the species *Bruguiera cylindrica (L.*), and *Sonneratia alba Smith.* included in the sapling level, because it has a maximum diameter of <20 cm.

Using the data in Table 2, calculations are then carried out to determine the value of the above ground and subsurface biomass and the results are presented in Figure 6.

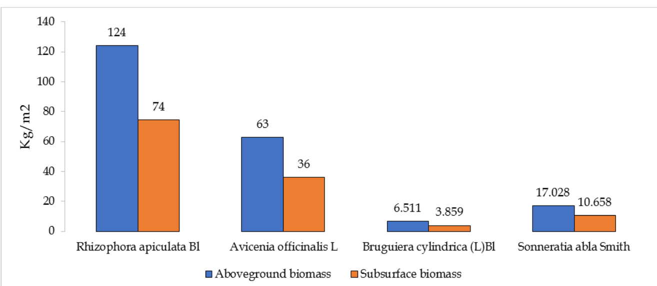


Figure 6. Biomass of Mangrove Plants in the Nania Zone

Figure 6 shows that the type of *Rhizophora apiculata Bl*. and *Avicennia officinalis L*. have high biomass value. This is due to the composition and structure of the two mangrove plant species. Both species of mangrove plants are tree-shaped, *Avicennia* usually has a height of up to 12 m, sometimes even up to 20 m, while *Rhyzophora* can reach a height of up to 30 m with a trunk diameter of up to 50 cm (Noor et al., 2006).

Mangrove Ecosystem in the Negeri Lama Zone

The Negeri Lama Main Zone is located at a geographic position of 3°38'04.9502"S and 128°14'31.0789" E (Figure 7).

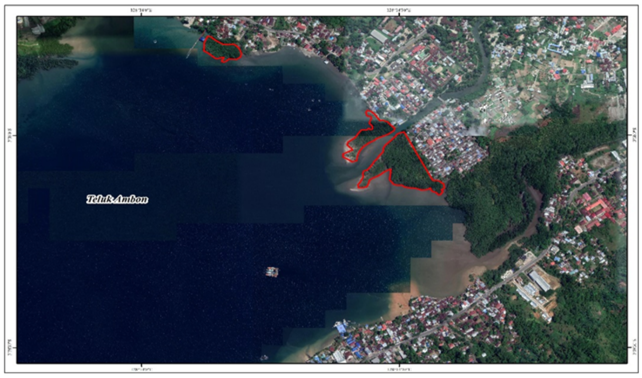


Figure 7. Ecosystem Mangrove Zona Negeri Lama

In the Negeri Lama Zone, there were 2 mangrove species that met the measurement criteria (± 10 cm), namely *Sonneratia alba Smith* and *Rhizophora apiculata Bl.* The composition of each species is as follows: *Sonneratia alba Smith* is the most dominant species (74%) and *Rhizophora apiculata Bl* (26%). The structure of the mangrove stands measured including height and diameter is presented in Table 3.

Table 3. Structure of Mangrove Stands in the Negeri Lama Zone

Species	Diameter (cm)		Heigh (m)	
	Min	Max	Min	Max
Rhizophora apiculata Bl.	10.19	16.88	7	11
Sonneratia alba Smith.	8.28	23.57	4	12

The data above shows that *Sonneratia alba Smith* is included in the large tree category, because it has a maximum diameter of > 20 cm and a maximum height of 12 m. While the type of *Rhizophora apiculata Bl* is categorized in the sapling level, because it has a maximum diameter of <20 cm.

Based on the data in Table 3, calculations are then carried out to determine the value of the above ground and subsurface biomass and the results are presented in Figure 8. Figure 8 shows that the species *Sonneratia alba Smith* has a high biomass value. This is due to the composition and structure of the stand owned by this type.

