Assessment of mangrove biodiversity and community structure as a basis for sustainable conservation and management plan in Tambakbulusan, Demak, Central Java

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Abstract. Mangrove community have an essential role in coastal areas because they provide various ecosystem services, including ecological, economic, and social benefit that can support local communities' livelihoods. However, most mangroves are threatened due to deforestation, land use change, and climate change. Tambakbulusan is one of the villages on the north coast of Central Java that has experienced abrasion and tidal flooding due to degradation of the mangrove. This study aims to assess the structure and biodiversity of mangrove community to provide the framework for a sustainable conservation in Tambabulusan, Demak, Central Java. Data on mangrove vegetation was obtained using the belt transect method. A total of 9 plots were established at three research sites to identify data on mangrove vegetation. The analysis of vegetation formulas was used to obtain the value of Important Value Index (IVI), while Shannon Wienner's Index (H') and Evenness Index (J) was also measured. Thirteen species of mangrove vegetation were found at the research site, eleven of which are true mangrove species that are included in the Least Concern (LC) category of IUCN (International Union for Conservation of Nature) red list, while the other two were mangrove-associated species. The most dominant species in the tree and seedling category was *Rhizophora mucronata*, with an IVI of 98.86% and 57.34%, while the sapling category was dominated by *Avicennia marina* with an IVI of 62.61%. Overall, the diversity index was categorized as moderate, while the evenness index was relatively high. These findings provide insight into the mangrove community and essential information for sustainable mangrove conservation and management plan, especially in Tambakbulusan coastal area.

Key Words: Shannon Wienner's index, evenness index, species dominance, deforestation.

Introduction. Mangroves are a group of plants that thrive in the intertidal zone at low latitudes along tropical and subtropical coastal areas (Kusmana & Sukristijiono 2016; Serosero et al 2020). Because of their high capacity for adaptation, mangrove communities show a high level of ecological stability even though the physical and geological conditions of the intertidal zone are prone to experiencing dramatic change (Alongi 2015). The mangrove ecosystem is also an important coastal ecosystem that provides various ecosystem services and essential ecological functions (Kauffman et al 2017). These ecosystem services include natural barriers that protect the coastal area from storms, tsunamis, and erosion (Asari et al 2021; Nur & Hilmi 2021), habitats for breeding, feeding, and nursery for various fish species (Vincentius et al 2018), and ecotourism opportunities that can enhance coastal communities livelihoods (Eddy et al 2016; Sarhan 2018). On a global scale, mangrove ecosystems are also recognized for their capacity to store and absorb a large amount of carbon and significantly contribute to the climate change mitigation (Donato et al 2011).

Despite providing various ecosystem services that are beneficial for the environment and coastal communities livelihoods, most of mangrove ecosystems are threatened by anthropogenic and natural factors (Giri et al 2011). Globally, mangrove ecosystems had an annual deforestation rates >2% in the early 2000s (Valiela et al 2001), which slowed down to 0.3-0.7% (Friess et al 2019; Hamilton & Casey 2016), but it still higher than the tropical forest deforestation rate of 0.5% per year (IPCC 2019). The loss of mangroves in Southeast Asian countries mainly occurs due to the conversion of mangroves into aquaculture ponds because of the significant need to fulfil fisheries export purposes, which are expected to generate economic growth (Goldberg et al 2020). Furthermore, the other causes of mangrove loss include the conversion of mangroves into agriculture land (Bryan-Brown et al 2020), plantations (Richards & Friess 2017), and the rapid development of coastal areas (Alongi 2015). These have caused biodiversity loss, increased carbon emissions and various environmental and socio-economic problems in coastal areas.

As one of the countries with the largest mangrove ecosystem in the world, Indonesia has lost 10-31% of its mangroves (Hamilton & Friess 2018), with an annual rate of deforestation between 0.26-0.66% (Hamilton & Casey 2016). This massive loss is also primarily due to the conversion of mangroves into aquaculture ponds (Eddy et al 2021). It is estimated that mangrove forests in Indonesia were facing deforestation, mainly for aquaculture development, since the 1800s (Ilman et al 2016). The aquaculture development is predicted to continue and potentially result in the loss of 700,000 hectares of mangrove forests in Indonesia (Fawzi & Husna 2021). The loss of mangroves due to their conversion into aquaculture ponds potentially reduces carbon stock by 554±230 Mg C ha^{-1} and increases carbon emissions by 1,894 Mg CO_2e ha^{-1}, comparable with a degraded peatland's emissions (Kauffman et al 2017). In the long term, the conversion of mangroves into aquaculture ponds might not be able to provide substantial economic benefits and resulting in aquaculture productivity decline due to pollution and erosion, which would impact the income of coastal communities (van Wesenbeeck et al 2015).

Tambakbulusan is one of the areas on the north coast of Demak, Central Java, which experienced a massive conversion of mangroves into aquaculture ponds. In the early 2000s, tidal flash floods occurred in Tambakbulusan and resulted in thousands of ponds being damaged and abandoned. Mangrove degradation in Tambakbulusan has caused coastal areas to be more vulnerable to shoreline changes due to abrasion and sea level rise, which has significantly impacted the socio-economic conditions of the local community (Primasti et al 2021). Hence, this area requires sustainable mangrove conservation and management initiatives. In this regard, knowledge of the community structure and mangroves' biodiversity is essential to develop sustainable conservation and management planning (Malik et al 2019). Thus, this study aimed to assess the biodiversity and community structure of mangroves in Tambakbulusan, Demak, Central Java. The findings of this study are expected to provide essential information and scientific reference for the development of mangrove management and conservation plans in Tambakbulusan, Demak, Central Java.

