Vol. 10(3): 400-416, September 2022

DOI: https://doi.org/10.23960/jsl.v10i3.596

Jurnal Sylva Lestari

P-ISSN: 2339-0913
E-ISSN: 2549-5747

Journal homepage: https://sylvalestari.fp.unila.ac.id

Full Length Research Article

The Mangrove Density, Diversity, and Environmental Factors as Important Variables to Support the Conservation Program of Essential Ecosystem Area in Muara Kali Ijo, Pantai Ayah, Kebumen

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ARTICLE HISTORY:

Received: 17 May 2022
Peer review completed: 18 June 2022
Received in revised form: 20 June 2022
Accepted: 15 August 2022

KEYWORDS:

Crocodylus porosus preservation
Essential ecosystem conservation
Mangrove zonation
Muara Kali Ijo
Wetland conservation

ABSTRACT

The planning of wetland essential ecosystem area (EEA) conservation and preservation activities is important to support ecosystem stability, including the mangrove ecosystem. These activities should consider the ecological, economic, and social aspects. This study aimed to analyze the indicator of the mangrove ecosystem to support the planning program of EEA conservation in Muara Kali Ijo, Pantai Ayah, Kebumen. The research method used the mapping and planning analysis of the EEA conservation program using the indicator of mangrove density, mangrove diversity, and environmental indicators. The results showed that mangrove density in Muara Kali Ijo was 1,500-4,300 trees/ha (moderate to very dense) and was dominated by *Rhizophora mucronata* and *Rhizophora styllosa*. The potential of total dissolved solids, water salinity, potential hydrogen, dissolved oxygen, biological oxygen demand, and nitrate had a good condition to support the mangrove's life and growth. The ecosystem essential planning also had activity to conserve and preserve the *Crocodylus porosus*. The planning of ecosystem essential was developed in 18.5 ha, divided into five zones: mangrove preservation area of 5.90 ha, mangrove utilization area of 6.40 ha, mangrove arboretum of 4.40 ha, mangrove rehabilitation area of 1.30 ha, and specific utilization area of 0.5 ha. The wetland EEA in Muara Kali Ijo has important value in preserving the area from coastal disaster and increasing economic value with tourism and other activities.

1. Introduction

The wetland essential ecosystem area (EEA) is a natural or artificial ecosystem to support the conservation of habitats, natural reservation, organism life, and social welfare. The EEA has several characteristics and aspects that are: (1) has important ecological or high conservation value consisting of mangrove area, karst, peatland, and inland water/wetland (lake, river, swamp, brackish water, tidal ecosystem), (2) has specific habitat and landscape including endemic habitats and the wildlife ecosystem, and (3) give resource backup including a botanical garden and forest park (Sahide et al. 2020; Yang et al. 2021). In addition, the EEA is developed to support the conservation of organism diversity or water quality, reduce water pollution, and support ecosystem services contributions and economic growth (Sahide et al. 2020; Yang et al. 2021).

The wetland EEA in Muara Kali Ijo, Pantai Ayah, Kebumen has a mangrove area of 28.41 ha. Based on the Central Java Governor Decision Letter Number 552.52/31 of 2020, 18.5 ha of the EEA in Muara Kali Ijo were built as a local protection area of beaches and estuaries (Tim Penyusun EEA Kali Ijo Kebumen 2020). The EEA in Muara Kali Ijo was developed to support and preserve the mangrove ecosystem, *Crocodylus porosus* preservation, and increase social income and welfare.

The EEA in Muara Kali Ijo aims to support the conservation of the mangrove ecosystem as an essential ecosystem in Pantai Ayah, Kebumen, because the mangrove ecosystem has a specific affinity (Hilmi et al. 2021e), specific environment (Hilmi et al. 2021a, 2022b; Xiong et al. 2018), specific habitat (Hilmi 2018; Hilmi et al. 2021d; Purnama et al. 2022), and specific ecosystem (Cochard 2017; Hilmi et al. 2015; Lapolo et al. 2018). In addition, the mangrove ecosystem in Muara Kali Ijo also has specific functions to reduce and protect tidal flooding (Hilmi et al. 2022a; Marois and Mitsch 2017) and permanent water inundation (Bomer et al. 2020), decreasing of coastal disasters (Cooray et al. 2021; Nur and Hilmi 2021), decreasing of heavy-metal pollution (Chen et al. 2021; Hilmi et al. 2017b; Syakti et al. 2013; Xin et al. 2014; Zhang et al. 2019), support carbon conservation (Hilmi 2017a), and support feeding, nursery dan spawning activity (Jones et al. 2015; Lapolo et al. 2018; Nurhayati et al. 2021; Reis et al. 2021). Besides, the mangrove ecosystem in Muara Kali Ijo is also used as a tourism area and *Crocodylus porosus* preservation (Tim Penyusun EEA Kali Ijo Kebumen 2020).