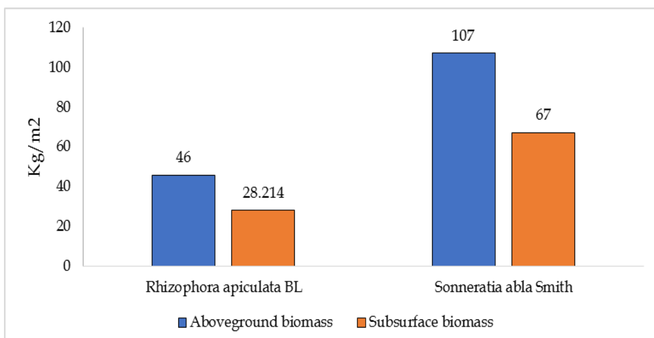


Figure 8. Biomass of Mangrove Plants in the Negeri Lama Zone

Mangrove Ecosystem in the Passo Zone

The Passo Zone is located at a geographic position 3°38'06.1036" S and 128°14'42.7802" E (Figure 9).

Figure 9. Ecosystem Mangrove Passo Zone

In the Passo Zone, there were 4 mangrove species that met the measurement criteria (± 10 cm), namely *Aegiceras corniculatum (L.) Blanco*, *Bruguiera cylindrica (L.) Bl.*, *Sonneratia alba Smith* and *Rhizophora apiculata Bl.* The composition of each species is as follows: *Rhizophora apiculata Bl* is the most dominant species (44%), followed by *Sonneratia alba Smith* (38%), *Bruguiera cylindrica* (L.) Bl (13%), *Aegiceras corniculatum (L.) Blanco* (3%). The structure of the mangrove stands measured including height and diameter is presented in Table 4.

Tabel 4. Structure of Mangrove Stands in the Passo Zone

Species	Diameter (cm)		Heigh (m)	
	Min	Max	Min	Max
Aegiceras corniculatum (L.) Blanco	10.19	11.15	5	6
Bruguiera cylindrica (L.) Bl.	10.19	12.42	4	6
Rhizophora apiculata Bl.	10.19	15.61	5	10
Sonneratia alba Smith.	10.19	15.34	3	7

In table 4 it is clear that in the Passo zone all mangrove species recorded such as *Aegiceras corniculatum (L.) Blanco*, *Bruguiera cylindrica (L.) Bl.*, *Sonneratia alba Smith* and *Rhizophora apiculata Bl* belong to the sapling level, because they have a maximum diameter of <20 cm.

Base on the data in Table 4, calculations are then carried out to determine the value of the above ground and subsurface biomass and the results are presented in Figure 10.

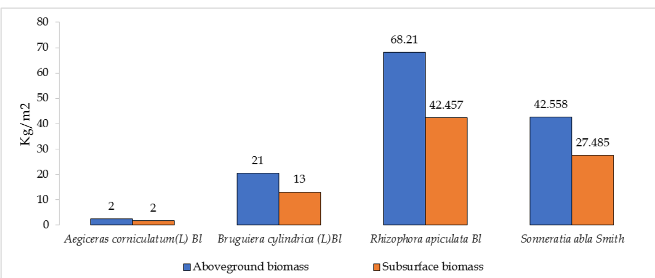


Figure 10. Biomass of Mangrove Plants in the Passo Zone

The calculation results show that *Rhizophora apiculata Bl* and *Sonneratia alba Smith* have high biomass values. This is due to the composition and structure of the stands owned by both types.

Mangrove Biomass of Ambon Bay

The accumulated value of biomass for each main zone in Ambon Bay can be seen in Figure 11.