Material and Method

Description of the study sites. This study was conducted in the mangrove ecosystem of Tambakbulusan, Demak Regency, Central Java from June to July 2022. The mangrove ecosystem in Tambakbulusan is located along the coast at the western part of the village. The area is located at latitude $6^0$51'21.51'' S - $6^0$50'9.52'' S and longitude $110^0$31'8'' E - $110^0$31'24.80'' E which is directly adjacent to the Java Sea, with an area of 138.12 ha (Ministry of Environment and Forestry Republic of Indonesia 2021). Most of the landward and middle zone mangrove in Tambakbulusan is located around aquaculture ponds and abandoned ponds, while the front zone mangrove near the coast is severely damaged due to abrasion (Figure 1).

Figure 1. The condition of mangrove in Tambakbulusan, Demak, Central Java. (A) The front zone of mangrove impacted by abrasion; (B) Landward and middle zone around aquaculture ponds (original photos).

Data collection. The three sampling sites at the study area were determined using the purposive sampling, a method that identifies different characteristics related to the objective of the study (Tongco 2007) (Figure 2). The accessibility and the representativeness of the locations were criteria for choosing the sampling sites in this study. The sampling site was restricted to three locations, including mangroves in river estuaries (TB3), mangroves in abandoned ponds (TB2), and mangroves in ecotourism areas (TB1). At each sampling site, a belt transect of 100 m long was placed perpendicular to the coastline. A total of nine sampling plots were established in three research sites along the coast. The sampling plot size is 10 x 10 m^2 for trees (diameter >4 cm), 5 x 5 m^2 for saplings (height ≥1.5 m, and diameter ≤4 cm), and 2 x 2 m^2 for seedlings (height <1.5 m) (English et al 1997). In each sampling plot, vegetation data including the species composition, density, and diameter at breast height (dbh) were collected. In addition, water quality data, including salinity, temperature, pH and dissolved oxygen (DO), were analyzed using the HORIBA water checker with three repetitions at each research site. The water quality data is then compared with the quality standard of seawater (Appendix VIII of Government Regulation Number 22 of 2021 on the Implementation of Environmental Management Protection). Secondary data on aquaculture ponds were also gathered for this research from the Central Bureau of Statistics (BPS) of Demak Regency, Central Java.

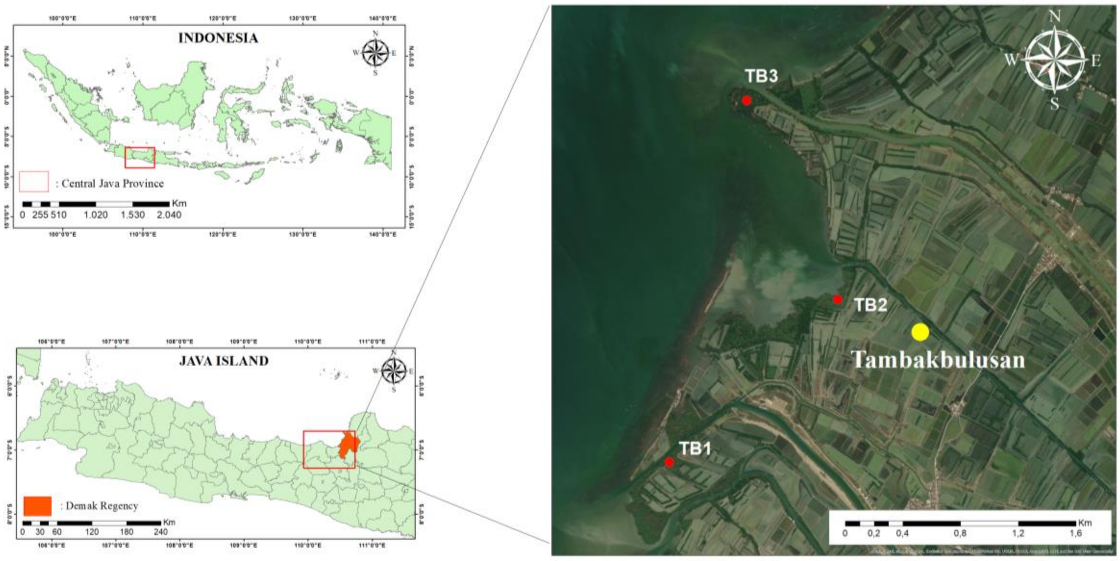

Figure 2. Research sites in Tambakbulusan mangrove ecosystem, Demak Regency, Central Java.

Data analysis

Species composition and diversity. Species composition and diversity were computed using the inventory data of vegetation. The species composition in the mangrove ecosystem is described by calculating the relative density (RDi), relative frequency (RFi), and relative cover (RCi) of each species (Faridah-Hanum et al 2012). In addition, the description of the influence and role of a species on the community is determined by calculating the Importance Value Index (IVI). The IVI ranged from 0 to 300%; the species with the highest IVI indicates dominance in the community. The following equations were used to calculate RDi, RDi, RCi, and IVI (English et al 1997).

$$Rdi\ (\%) = (ni / \sum n) \times 100$$

Where:
RDi - the relative density of species i (%);
ni - the number of individual species i;
∑n - the total number of individuals of all species.

$$Rfi\ (\%) = (Fi / \sum F) \times 100$$

Where:
RFi - the relative frequency of species i (%);
Fi - the frequency of species i;
∑ F - the total frequency of all species.