The stability of the mangrove ecosystem (using indicator density, diversity, and environmental condition) is a key variable in supporting EEA conservation activity in Muara Kali Ijo. The mangrove stability both of the mangrove density, diversity, and environmental factors are required to support the EEA conservation activities in Muara Kali Ijo, including supporting buffering, protecting, preserving, and developing social-economic activities and conserving *Crocodylus porosus* habitat (Giri et al. 2015; Hilmi et al. 2021b; Santos et al. 2016; Sari et al. 2016). The planning of EEA conservation in Muara Kali Ijo has many benefits, especially in conserving the coastal ecosystem and preserving the *Crocodylus porosus.* The planning of the EEA conservation program in Muara Kali Ijo also expects to support the people's income, economy, and social welfare. The novelty of this paper explains the concept of the wetland EEA conservation program to support mangrove conservation as the main ecosystem, which has the function of reducing coastal disaster impact, preserving protected animals, and supporting social activities. This research aimed to analyze the indicator of mangrove density, diversity, and environmental factors to support the planning of the EEA conservation program in Muara Kali Ijo.

2. Materials and Methods

2.1. Study Area

This research was conducted in the mangrove ecosystem area of Muara Kali Ijo, Pantai Ayah, Kebumen Regency, Central Java Province. The research stations were divided into two stations: (1) vegetation and environment station at 7° 42' 58"–7°43'14" south latitude and 109° 23' 17"–109° 23' 39" east longitude (**Table 1**) and (2) social-economic stations in Pantai Ayah at

7° 41’ 54” south latitude and 109° 23’ 17’’ east longitude (Tim Penyusun EEA Kali Ijo Kebumen 2020).

2.2. Methods

2.2.1. Sampling technique

This research was divided into three objects (following the concept of mangrove sampling) that were: (1) Mangrove density using cluster sampling with a transect method system (Cochran 1991; Hilmi et al. 2021c, 2021e) to analyze mangrove density and diversity, (2) environment variable using cluster sampling following mangrove transect (Hilmi et al. 2021c, 2021e) to analysis water and soil/substrates properties, and (3) social and economy using the stratified sampling techniques (Cochran 1991) to support analysis the wetland EEA conservation program planning. This research was also divided into two-stage research that was January-March 2022 to analyze mangrove density, diversity, and environmental properties and November 2021–February 2022 to support in-depth interview activity in the mangrove ecosystem of Muara Kali Ijo.

2.2.2. Mangrove sampling

The mangrove sampling used cluster sampling with the transect method system (Hilmi et al. 2021e; Kusmana, 1997) (**Table 1**). The mangrove ecosystem was divided into 4 stations that were (1) mangrove area ecotourism and utilization, (2) mangrove area preservation, (3) mangrove arboretum, and (4) mangrove rehabilitation area. The research stations follow the activity of the wetland EEA conservation program in Muara Kali Ijo. The sampling size to analyze mangrove ecosystems was 10 m × 10 m (mangrove tree), 5 m × 5 m (mangrove sapling), and 2 m × 2 m (mangrove seedling). The number of sampling plot of mangrove vegetation at each station were 10 plot mangrove samples. This study had 40 mangrove sampling plots.

Table 1. Research station of vegetation sampling

Stations	Station name	Latitude	Longitude
Station 1 (ST1)	Mangrove ecotourism and utilization area	-7.719324°	109.391699°
Station 2 (ST2)	Mangrove preservation area	-7.720502°	109.392634°
Station 3 (ST3)	Mangrove arboretum	-7.71944°	109.390724°
Station 4 (ST4)	Mangrove rehabilitation area	-7.71654°	109.388204°

2.2.3. Environment sampling

The environment sampling was required to analyze the mangrove suitability in Muara Kali Ijo. The environment sampling was conducted by cluster sampling following the mangrove vegetation sampling. The environment variables included (1) soil texture and (2) water quality with the related salinity, electrical conductivity (EC), pH, total dissolved solids (TDS), dissolved oxygen (DO), chemical oxygen demand (COD), and biochemical oxygen demand (BOD), and ammoniac (NH_3N) (Nusantara et al. 2015; Xiao et al. 2019; Xiong et al. 2018). The environment sampling was taken following the mangrove sampling. This analysis of environment variables used 20 sampling plots.