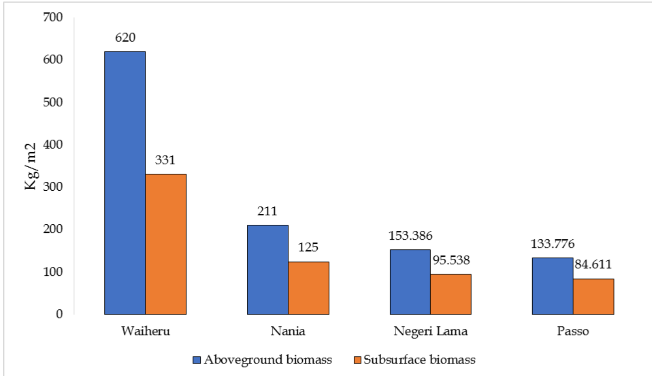


Figure 11. Biomass of Mangrove Plants in the Ambon bay per zone

The results of the analysis show that the highest mangrove plant biomass is found in the Waiheru Zone, followed by the Nania Zone, the Negeri Lama Zone and the Passo Zone. Aboveground biomass in this study was generally higher than subsurface biomass. This is in line with the results of research by Ahmed et al. (2023) and Komul et al. (2016) who revealed the same thing that in forest ecosystems, aboveground biomass is always higher than subsurface biomass. In addition, the productivity of mangrove plant biomass is highly dependent on the age of the plant, the species, and the environment in which it lives (Qiu et al., 2011).

Mangrove Ecosystem of Muara Angke

General condition

Administratively, the Muara Angke area is included in Kapuk Muara and Pluit Village, Penjaringan District, North Jakarta Municipality, precisely at position 106° 43"-106° 48" East Longitude and 6° 06"-6° 10" South Latitude. This area has a mangrove area adjacent to housing and residential areas. Its location in the vicinity of residential areas makes the Angke Kapuk mangrove ecosystem very vulnerable to damage and area conversion. The Angke Kapuk Mangrove ecosystem area has the potential to continue to be under pressure, mainly due to activity from the built-up areas around it (Bayan et al., 2016; Sofian et al., 2020; Wardhani, 2011).

To determine the level of damage that occurred in the Angke Kapuk mangrove ecosystem, an assessment was made of the condition of the structure and composition of the mangrove species. The assessment focused on a conservation area, namely the Muara

Angke Wildlife Sanctuary. The results of the assessment indicated that the area had a fairly low species composition and was dominated by *Sonneratia alba Smith*. This relatively low species variation indicates a high level of damage to the Muara Angke mangrove ecosystem. This happens because there is a lot of environmental pressure on this area, starting from environmental pollution and the development of settlements in the vicinity. The high pollution of heavy metals such as Pb and Cd in the Jakarta Bay was revealed from several research results such as Wahyuningsih et al. (2015), Rumanta (2019), and Rumanta (2023). High concentration of heavy metals in plants can cause stress/toxicity and chlorosis in young leaves and inhibit plant growth (Singh et al., 2016, 2022; Yang et al., 2020).

Mangrove Biomass of Muara Angke Area

The mangrove species composition in the Muarea Angke Wildlife Reserve Area is dominated by *Sonneratia alba Smith* and this species was found in all observation plots. The results of identification and measurement of mangroves in the observation plots are presented in Table 5.

Table 5. Structure of Mangrove Stands in the Muara Ange

Species	Diameter (cm)		Heigh (m)	
	Min	Max	Min	Max
Sonneratia alba Smith.	10	75	4	9

The measurement results showed that the species *Sonneratia alba Smith* in the Muara Angke Wildlife Reserve was included in the large tree category because it had a maximum diameter of ≥ 20 cm and a maximum height of 9 m.

The measurement data on the diameter and height of the mangrove stands are then used to calculate the value of the above and below the surface biomass. The calculation results are presented in Figure 12.