$$RCi\ (\%) = (Ci / \sum C) \times 100$$

Where:
RCi - the relative coverage of species i (%);
Ci - the i^{th} species' areal of coverage; Ci is calculated by dividing basal area ($\pi dbh^2/4$) by the total area of the plots (A)
∑ F - the total area of all species' coverage.

$$IVI\ (\%) = RDi + RFi + RCi$$

The species diversity was determined using Shannon-Wienner Index (H') (Djufri et al 2016). H' is classified as follows: low diversity ($H'<1$), moderate diversity ($1<H'\leq3$), and high diversity ($H'>3$) (Ludwig & Reynold 1988). The calculation of H' uses the following equation (Odum 1993):

$$H' = \sum \quad Pi \ln Pi;\ Pi = (ni/N)$$

Where:
H' - Shannon-Wienner index;
Pi - fraction of the individuals of i^{th} species of the total individuals of all species;
Ln - the logarithm of Pi;
Ni - density of the i^{th} species;
N - total density of all species.

The Evenness Index of species Pielou (J) was calculated to describe the level of each species' distribution. The value of J is classified into three categories, including low species evenness ($J<0.03$), moderate species evenness ($0.3<J<0.6$), and high species evenness ($J>0.6$) (Magurran 1988; Edwin et al 2021). The calculation of J uses the following equation (Odum 1993):

$$J = H' / \ln (S)$$

Where:
J - species evenness index;
S - total number of species;
H' - species diversity index.

Results

Species composition and structure. Thirteen species of mangrove were discovered in the sampling plots at all research site, eleven of which are true mangrove species that are included in the Least Concern (LC) category of IUCN (International Union for

Conservation of Nature) red list. Those species belonged to the Acanthaceae, Pteridaceae, Avicenniaceae, Rhizophoraceae, Euphorbiaceae, Meliaceae, Sonneratiaceae, Fabaceae and Apocynacea families (Table 1). True mangrove consists of eleven species including *Acanthus ebracteatus*, *Acanthus ilicifolius*, *Acrostichum aureum*, *Avicennia alba*, *Avicennia marina*, *Bruguiera cylindrica*, *Rhizophora apiculata*, *Rhizophora mucronata*, *Excoecaria agallocha*, *Xylocarpus moluccensis*, *Sonneratia alba* (Figure 3). Meanwhile, two other species are included in the mangrove associate type, namely *Derris trifoliata* and *Calotropis gigantea* (Figure 4).

Table 1

Mangrove species identified in the mangrove communities of Tambakbulusan, Demak, Central Java

Families	*Species*	*Local name*	*Red list IUCN**	*Site*		
				TB1	*TB2*	*TB3*
Acanthaceae	*Acanthus ebracteatus*	(TM) Jeruju	LC	-	-	+
	Acanthus ilicifolius	(TM) Jeruju	LC	+	+	+
Pteridaceae	*Acrostichum aureum*	(TM) Krakas	LC	+	+	-
Avicenniaceae	*Avicennia alba*	(TM) Api-api	LC	+	+	+
	Avicennia marina	(TM) Api-api putih	LC	+	+	+
Rhizophoraceae	*Bruguiera cylindrica*	(TM) Pertut	LC	-	+	+
	Rhizophora apiculata	(TM) Bakau akik	LC	+	+	+
	Rhizophora mucronata	(TM) Bakau	LC	+	+	+
Euphorbiaceae	*Excoecaria agallocha*	(TM) Buta- buta	LC	+	+	-
Meliaceae	*Xylocarpus moluccensis*	(TM) Nyiri batu	LC	+	-	-
Sonneratiaceae	*Sonneratia alba*	(TM) Pidada	LC	+	+	+
Fabaceae	*Derris trifoliata*	(MA) Tuba laut	-	-	+	+
Apocynaceae	*Calotropis gigantea*	(MA) Widuri	-	-	-	+

*The IUCN Red List of Threatened Species 2021-3; TM=True Mangrove; MA=Mangrove Associate; (+) indicated the presence of species.