2.2.4. In-depth interview

In-depth interviews were conducted with the government of Ayah Village, Forest Village Community Organization or *Lembaga Masyarakat Desa Hutan* (LMDH) of Ayah Village, Community Evaluation Group or *Kelompok Masyarakat Pengawas* (Pokwamas), Forest Farmer Group or *Kelompok Tani Hutan* (KTH) Pansela, farmers, Sri Rejeki farmers, Tourism Awareness Group or *Kelompok Sadar Wisata* (Pokdarwis), Village-Owned Enterprises or *Badan Usaha Milik Desa* (*BUMDES*), fishermen of Logending, Pansela NGO, and facilitators with total respondents were 67 respondents (**Table 2**). The variables of the in-depth interview were (1) indicators of the Essential Ecosystem program, (2) the activity of mangrove conservation in the Ecosystem essential program, and (3) the activity of the wetland EEA conservation program following the concept and activity of mangrove conservation.

Table 2. Respondents of the in-depth interview in Pantai Ayah

No.	Respondent	Total	Role
1	Ayah Beach people	20	The community in Ayah village, and sampling technique using Following education stratification
2	Government of Ayah Village	3	The village head and staff
3	LMDH of Ayah Village	3	The public figure in Pantai Ayah
4	Forest Farmer Group Pansela	5	The community of mangrove activists in Pantai Ayah
5	Sri Rejeki farmers	5	The community of farmers in Pantai Ayah
6	Pokdarwis	3	The community for tourism activities
7	BUMDES	3	Village community business in Ayah Village
8	Fishermen group of Logending	6	The community of fishermen in Pantai Ayah
9	Pokwamas	5	Supervisory community group in Ayah Village
10	Facilitators from Forestry Service Branch (CDK VIII), Office of Housing, Settlement, and Environment of Kebumen (DPLH Kebumen), Office of Marine and Agriculture of Kebumen (DKP Kebumen), and Office of Tourism.	5	Facilitator
11	NGO pansela	3	NGO
12	Academician	2	IPB, UNSOED
13	Pers/media	1	Ratih TV/ Kominfo
14	Rescue Tagana	3	First aids community
	Total	67	

2.3. Data Analysis

2.3.1. Mangrove density and diversity

The mangrove density was calculated using Equation 1 (Cooray et al. 2021; Hilmi et al. 2021f; Xiong et al. 2018):

$$Tree\ density\ (tree/ha) = \frac{Number\ of\ trees\ (tree)}{Area\ (ha)} \quad (1)$$

The density of the tree having a diameter > 4 cm adopted a line transect method using a sampling plot of 10 m × 10 m. The classification of mangrove density followed Hilmi et al. (2019).

The domination index used the important value index (IVI) of mangroves was divided into Frequency relative, domination relative, and relative density (Hilmi et al. 2017a; Kusmana 1997). The diversity index used the Shanon Wiener analysis (Hilmi et al. 2015; Magurran 1996) as follows:

$$H' = \sum_{i=1}^{s} (pi)(log_2 pi) \quad (2)$$

where H' is Shanon Wiener index, Pi is the proportion of mangrove trees -i, and s is the number of species.

2.3.2. *Coastal and mangrove zoning*

The coastal and mangrove zoning in management of the EEA conservation program was conducted the conservation activity following the Decree of Central Java Governor Number 522.52/32/2019 regarding Collaboration Forum of EEA in Central Java) and Decree of Central Java Governor Number 552.52/31 of 2020 regarding Determination of EEA and Management of Mangrove Wetlands in Central Java (Tim Penyusun EEA Kali Ijo Kebumen 2020). The activities for arranging coastal zoning and mangrove conservation in wetland EEA were (1) the analysis expectation of respondents (%), (2) in-depth interview of the conservation activity in the EEA program, (3) breakdown of the area of the EEA program with mapping analysis.

2.3.3. *Mapping analysis*

The mapping analysis of the EEA conservation program was conducted by overlaying the EEA conservation program and coastal and mangrove landscape and developing the planning activity in the EEA conservation program. The mapping analysis of the EEA program used ArcGis software with an overlay system between the Landsat 2020, Google Earth, Kebumen administration map, and in-depth interview results.

3. Results and Discussion

3.1. *The Planning of Wetland EEA Conservation Program to Support Mangrove Conservation*

The planning of the wetland EEA conservation program in Muara Kali Ijo was to support mangrove conservation and *Crocodylus porosus* preservation. This program is shown in **Fig. 1** and **Table 3.** The wetland EEA conservation program had the supporting factors that were distribution and mangrove species domination (Hilmi et al. 2015, 2021e; Teh et al. 2008) and provided environmental services (Hilmi et al. 2017a; Hu et al. 2020), provided activity potentials (Owuor et al. 2019), performed enrichment, rehabilitation activities and protection of *Crocodylus porosus* habitat (Duncan et al. 2016; Hilmi et al. 2022b).