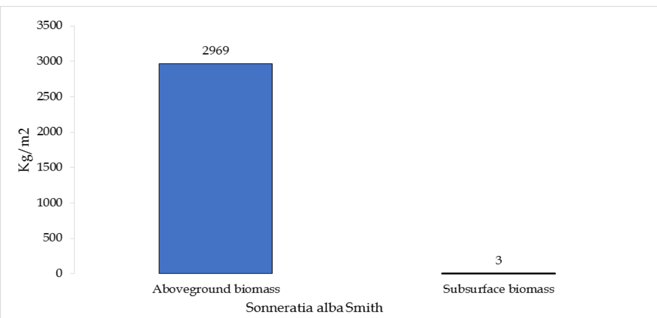


Figure 12. Biomass of Mangrove Plants in Muara Angke wildlife Sanctuary, Jakarta Bay

The calculation results show that the species *Sonneratia alba Smith* has a high biomass value. This is due to the composition and structure of the stand owned by this type. In terms of species composition, Sonneratia alba Smith is a very dominant plant with the highest stand structure among other mangrove plants. The results of Mujadid et al. (2020) also revealed that the most dominant mangrove plants in the Muara Angke Wildlife Park were *Sonneratia* and *Nypha fruticans.*

The results of this study also indicate that the mangrove ecosystem in Ambon Bay is relatively more well preserved than the mangrove ecosystem in Jakarta Bay, Muara Angke region. In fact, according to Rihulay et al. (2022) in the 1999-2020 period the Ambon Bay area experienced an additional 248,654 M^2 of cover. In contrast to the Ambon Bay Mangrove, the Muara Angke mangrove area is under quite heavy pressure due to very high environmental pollution both organic and inorganic, as well as expanding development which threatens its existence. According to Susanto et al. (2019), in the past 30 years, most of the Muara Angke conservation area with an area of more than 1,000 hectares has suffered very severe damage and can no longer be saved. In addition, Mayalanda et al. (2014) revealed that the damaged rate of mangrove vegetation in Muara Angke Wildlife Reserve is about 0.569 ha/year. The same thing happened to the Muara Gembong Teluk Jakarta mangrove forest, which is experiencing the fastest rate of destruction in the world (Kristina et al., 2022).

Conclusion

The composition of mangrove species in Ambon Bay consists of 6 mangrove species, namely: *Bruguiera cylindrica (L.) Bl, Rhizophora apiculata Bl, Sonneratia alba Smith, Aegiceras corniculatum (L.) Blanco, Avicennia officinalis L, Ceriops tagal*. The results of this study also indicated that in the Ambon Bay mangrove ecosystem, *Rhizophora apiculata Bl* and *Sonneratia alba Smith* species had higher biomass values compared to the other four types of mangrove plants. Meanwhile, in Jakarta Bay, the composition of mangrove plants is dominated by *Sonneratia alba Smith.* The high content of biomass in the species *Rhizophora apiculata Bl* and *Sonneratia alba Smith* is due to the composition and structure of the stand of the two plant species. The subsurface biomass in the Jakarta Bay and Ambon area is lower than the aboveground biomass. The results of this study also indicate that the mangrove ecosystem in Ambon Bay is relatively more well preserved than the mangrove ecosystem in Jakarta Bay, Muara Angke region. This is because the Muara Angke mangrove area is under relatively high pressure due to high environmental pollution, both organic and inorganic, as well as development that continues to threaten its existence.

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Author Contributions

All authors listed in this article contributed to research and article development. The draft of the article was made together led by the lead researcher Sadra Sukmaning Adji and the finalization process and correspondence for publication the articles by Maman Rumanta.

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Conflicts of Interest

For the publication of this article, we declare that there is no conflict of interest between the researchers themselves and between the researchers and the funder.