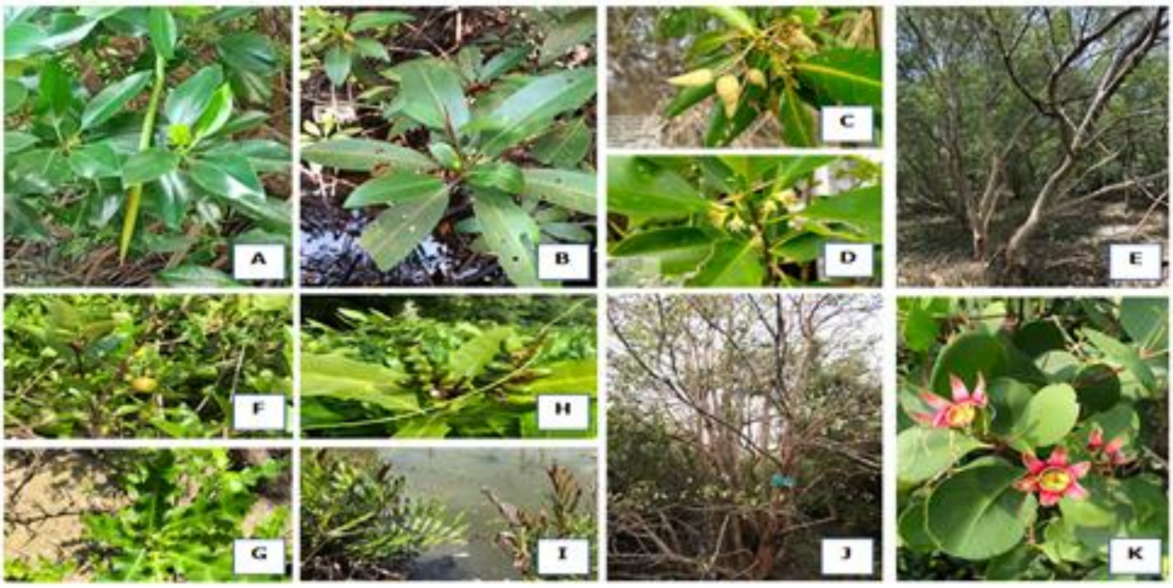

Figure 3. True mangrove species identified in Tambakbulusan, Demak, Central Java. (A) *Rhizophora mucronata*; (B) *Rhizophora apiculata*; (C) *Avicennia alba*; (D) *Bruguiera cylindrica*; (E) *Avicennia marina*; (F) *Xylocarpus moluccensis*; (G) *Acanthus ebractatus*; (H) *Acanthus illicifolius*; (I) *Acrostichum aureum*; (J) *Excoecaria agallocha*; (K) *Sonneratia alba.*

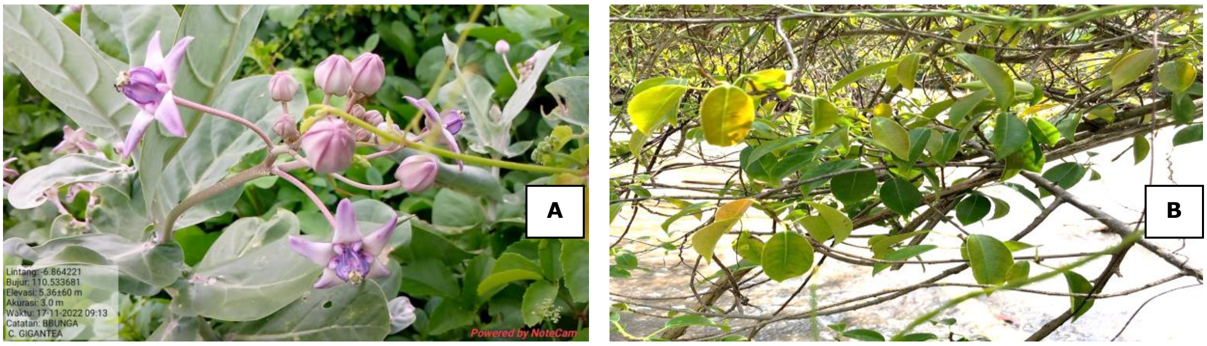

Figure 4. Mangrove associate species identified in Tambakbulusan, Demak, Central Java. (A) *Calotropis gigantea*; (B) *Derris trifoliata.*

A total of 576 standing live mangrove vegetation items were found in 9 plots, at all research sites, including 267 trees, 125 saplings, and 182 seedlings (Table 2). The most abundant true mangrove species in Tambakbulusan were *A. marina* and *R. mucronata*, with a percentage of 30.90 and 28.65%, respectively, while the less abundant species found at the research sites were *X. moluccensis* and *A. ebracteatus*, namely 1.74 and 0.35%, respectively (Figure 5).

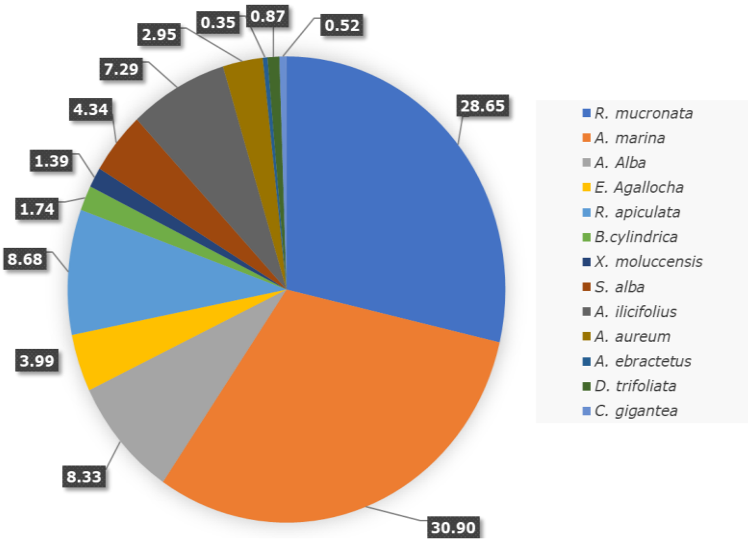

Figure 5. Percentage distribution of mangrove species at Tambakbulusan.

The relative density (RDi) of *A. marina* was the highest in the tree and sapling categories, followed by *R. mucronata* and *A. alba*, while in the sapling categories, *R. mucronata* had the highest relative density, followed by *A. illicifolius* and *A. marina*. The highest relative frequency (RFi) in the tree categories was observed for *A. marina*, while in the sapling and seedling categories it was observed for *R. mucronata*. The relative coverage (RCi) in the research sites was dominated by *R. mucronata* and followed by *A. marina* and *A. alba*. Furthermore, *R. mucronata* also had the largest basal area (BA) of all species at the research sites. Based on the calculation of the important value index, it was determined that the dominant species in the tree and seedling categories of the mangrove community at Tambakbulusan was *R. mucronata*, with an IVI value of 98.86% and 57.34%, followed by *A. marina* (91.14%), for the tree category, and *A. illicifolious* (41.85%) for the seedling category. Meanwhile, the most dominating species in the sapling categories was *A. marina*, with an IVI value of 62.61%, followed by *R. mucronta* (51.69%) and *A. alba* (28.93%) (Table 2).