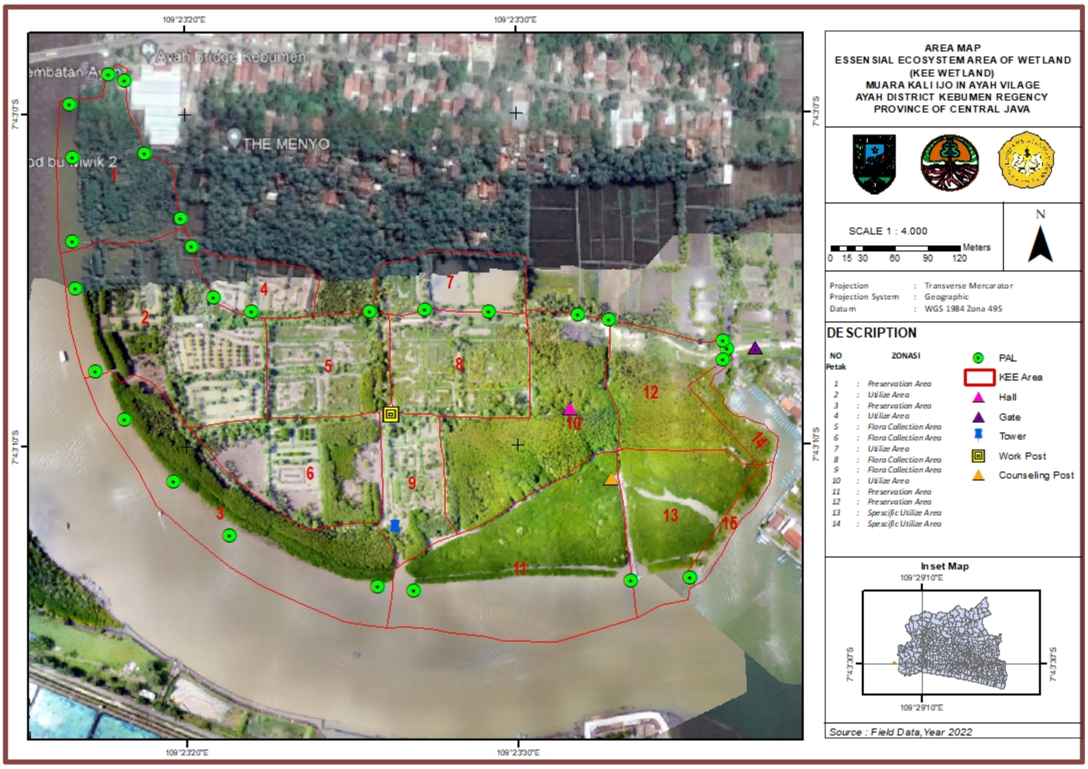

Fig. 1. The map of the wetland EEA conservation program in Muara Kali Ijo.

Table 3. The planning activity of the wetland EEA conservation program in Muara Kali Ijo

Area number	The mangrove conservation program	The planning area (ha)	The concept of an activity program in the EEA conservation
1	Mangrove Rehabilitation	1.3	Reducing waste contaminants, education tour of mangrove planting for students and the public, and *Crocodylus porosus* preservation
2	Utilization	6.4	Mangrove ecotourism, sylvofishery, non-timber forest product development, mangrove seed business
4	Utilization		
7	Utilization		
10	Utilization		
12	Utilization		
3	Preservation	5.9	Developing of the security area, developing of sign and prohibition board, conservation education and counseling, monitoring of mangrove ecosystem and wildlife, environmental law enforcement, and *Crocodylus porosus* preservation
11	Preservation		
13	Preservation		
5	Mangrove arboretum	4.4	Mangrove collection garden, mangrove field laboratory, a center for mangrove identification, research and development, and *Crocodylus porosus* preservation
6	Mangrove arboretum		
8	Mangrove arboretum		
9	Mangrove arboretum		
14	Specific utilization	0.5	Fishing boat landing
15	Specific utilization		

The activities of the wetland EEA conservation program in Muara Kali Ijo were divided into four activities, including mangrove rehabilitation (1.3 ha), mangrove utilization (6.4 ha), and mangrove preservation (5.9 ha), and specific utilization (0.5 ha). The planning activities to support the wetland EEA conservation program in Muara Kali Ijo were reducing waste contaminant, education on mangrove planting, mangrove ecotourism, sylvofishery, non-timber forest product development, mangrove planting business, developing of the security area, developing of sign and prohibition board, conservation education and counseling, monitoring of mangrove ecosystem and wildlife, environmental law enforcement, mangrove collection garden, mangrove field laboratory, the center of mangrove identification, research and development, and a fishing boat program. The wetland EEA conservation program has been implemented well and positively impacts the stability of the mangrove ecosystem.