References

Ahmed, Y., Kurniawan, C. A., Efendi, G. R., R, P., Nainggolan, F. A., & Samudra, M. B. G. S. (2023). Estimasi Cadangan Karbon Mangrove Berdasarkan Perbedaan Tahun Tanam Rehabilitasi Mangrove di Kawasan Ekowisata Mangrove Pandansari, Kabupaten Brebes. *Buletin Oseaanografi Marina*, *12*(1), 9–19. https://doi.org/10.14710/buloma.v12i1.40871

Bayan, I. E., Yulianda, F., & Setyobudiandi, I. (2016). Degradation analysis of mangrove ecological function as macrozoobenthos habitat and its management in the Angke Kapuk Coastal Area, Jakarta. *Bonorowo Wetlands*, *6*(1), 1–11. https://doi.org/10.13057/bonorowo/w060101

Belseran, C. (2022). Kala Hutan Mangrove Teluk Ambon Tergerus. *Mongabay*. Retrieved from https://www.mongabay.co.id/2022/06/15/kala-hutan-mangrove-teluk-ambon-tergerus/

Chave, J., Coomes, D., Jansen, S., Lewis, S. L., Swenson, N. G., & Zanne, A. E. (2009). Towards a worldwide wood economics spectrum. *Ecology Letters*, *12*(4), 351–366. https://doi.org/10.1111/j.1461-0248.2009.01285.x

Giri, C., Ochieng, E., Tieszen, L. L., Zhu, Z., Singh, A., Loveland, T., Masek, J., & Duke, N. (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography*, *20*(1), 154–159. https://doi.org/10.1111/j.1466-8238.2010.00584.x

Howard, J., Hoyt, S., Isensee, K., Pidgeon, E., & Telszewski. (2014). *Coastal blue carbon. Methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows*. Conservation International, Intergovern-mental Oceanographic Commission of UNESCO, International Union for Conservation of Nature.

K.L.H.K. (2021). *Data dan Informasi: Pemetaan Tematik Kehutanan Indonesia*. Retrieved from https://sigap.menlhk.go.id/sigap-trial/files/download/2-booklet-pdtk-2021_indo.pdf.

Komiyama, A., Poungparn, S., & Kato, S. (2005). Common allometric equations for estimating the tree weight of mangroves. *Journal of Tropical Ecology*, *21*(4), 471–477. https://doi.org/10.1017/S0266467405002476

Komul, Y. D., Mardiatmoko, G., & Maail, R. S. (2016). Analisis Kandungan Biomassa dan Karbon Tersimpan (Carbon Stock) pada PSP (Plot Sampling Parmanent) Hutan Negeri Soya Kota Ambon. *Jurnal Hutan Pulau-Pulau Kecil*, *1*(1), 72. https://doi.org/10.30598/10.30598/jhppk.2016.1.1.72

Kristina, G., & Setiawan, T. (2022). Pendekatan Desain Keseharian Pada Ekowisata Mangrove Di Desa Pantai Mekar, Muara Gembong, Bekasi. *Jurnal Sains, Teknologi, Urban, Perancangan, Arsitektur (Stupa)*, *3*(2), 1835. https://doi.org/10.24912/stupa.v3i2.12333

Mayalanda, Y., Yulianda, F., & Setyobudiandi, I. (2014). Strategy for mangrove ecosystem rehabilitation throughout damaged level analysis at Muara Angke Wildlife Sanctuary, Jakarta. *Bonorowo Wetlands*, *4*(1), 12–36. https://doi.org/10.13057/bonorowo/w040102

Mujadid, I., Junita, I., & Rahmad, B. (2020). Mangrove Biodiversity at Muara Angke Animal Sanctuary, Kapuk, North Jakarta. *Sintesa: Jurnal Ilmu Pendidikan*, *15*(1), 17–25. Retrieved from https://sintesa.stkip-arrahmaniyah.ac.id/index.php/sintesa/article/view/18

Murray, B., Pendleton, L., Jenkins, W., & Sifleet, S. (2011). *Green payments for blue carbon: economic incentives for protecting threatened coastal habitats*. Nicholas Institute for Environmental Policy Solutions, Duke University.