Table 2

The total number of trees, basal area, percentage of relative density, frequency, and coverage, in Tambakbulusan mangrove communities

Species	*No of indiv (Ni)*	*Basal area (m^2 ha^{-1})*	*Relative values (%)*			*IVI (%)*
			Density	*Frequency*	*Cover*	
Tree						
Rhizophora mucronata	77	10.29	32.05	22.96	43.85	98.86
Avicennia marina	94	7.20	35.63	26.11	29.40	91.14
Avicennia alba	30	1.52	9.25	12.59	4.84	26.68
Excoecaria agallocha	16	1.59	3.67	9.26	2.93	15.86
Rhizophora apiculata	22	2.36	7.85	9.44	7.89	25.18
Xylocarpus moluccensis	5	1.27	1.22	2.78	1.02	5.02
Bruguiera cylindrica	7	11.25	3.71	7.04	2.52	13.27
Sonneratia alba	16	27.40	6.61	9.81	7.56	23.98
Total	267	62.89	100.00	100.00	100.00	300.00
Sapling						
Rhizophora mucronata	29	-	24.19	27.50	-	51.69
Avicennia marina	48	-	35.94	26.67	-	62.61
Avicennia alba	18	-	13.93	15.00	-	28.93
Excoecaria agallocha	7	-	4.75	7.50	-	12.25
Rhizophora apiculata	16	-	13.60	11.67	-	25.26
Xylocarpus moluccensis	3	-	1.82	3.33	-	5.15
Bruguiera cylindrica	3	-	3.45	4.17	-	7.61
Sonneratia alba	3	-	2.33	4.17	-	6.49
Total	127		100.00	100.00	-	200.00
Seedling						
Rhizophora mucronata	59	-	29.92	27.42	-	57.34
Avicennia marina	36	-	17.08	15.25	-	32.33
Rhizophora apiculata	12	-	7.24	6.36	-	13.61
Sonneratia alba	6	-	2.13	6.67	-	8.79
Acanthus ilicifolius	42	-	24.12	17.73	-	41.85
Acanthus ebracteatus	2	-	1.90	3.03	-	4.94
Calotropis gigantea	3	-	2.86	3.03	-	5.89
Acrostichum aureum	17	-	8.19	8.89	-	17.08
Derris trifoliata	5	-	6.55	11.62	-	18.16
Total	182		100.00	100.00	-	200.00

The density of each mangrove species and growth-stages are shown in Figure 6.

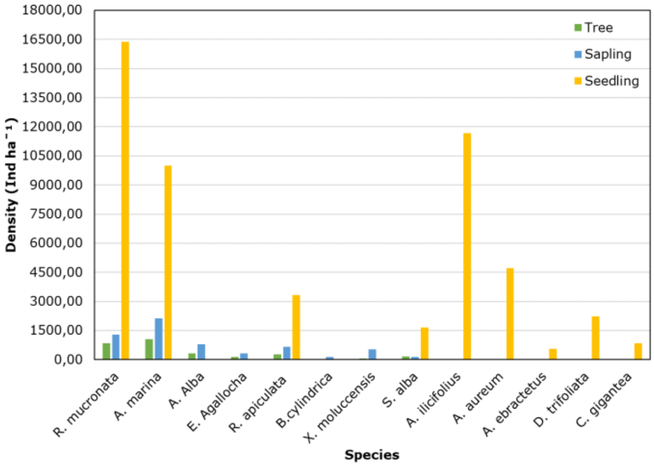

Figure 6. Density of species at each growth-stage in mangrove community of Tambakbulusan, Demak, Central Java.

Overall, it can be seen that the density of the seedling category is much higher than that of the tree and sapling categories, which can be seen especially in the species *R. mucronata*, *A. marina*, *R. apiculata*, *and S. alba*. Meanwhile, *R. mucronata* was recorded as having the highest density in the seedling category, 16,388.89 ind ha^{-1}, followed by *A. ilicifolious* (11,666.67 ind ha^{-1}) and *A. marina* (10,000 ind ha^{-1}). Several true mangrove species, such as *A. alba, B. cylindrica, E. agallocha*, and *X. mollucensis*, were absent from the seedling category in the sampling plots, at all research sites.

The high density of the seedling species category of *R. mucronata* is presumed to be the result of the mangrove rehabilitation efforts in Tambakbulusan village, which includes planting of *R. mucronata* at several locations that have experienced mangrove degradation (Figure 7).

Figure 7. (A) Seedling categories of *Rhizophora mucronata*; (B) one of the locations for planting *Rhizophora mucronata* propagules in Tambakbulusan, Demak, Central Java (original photos).

Diversity and evenness index. The highest species diversity index (H') for the tree category was found on the TB1 site (1.70), while for the sapling and seedling categories it was determined for the sites TB2 (1.57) and TB3 (1.85), respectively (Figure 8A). The average H' value at three different research sites in the Tambakbulusan mangrove community is 1.56, classified as a moderate category. The lowest J was found in the tree category, at TB 2, with a value of 0.75 (Figure 8B). The overall average value of J at the three research sites shows a value of 0.87, which is classified as a relatively high.