The mangrove conservation activity was an important activity to support the success of the wetland EEA conservation program in Muara Kali Ijo. The mangrove conservation activities are presented in **Table 4.** The best choice of mangrove conservation activities was mangrove greenbelt (32%), mangrove arboretum (24%), and mangrove utilization and ecotourism (17-18%). The wetland EEA conservation program had an activity to increase ecosystem services, reduce coastal disasters, and increase community empowerment

Table 4. Mangrove conservation and preservation in the wetland EEA conservation program

No	The mangrove conservation program	Percentage expected of the respondent (%)	Area (ha)	The conservation activity in the wetland EEA conservation program
1	Mangrove ecotourism	17	3.4	Sustainable ecotourism services from the mangrove ecosystem
2	Mangrove rehabilitation	7	1.3	The mangrove replanting and rehabilitation are developed to reduce the impact of coastal disasters and *Crocodylus porosus* preservation
3	Coastal rehabilitation	3	0.5	Rehabilitation and development of the coastal area with mangrove planting to reduce the impact of coastal degradation and *Crocodylus porosus* preservation
4	Mangrove arboretum	24	4.4	This activity aims to increase mangrove diversity, especially species richness and species abundance
5	Mangrove greenbelt	32	5.9	Developing a mangrove greenbelt to reduce the impact of coastal disaster and *Crocodylus porosus* preservation
6	Mangrove utilization	18	3	Improving and increasing the quality and quantity of community empowerment

The wetland EEA conservation in Muara Kali Ijo used *Rhizophora mucronata*, *Nypa frutican*, *Avicennia alba,* and *Sonneratia caseolaris* as the best mangrove species to support people's activities. Meanwhile, *Acronticum aureum Achantus ilicifolius*, *Lagerstroemia spesiosa*, *Calophylum inophyllum*, *Cerbera manghas*, *Derris trifoliata*, *Hibiscus tiliaceus,* and *Terminalia catappa* were rarely used for peoples life.

The wetland EEA conservation program in Muara Kali Ijo also had a program to rehabilitate the habitat of Pisces, Mollusca, Crustaceaae, and Aves. The potential Pisces in wetland EEA of Muara Kali Ijo were *Periophthalmus* sp., *Glossogobius circumpectus*, *Mystus nigriceps*, and *Chanos chanos*. Meanwhile, the commonly found mollusca included *Cassidula aurisfelis* and *Telecopium Telescopium*. The commonly found crustaceaae included *Uca* sp., *Scylla* sp., and *Macrobranchium rosenbergii*. In contrast, the commonly found aves included *Butorides striata, Egretta intermedia, Centropus sinensis*, *Tyto alba*, *Streptopelia chinensis*, *Collocalia esculenta*, *Caprimulgus affinis*, *Acridotheres javanicus*, *Halycon chloris*, *Halycon cyaniventris, Actitis hypoleucos*, *Amaurornis phoenicurus,* and *Nycticorax nycticorax*. Furthermore, the potential of mammals in the wetland EEA of Muara Kali Ijo included *Felis bengalensis, Paradoxurus hermaphrodites, Herpestes javanicus,* and *Aonyx ciereus*. Besides, the reptiles in the wetland EEA of Muara Kali Ijo consisting *Carettochelys insculpta*, *Ahaetulla prasina*, *Phyton reticulatus, Boiga dendrophila*, *Varanus salvator,* and *Crocodylus porosus*.

The wetland EEA conservation program in Muara Kali Ijo had a vision of "implementing the sustainable and fair management of mangrove EEA in Muara Kali Ijo for people's welfare" gave positive impact on conserving and preserving the habitat of saltwater crocodile (*Crocodylus porosus*) as an animal of Appendix II CITES. Thus, the EEA activities had intensive activity to conserve the existence of *C. porosus*. The wetland EEA of Muara Kali Ijo also had activities to increase social income and welfare.

3.2. The Indicators of Density, Diversity, and Environmental Factors

3.2.1. The physical and chemical environment

The environmental factors of the mangrove ecosystem in Muara Kali Ijo are presented in **Table 5.** The data in **Table 5** showed that the mangrove ecosystem in Muara Kali Ijo had (1) soil texture of sandy clay, (2) potential water pH between 7.38-8.03, (3) water salinity between 0.6–19.6 ppt, (3) electrical conductivity (EC) between 1222–31685 µS/cm, (4) total dissolved solids (TDS) between 795–20585 mg/l, (5) chemical oxygen demand (COD) between 9.77–82.5 ppm, (6) biochemical oxygen demand (BOD) between 2.12–18.6 ppm, (7) dissolved oxygen (DO) between 3.09–6.45 ppm, and (8) ammoniac (NH_3N) between 0.0012–0.1108 ppm.