Qiu, Y. W., Yu, K. F., Zhang, G., & Wang, W. X. (2011). Accumulation and partitioning of seven trace metals in mangroves and sediment cores from three estuarine wetlands of Hainan Island, China. *Journal of Hazardous Materials*, *190*(1–3), 631–638. https://doi.org/10.1016/j.jhazmat.2011.03.091

Rihulay, T. D., & Samuel Papilaya, F. (2022). Analisa Perubahan Luas Tutupan Lahan Mangrove di Teluk Ambon Dalam Menggunakan OBIA. *Journal of Information System,Graphics, Hospitality and Technology*, 4(01), 7–12. https://doi.org/10.37823/insight.v4i01.183

Rumanta, M. (2019). The potential of rhizophora mucronata and sonneratia caseolaris for phytoremediation of lead pollution in Muara Angke, North Jakarta, Indonesia. *Biodiversitas*, *20*(8), 2151–2128. https://doi.org/10.13057/biodiv/d200808

Rumanta, M. (2023). Cadmium pollution in waters and commercial shellfish in Jakarta Bay. *International Journal of Bioscience*, *22*(2), 260–268. http://dx.doi.org/10.12692/ijb/22.2.260-268

Simons, E. (2021). Analysis: Which countries are historically responsible for climate change? In *Carbon Brief: Clean on Climate*. Retrieved from https://www.carbonbrief.org/analysis-which-countries-are-historically-responsible-for-climate-change/

Singh, S., Diksha, Mahajan, E., & Sohal, S. K. (2022). Effect of heavy metals on insects. *Appraisal of Metal(Loids) in the Ecosystem*, *5*(3), 361–390. https://doi.org/10.1016/B978-0-323-85621-8.00014-5

Singh, S., Parihar, P., Singh, R., Singh, V. P., & Prasad, S. M. (2016). Heavy metal tolerance in plants: Role of transcriptomics, proteomics, metabolomics, and ionomics. *Frontiers in Plant Science*, *6*(FEB2016), 1–36. https://doi.org/10.3389/fpls.2015.01143

Sofian, A., Kusmana, C., Fauzi, A., & Rusdiana, O. (2020). Evaluating the Conditions of Angke Kapuk Mangrove Ecosystem Jakarta Bay and its Consequences on Ecosystem Services. *Jurnal Kelautan Nasional*, *15*(1), 1–12. Retrieved from http://ejournal-balitbang.kkp.go.id/index.php/jkn/article/view/7722

Susanto, S., & Tjahjadi, E. (2019). Pusat Informasi Ekosistem Mangrove. *Jurnal Sains, Teknologi, Urban, Perancangan, Arsitektur (Stupa)*, *1*(1), 40. https://doi.org/10.24912/stupa.v1i1.4018

Suyadi. (2022). A Decade of Mangrove Forest Condition in Ambon Bay, Maluku. *Jurnal Biologi Indonesia*, *8*(1), 197–203. Retrieved from https://e-journal.biologi.lipi.go.id/index.php/jurnal_biologi_indonesia/article/download/3077/2665

Wahyuningsih, T., Rumanta, M., & Nurdin, G. (2015). Pencemaran Pb dan Cd pada Hasil Perikanan Laut Tangkapan Nelayan di Sekitar Teluk Jakarta. *Seminar Nasional Konservasi Dan Pemanfaatan Sumber Daya Alam 2015*, *1*(1), 105–111. Retrieved from https://media.neliti.com/media/publications/169693-ID-pencemaran-pb-dan-cd-pada-hasil-perikana.pdf

Wardhani, M. K. (2011). Kawasan Konservasi Mangrove: Suatu Potensi Ekowisata. *Jurnal Kelautan*, *4*(1), 60–79. https://doi.org/10.21107/jk.v4i1.891

Yang, Y., Zhang, L., Huang, X., Zhou, Y., Quan, Q., Li, Y., & Zhu, X. (2020). Response of photosynthesis to different concentrations of heavy metals in Davidia involucrata. *PLoS ONE*, *15*(3), 1–16. https://doi.org/10.1371/journal.pone.0228563