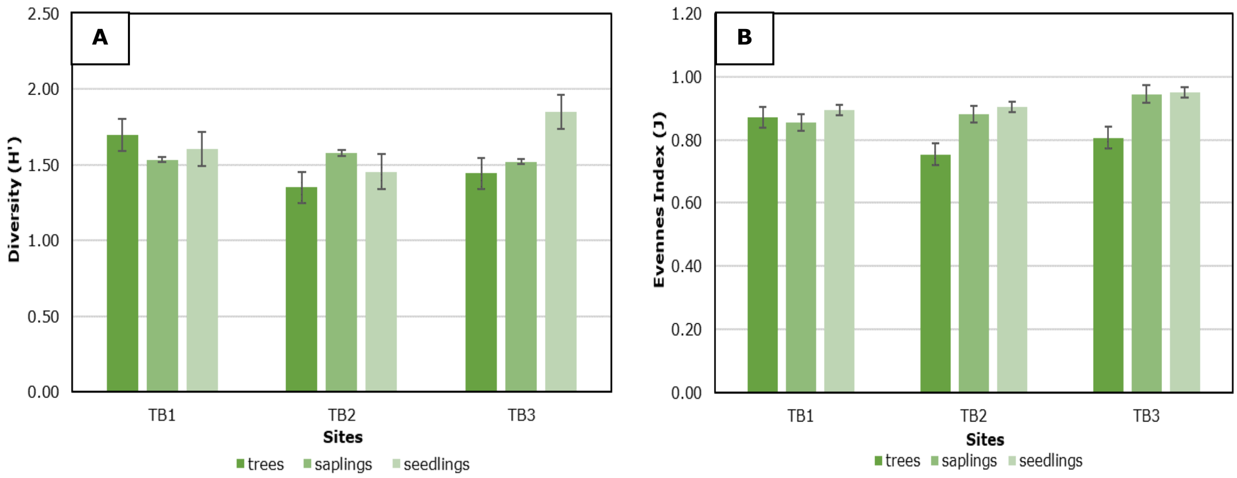

Figure 8. (A) Diversity index (H'); (B) Evenness index (J) of mangrove species at each growth-stages in mangrove community of Tambakbulusan, Demak, Central Java.

Water quality parameters. The water quality in the mangrove community was determined by several parameters, such as salinity, temperature, pH, and dissolved oxygen (DO). Based on the result, the water quality in the mangrove community of Tambakbulusan, Central Java, was categorized as relatively good condition. The salinity in all research sites ranged from 27.67 to 30.00 ppt (Figure 9A), the pH ranged from 7.07 to 7.20 (Figure 9B), temperatures were between 31.33 and 32.00ºC (Figure 9C), and DO value ranged from 5.90 to 6.90 mg L^{-1} (Figure 9D).

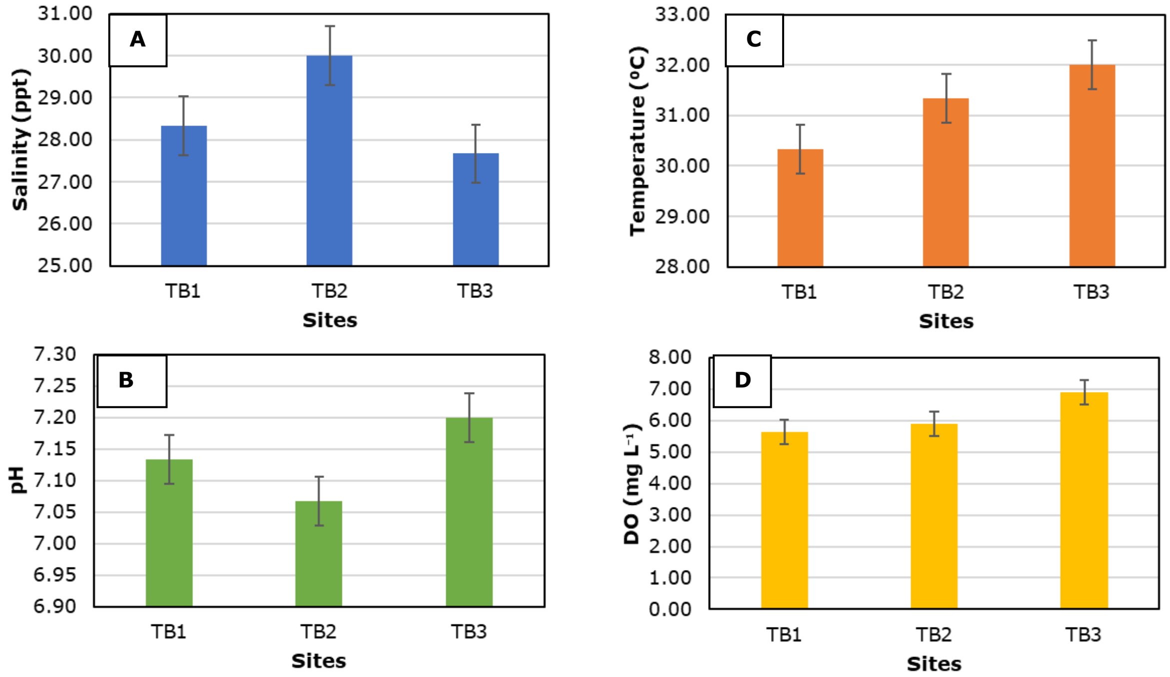

Figure 9. Water quality parameters of (A) salinity, (B) pH, (C) temperature and (D) DO in the mangrove community of Tambakbulusan, Demak, Central Java.