Table 5. The environmental factor of the mangrove ecosystem in Muara Kali Ijo

Location	Soil texture	Water quality							
		pH	Salinity (ppt)	EC (µS/cm)	TDS mg/l	COD (ppm)	BOD (ppm)	DO (ppm)	NH_3N (ppm)
Ecotourism and mangrove utilization area	Sandy-clay	7.38-7.55	2-3.6	3812-6690	2479-4357	9.77-35.8	2.12-5.87	3.09-3.40	0.0012-0.0637
Mangrove preservation area	Sandy-clay	7.36-8.03	0.6-5.3	29.2-30.1	795-7333	12.2-23.5	3.71-3.99	3.28-6.45	0.098-0.1033
Mangrove rehabilitation area	Sandy-clay	7.73-8	12.9-19.6	21640-31685	14070-20585	59.6-82.5	12.11-18.6	4.33-5.33	0.0754-0.0814
Mangrove arboretum	Sandy-clay	7.53-7.98	4.9-19.4	8790-31455	5715-20455	16.1-75.8	3.35-14.5	3.04-4.88	0.085-0.1108

Notes: pH on-site (SNI 6989.11:2019), COD (SNI 6989.2:2019), BOD_5 (SNI 6989.72:2009), DO in the lab (SNI 06.6989.14-2004), NH_3-N (SNI 06.6988.30-2005), TDS (Conductor TDS meter), EC (SNI 6989.1:2019), Salinitas (hand refractometer).

Temperature is an important indicator to support organisms living in the mangrove ecosystem. The potential temperature in the mangrove ecosystem Muara Kali Ijo was 29.2–31.3°C and classified as a normal condition according to Government Regulation Number 82 of 2001 and has a positive impact on organism life and growth (Domínguez-Domínguez et al. 2019; Hilmi et al. 2015, 2021c; Kusmana and Maulina 2015; Yanuartanti et al. 2015).

Potential pH showed the acidity level of liquid substance and significantly influenced water quality and water biota/organism life. The pH value in Muara Kali Ijo was approximately 7.36-8.03 and classified into normal condition (good category) to Government Regulation Number 82 of 2001. Mangrove ecosystem can grow well between 5.00-8.00 (Domínguez-Domínguez et al. 2019; Kusmana and Maulina 2015; Yanuartanti et al. 2015). The potential pH in Muara Kali Ijo was different from the pH in North Jakarta, which had a pH of between 5.0-6.4 (Hilmi et al. 2022b), and in Segara Anakan was between 5.85-7.05 (Hilmi et al. 2021a).

Water salinity is a limiting factor for the stratification of water organism distribution vertically and horizontally. The salinity distribution patterns in mangrove zones were influenced by the movement and mixing processes of water material (Hilmi et al. 2021d; Yin et al. 2018; Ysebaert et al. 2016). The salinity was approximately 0.6-19.6 ppt (good category) according to Government Regulation Number 82 of 2001. Mangroves can live a good life on the potential salinity between 6.0-7.5 ppt (Hilmi et al. 2021a). The salinity potential in Segara Anakan was between 18 -31.0 ppt in water and 5.21-7.05 ppt in groundwater (Hilmi et al. 2021a). Salinity showed that the dissolved salt ion level in seawater influenced the osmoregulation processes of marine organisms. Salinity also will influence the oxygen solubility and biological decomposition speed in the mangrove ecosystem (Henmi et al. 2017; Soares et al. 2018).

The potential of COD shows the amount of oxygen required to chemically oxidize all organic materials using a strong oxidizing agent (Abdelhakeem et al. 2016; Alam et al. 2021). The mangrove ecosystem in Muara Kali Ijo had a COD level between 9.77-82.5 mg/l. The high COD occurred in the rehabilitation zone, fishpond area, and covering of nipah plants. The potential of lower COD in another area occurred because of the potential of garbage and waste from market activities and fishing activities.

The potential of BOD is defined as the amount of oxygen required by microorganisms to decompose the organic materials and nitrogen compounds. The amount of oxygen microorganisms require depends on the number and types of organic materials. The parameter of BOD can be used to analyze DO levels caused by the decomposition of organic materials from domestic waste (Abdelhakeem et al. 2016; Kagalkar et al. 2011). The mangrove ecosystem in Muara Kali Ijo had BOD between 2.12-18.6 mg/l.

The potential of DO is required for the living respiration and oxidation process in the aquatic ecosystem. The other function of oxygen was an indicator of chemical compounds in the water. Based on the data, the DO level in the mangrove ecosystem of Muara Kali Ijo is between 3.04-6.45 mg/l. The highest oxygen level occurred in the preservation area (6.45 mg/l) and was used as the animal habitat zone, seed source, research, education, and green belt. In contrast, the arboretum zone had the lowest DO (3.04 mg/l) due to the zone location being close to the fishpond area and farming activities. The higher DO potential in the water shows the higher fertility of the aquatic ecosystem (Bouillon et al. 2008; Smiley and Trofymow 2017; Zhang et al. 2021).

The last indicator is the potential ammoniac as a matter dissolved from the decomposition of organic materials and oxygen activity (Wang et al. 2018; Yin et al. 2018). The highest ammoniac concentration had impacts on decreasing DO and the aquatic organism's physiological and metabolic function, including respiration activity. The ammonic level in the mangrove ecosystem in Muara Kali Ijo was between 0.0012-0.1108 ppm. The highest concentration occurred in the plant collection zone because it was used for fishpond and farming activities.

3.2.2. The indicators of mangrove density and diversity

3.2.2.1. Mangrove density

Mangrove density covering mangrove trees, saplings, and seedlings is shown in **Table 6**, **Table 7**, and **Table 8.** The mangrove ecosystem in Muara Kali Ijo had a density of between 1500 (moderate) – 4830 (very dense). The data presented in **Table 6** also described that *Rhizophora apiculata* and *Rhizophora mucronata* were the most dominant. However, *Avicennia marina* and *Sonneratia alba* were co-dominant, while *Ceriops tagal, Bruguiera gymnorrhiza,* and *Rhizophora styllosa* had the lowest density. The number of species found in the tree and sapling category had 8 species, while the seedling category had 6 species.

Table 6. The mangrove trees density in Muara Kali Ijo

Mangrove species	**Important value index (IVI)**				**Density (tree/ha)**			
	ST1	**ST2**	**ST3**	**ST4**	**ST1**	**ST2**	**ST3**	**ST4**
Rhizophora mucronata	241.1	91.5	63.1	132.7	1580	500	400	1900
Rhizophora apiculata	58.9	0	21.1	16	2800		100	200
Avicennia marina	0	124.9	42.6	31.5		800	400	400
Ceriops tagal	0	0	63.2	0			100	
Soneratia alba	0	83.6	83.7	0		200	700	
Bruguiera gymnorhiza	0	0	26.3	0			200	
Rhizophora stylosa	0	0		119.8				1700
Total					4830	1500	1900	4200
Classification					Very dense	Mode rate	Dense	Very dense

Table 7. The mangrove sapling density in Muara Kali Ijo

Mangrove species	**Important value index (IVI)**				**Density (tree/ha)**			
	ST1	**ST2**	**ST3**	**ST4**	**ST1**	**ST2**	**ST3**	**ST4**
Rhizophora mucronata	151.6	114.2	34.5	91.3	63200	65200	29200	30400
Rhizophora apiculata	48.4	55.9	22.2	0	11200	21200	5600	
Avicennia marina	0	29.9	23.6	0		7200	14000	
Aegiceras cornilatum	0	0	49.1	0			43200	
Avicennia alba	0	0	4.8	0			400	
Bruguiera gymnorhiza	0	0	45.9	0			38800	
Soneratia alba	0	0	15.1	0			8400	
Rhizophora stylosa	0	0	4.8	108.7			400	
Total					74400	93600	140000	734600

The density of the mangrove ecosystem found in the research location had a potential between 200-2,800 trees/ha for the tree category, 400-65,200 trees/ha for the sapling category, and 5,000-67,500 trees/ha for the seedling category. The potential of mangrove species found in Muara Kali Ijo was still lower than the mangrove ecosystem in Segara anakan (Hilmi et al. 2021c). The mangrove species in Segara anakan included *Aegiceras corniculatum, Avicennia alba, A. marina, A. officinalis, Bruguiera gymnorrhiza, B. parviflora, B. sexangula, Callophylum inophylum, Carbera manghas, Ceriops decandra, C. tagal, Rhizophora apiculata, R. mucronata, R. stylosa,* *Sonneratia alba, S. caseolaris, Tespia pulpunea, Terminalia cattapa, Xylocarpus granatum,* and *X. moluccensis* with the density of 166-4000 trees/ha (East Segara Anakan), 133-3000 trees/ha (West Segara Anakan), and 220-1100 trees/ha (North Jakarta Beach) (Hilmi et al. 2021c, 2022a).

Table 8. The mangrove seedling density in Muara Kali Ijo

Mangrove species	Important value index (IVI)				Density (tree/ha)			
	ST1	ST2	ST3	ST4	ST1	ST2	ST3	ST4
Rhizophora mucronata	185.3	200	83.4	158.3	67500	5000	17500	7200
Rhizophora apiculata	14.7	0	0	0	2500			
Avicennia marina	0	0	0	0				
Ceriops tagal	0	0	69	0			12500	
Bruguiera gymnorhiza	0	0	47.6	0			5000	
Rhizophora stylosa	0	0	0	41.7				2000
Total					70000	5000	35000	9200

The potential of mangrove seedlings and saplings describes the potential of mangrove generation in Muara Kali Ijo. The data presented in **Table 5** and **Table 6** show that the potential of mangrove regeneration in Ayah Village was classified as moderate. However, the potential of species diversity for the regeneration system in the mangrove ecosystem was only dominated by *R. mucronata* and *R. apiculata*.