Production of aquaculture ponds in Tambakbulusan. The coastal areas in Demak Regency, including Tambak Bulusan, have been used as massive aquaculture ponds since the 1980s. Aquaculture ponds in the Demak regency are dominated by the cultivation of milkfish, tiger prawns and vannamei shrimp (Marine and Fisheries Service, Demak Regency). Aquaculture ponds production in Demak Regency had a relatively increasing trend from 1995 (2,075 tons) to 2018 (12,929 tons) (Figure 10a) (Arief & Laksmi 2006; BPS-Statistic of Demak Regncy 2007, 2014, 2019), before declining significantly in 2021 (7,311 tons) (BPS-Statistic of Demak Regency, 2021). In contrast, the production trend of the aquaculture ponds in Tambakbulusan decreased from 2007 (2,604 tons) to 2021 (375 tons), which is in line with the decrease in the value of income from aquaculture ponds, namely from USD 1,569,500.15 in 2007, to USD 796,878.15 in 2021 (Figure 10b) (BPS-Statistics of Demak 2007; 2014; 2018; 2022).

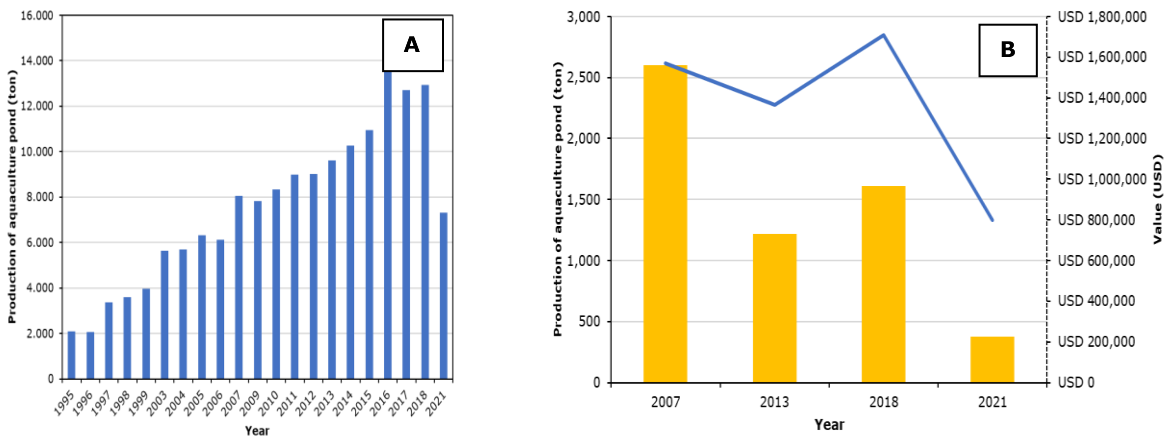

Figure 10. Production of aquaculture ponds in (A) Demak Regency; (B) Tambakbulusan Village.

Discussion. The Tambakbulusan mangrove ecosystem consists of thirteen mangrove species from eight different families. Referring to the conservation status category of the IUCN red list of the Threatened species version 2021-3 (IUCN 2021), it is known that there are eleven true mangrove species which include *A. ebracteatus, A. ilicifolius*, *A. aureum*, *A. alba*, *A. marina*, *B. cylindrica*, *R. apiculata*, *R. mucronata*, *E. agallocha*, *X. moluccensis*, and *S. alba* listed as Least Concern (LC) status. The existence of mangrove species that are included in the IUCN red list demands further protection and conservation efforts in that region (Manual et al 2022). More importantly, maintaining and protecting the diversity of mangrove ecosystems in Tambakbulusan would contribute to the global conservation efforts.

The species of true mangrove that are widely distributed and have an important role in the Tambakbulusan mangrove community are *R. mucronata* and *A. marina*, which had a higher IVI than other species found at the research site. This is in line with the research findings of Susilowati et al (2020), which reported that the most dominating mangrove species in Tambakbulusan was *R. mucronata* and *A. marina*. The domination of those two mangrove species is likely due to their tolerance for extreme environmental conditions, such as high salinity and muddy substrate types, supported by an aerial root system (pneumatophore) (Susanto et al 2018; Hariyanto et al 2019). In addition, the dominance of *R. mucronata* in the Tambakbulusan mangrove community is also the result of rehabilitation efforts that have been carried out since the early 2000s, after tidal flash floods damaged aquaculture ponds in that area. Regarding this, *Rhizophora* sp. is frequently used in mangrove rehabilitation and restoration projects due to its adaptability to various environmental conditions and the comparatively quick growth of its propagule (Mariano et al 2022).

The species diversity index in the Tambakbulusan mangrove community was in the moderate category (H'=1.56), indicated that the mangrove community might be unstable or distressed, requiring a sustainable management and a conservation effort (Goloran et al 2020). Meanwhile, the evenness index was classified as relatively high (J=0.87) which indicated that the mangrove species in the research site was evenly distributed (Manual et al 2022). The domination of *R. mucronata* as a result of rehabilitation effort supports the finding of a study by Primavera & Esteban (2008), which reported that mangrove rehabilitation in Southeast Asia does not primarily focus on increasing species diversity and tends to promote single species, especially *Rhizophora* sp. In this regard, rehabilitation initiatives that use single species can result in low species diversity values and the dominance of one species in an area (Malik et al 2019).

The density of each species and growth stage at the research site indicated that the seedling category tended to have a higher density than the tree and sapling categories. This result demonstrated that the Tambakbulusan mangrove community has good regeneration capability. However, to ensure the rehabilitation efforts provide significant results, it is still essential to monitor the growth of seedlings into saplings and trees. (Koswara et al 2017). Various techniques, such as propagule maintenance, seed production, evaluation of the optimal period for planting propagules, planting procedures, and post-planting monitoring, can support the success of the mangrove rehabilitation effort (Costa et al 2016). In addition, environmental parameters, including temperature, pH, DO, and salinity of water also greatly affect the growth of mangrove seedlings (Hastuti & Budihastuti 2016). Water quality parameters, at all research sites, are classified as relatively good for mangrove growth, according to the national seawater threshold for marine biota, especially mangrove (Government Regulation No 22/2021).

Mangrove degradation in Tambakbulusan was initially caused by the impact of anthropogenic activities related to the conversion of mangroves into fish and shrimp ponds. However, this degradation is currently exacerbated by the effects of climate change. The area of the mangrove ecosystem in Tambakbulusan is estimated to have decreased from 167.36 ha in 2015 (Faturrohmah & Marjuki 2017) to 138.12 ha in 2021 (Ministry of Environment and Forestry Republic of Indonesia 2021). In this regard, the reduced area of mangroves in Tambakbulusan can potentially exacerbate tidal floods and abrasion in the region's coastal areas. In addition, mangroves degradation in Tambakbulusan is also correlated with the decline in production and income from aquaculture ponds. Based on data from Wetlands International (2020), the loss of mangroves, which serve as a natural barrier in the Demak coastal area, has led to tidal floods that have seriously harmed and destroyed aquaculture ponds. In Tambakbulusan itself, around 420.44 ha of aquaculture ponds were inundated by tidal floods, causing a harvest failure in tiger prawns and milkfish commodities.

Therefore, the conservation and rehabilitation of mangroves are essential, considering the crucial role of mangroves in protecting the coastal area from various coastal disasters. In planning sustainable mangrove conservation and management efforts, the local coastal communities' social issues and economic needs must be considered and addressed (Bagarinao 2021). The issue of overfishing, particularly in the Java Sea, has led to a rising demand for aquaculture in that area. Aquaculture ponds activities are essential to the local community's economy in Tambakbulusan, so the management of mangroves must be integrated with the aquaculture (Fitzgerald 2000). In order to improve the environmental quality, income, and production from aquaculture ponds in Tambakbulusan, it is essential to carry out sustainable management and conservation of the mangrove ecosystems. This initiative could be linked with sustainable aquaculture, which can steadily increase the availability of fishery products without damaging the environment.

The mangrove-based silvofishery ponds are one of the methods that should be used to develop sustainable aquaculture, which might be a good alternative to minimize mangrove degradation (Fawziah & Husna 2021). Mangrove-based silvofishery ponds are a mutually beneficial solution for the biodiversity protection, climate change mitigation, and coastal people revenue (Harefa et al 2022), so it is considered a good approach to develop sustainable management and conservation planning (Suwarto et al 2015). Referring to the Decree of the Minister of Fisheries and Maritime Affairs No. 28 of 2004, silvofishery is explained as the utilization of mangroves in cultivation activities, while preserving the mangrove ecosystem and avoiding loss of the natural functions of the mangrove forest. Mangrove vegetation around silvofishery ponds, especially for mangrove species *A. marina* and *R. apiculata*, produce leaf litter which can accelerate fish growth and increase long-term productivity (Rejeki et al 2019).

According to the results of Amrial et al (2015), it is also known that the optimal proportion of silvofishery ponds for aquaculture is at a ratio of 60% mangroves and 40% ponds, for which a point of balance has been reached between economic and ecological conditions, improving the local communities livelihoods. The presence of mangroves around the ponds supports the sediment capture, pond pollution reduction, nutrient absorption, and organic matter provision for the cultivated species (Bao et al 2013). Hence, integrating standing live mangroves in silvofishery ponds is expected to be a possible solution to the coastal issues in Tambakbulusan. Besides, law enforcement, innovation research, as well as active involvement and collaboration from all stakeholders, particularly the coastal communities, are also necessary for the optimization of sustainable mangrove ecosystem management practices (Soeprobowati et al 2022).

According to the study's findings, Tambakbulusan, Demak, Central Java, has a substantial potential for mangrove communities, and it is important to preserve and protect them. Mangroves in this location significantly protect coastal areas and local community aquaculture ponds from tidal flooding and abrasion. In this regard, the mangrove-based silvofishery ponds might be the possible win-win solution for the mangrove conservation and management strategies in Tambakbulusan. The involvement of multiple parties, including the government, local communities, and other stakeholders, especially in the mangrove management, conservation, and restoration effort, accompanied by an increasing knowledge of the pond farmers about sustainable aquaculture, is essential to achieve the coastal environment’s quality and economic improvement in Tambakbulusan. Additionally, further studies are required, particularly to increase knowledge of mangrove rehabilitation procedures along with maintaining species diversity in degraded mangrove ecosystems.

Conclusions. Based on the findings of this study, Tambakbulusan has a considerable potential for developing its mangrove ecosystem. The sustainable conservation effort for the Tambakbulusan mangrove community is essential, considering that eleven true mangrove species are included on the least concern (LC) of the IUCN Red List: *A. ebracteatus, A. ilicifolius, A. aureum, A. alba, A. marina, B. cylindrica, R. apiculata, R. mucronata, E. agallocha, X. moluccensis,* and *S. alba*. The water quality in the mangrove communities at each research site is relatively good and meets the national seawater quality threshold for marine biota. This study highlights the importance of protecting and preserving mangrove ecosystems while considering the species biodiversity. in addition, the integration of management and conservation efforts with sustainable aquaculture and the stakeholders' engagement might be a relevant solution in protecting and preserving the mangrove ecosystem in Tambakbulusan, Demak, Central Java.

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