The highest mangrove tree density occurred in the utilization zone, reaching an average of 4,830 trees/ha and being used for mangrove tourism activities, sylvofishery, mangrove seedling business, and utilization of non-wood forest products. The highest mangrove saplings in Muara Kali Ijo occurred in the plant collection zone, reaching an average of 140,000 trees/ha, and used as arboretum, plant collection, buffer, or support for the reproduction sustainability of diverse animals living in the protection zone. And the highest mangrove seedling density occurred in the utilization zone, reaching an average of 70,000 trees/ha. The potential data on mangrove density showed that the mangrove ecosystem in Muara Kali Ijo is regenerating (Hilmi et al. 2015; Nur and Hilmi 2021). Mangrove density, domination, and regeneration of mangrove species have a positive impact on the potentials of plankton (Andriyani et al. 2020; Hilmi et al. 2020), other micro and macro-organisms (Su et al. 2012; Yin et al. 2018), land animal habitats, other organisms, and birds (Putra et al. 2019; Wolswijk et al. 2020).

3.2.2.2. Mangrove diversity

Mangrove diversity covering mangrove trees, saplings, and seedlings is shown in **Table 9**. The data showed that the mangrove density in the mangrove ecosystem of Muara Kali Ijo was lower in abundance and diversity because the mangrove ecosystem in Muara Kali Ijo only was dominated by *R. mucronata* and *R. apiculata*. Meanwhile, the dominant species in Muara Kali Ijo is different from the mangrove ecosystem in Segara Anakan. The mangrove ecosystem in Segara Anakan is dominated by *Nypa frutican*, *R. stylosa, R. apiculata, A. corniculatum, S. alba,* and *A. marina* (moderate) (Hilmi et al. 2021c). Furthermore, North Jakarta Beach is dominated by *A. marina, R. mucronata,* and *R. stylosa*. Hilmi et al. (2015) also explained that *Avicennia* spp. and *Sonneratia* spp. were dominant in West Segara Anakan, while *R. apiculata, N. fruticans,* and *A. corniculatum* were the dominant species in East Segara anakan.

Table 9. The mangrove diversity in Muara Kali Ijo

Growth stage	Station							
	S1	Status	S2	Status	S3	Status	S4	Status
Trees	0.4236		0.9701		1.5709		1.0938	
Sapling	0.4204	Low	0.7855	Low	1.6067	Low	0.6444	Low
Seedling	0.1541		0		0.4755		0.5236	

Based on the data in **Table 9**, the diversity index of mangrove vegetation in Muara Kali Ijo had the lowest category (Magurran 1996) because it had a value between 0.42-1.57 (mangrove e trees category), 0.42-1.61 (mangrove sapling category), and 0.15-0.52 (mangrove seedling category). The highest diversity value occurred in the mangrove arboretum, reaching 1.61, and was classified into the moderate category and used as the mangrove plant collection park. Meanwhile, the lowest diversity was in the mangrove tourism area. The mangrove plant diversity will show the potential of abundance, wealth, and even distribution of mangrove species had a high correlation with the stability level of the mangrove ecosystem (Hilmi et al. 2019; Sreelekshmi et al. 2018; Yanuartanti et al. 2015).

4. Conclusions

The wetland EEA conservation program in Muara Kali Ijo has many activities, such as protection, preservation, rehabilitation, collection, utilization, and preservation of animal habitats, especially saltwater crocodile (*Crocodylus porosus*) as an animal of Appendix II CITES. The wetland EEA in Muara Kali Ijo is composed of *Rhizophora apiculata* and *Rhizophora mucronata* as dominant species, *Avicennia marina* and *Sonneratia alba* as co-dominant species, while *Ceriops tagal, Bruguiera gymnorrhiza,* and *Rhizophora styllosa* have the lowest density.

Acknowledgments

The authors express gratitude to Graduate Program Universitas Jenderal Soedirman, Office of Marine and Agriculture of Kebumen (DKP Kebumen), Faculty of Fisheries and Marine Science Universitas Jenderal Soedirman, Faculty of Animal Husbandry, Universitas Jenderal Soedirman, and Institute for Research and Community Services (LPPM) Universitas Jenderal Soedirman for providing research grant (*Hibah Riset Institusi 2022*). The authors also appreciate anonymous reviews for significantly improving this paper.

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