Biodiversity and Conservation (2024) 33:875–903
https://doi.org/10.1007/s10531-023-02767-9

REVIEW PAPER

A review on the biodiversity and conservation of mangrove ecosystems in Indonesia

Rahman[1] · Frijona F. Lokollo[1] · Gratia D. Manuputty[1] · Ronald D. Hukubun[1] · Krisye[1] · Maryono[2] · Mintje Wawo[3] · Yusli Wardiatno[4]

Received: 4 March 2023 / Revised: 8 December 2023 / Accepted: 13 December 2023 /
Published online: 7 February 2024

Abstract
This study was conducted to analyze the biodiversity of mangrove species and fauna in Indonesia as well as the management strategies for its preservation. The results showed that the total number of mangrove species was 240, consisting of 48 true and 192 associated mangrove. This number also comprised 74 trees, 36 shrubs, 52 herbs, six palms, 43 epiphytes, 23 lianas, three ferns, and three parasite species. *Aglaia mackiana* was identified as a new record in the Papua region attributed to the New Guinea Coastal Current (NGCC), while *Ceriops australis* was newly found in regions of Papua, Bali—Nusa Tenggara (Timor, Flores, Sumbawa), Java, and Sumatra (Pulau Bilinton). The diversity of marine fauna in the mangrove area consisted of 125 fish species from 47 families and 169 macrozoobenthos from 52 families. In addition, there were 161 terrestrial faunas, consisting of 80 birds, 38 squamata, four crocodiles, six amphibians, 11 testudinate, and 21 mammal species. This high level of biodiversity was influenced by the commitment of the Indonesian government to managing mangrove ecosystems through conservation. These efforts were carried out to preserve and improve ecosystem services such as mangrove biodiversity, carbon stock potential, coastal protection, and the unique biodiversity of marine and terrestrial fauna. Based on the results, incredibly unique fauna included Crocodilus found in Papua, Kalimantan, Java, and Sumatra region, *Halcyon* sp. in Papua and Java region, *Anhinga* sp. in Kalimantan and Java region, as well as *Nasalis larvatus* in Kalimantan.

Keywords Biodiversity · *Aglaia mackiana* · *Ceriops australis* · Conservation · Ecotourism · True Mangrove

Introduction

Mangrove ecosystems are a group of trees and shrubs thriving in habitats shaped by tides, sharing similar morphological and physiological adaptations (Kathiresan and Bingham 2001). These coastal ecosystems hold significant economic, physical, and ecological value for humans (Bengen et al. 2022; Rahman et al. 2020a).

Communicated by Anurag Chaurasia.

Extended author information available on the last page of the article

Indonesia has a large area of mangrove ecosystems, with the Ministry of Environment and Forestry (2021) reporting a coverage of 3.36 million ha, which constitutes 23.1% of the global total mangrove area and 59.8% of the area in Southeast Asia. The country also possesses a very high biodiversity of mangrove species (flora) as reported by Soemodihardjo et al. (1993) which found 157 species of mangrove consisting of 52 trees, 21 shrubs, 13 liana, seven palm, 14 grass, eight herbs, three parasites, 36 epiphytes, and three fern. Meanwhile, Kusmana (2014) stated that the number of mangrove species reached 158, consisting of 89 trees, five palms, 19 lianas, 44 herbs, and one fern.

Several studies on mangrove in Indonesia have been carried out in various places, specifically for flora and fauna diversity (Rahman et al. 2020a). Some other studies have been conducted on fauna biodiversity in Halmahera as a health bioindicator (Abubakar et al. 2022), Youtefa Bay Tourism Park, Papua (Sari et al. 2022), and in Indonesia (Zahdi 2022). However, these studies, though valuable, remain partial, and do not provide a comprehensive overview of mangrove ecosystems along the coastal areas of Indonesia.

The mangrove ecosystems in Indonesia have a high diversity of marine and terrestrial fauna distributed along the coastal areas (Yudha et al. 2021), but the types and numbers in the seven major regions, including Papua, Maluku Islands, Bali—Nusa Tenggara Islands, Sulawesi, Kalimantan, Java, and Sumatra (Arifanti et al. 2021), remain unknown. To address these gaps, detailed studies should be conducted in each of these regions to produce data that can be inventoried. Each region represents unique mangrove ecosystems found in coastal areas on the mainland and small islands. Several of these areas face degradation caused by timber extraction and land conversion into fishponds, settlements, and public infrastructure (Ilman et al. 2016; Rahman et al. 2020b) resulting in reduced mangrove area, density, and diversity (Rahman et al. 2019).

Management efforts have been undertaken in various regions, one of which is conservation. Information regarding how conservation strategies are implemented and their impact on the existence of mangrove flora and fauna biodiversity is still limited. Therefore, this study aimed to determine mangrove biodiversity and its conservation in Indonesia. The results are expected to become a scientific basis for the Indonesian government in achieving sustainable management based on biodiversity conservation.

Methods

Literature search and review

Literature searches on mangrove species distribution were conducted within 5 years, from September 2017 to January 2023. The collected literature were related to data on the structure and distribution of mangrove communities in seven major areas within Indonesia (Fig. 1). Each region was represented by 30 to 60 mangrove habitats from the mainland and small island coastal areas. The searches were carried out on Google Scholar, Science Direct, springer, and research gate databases with the keywords “mangrove community structure”, “mangrove identification”, “mangrove ecosystem conditions”, “mangrove vegetation”, “mangrove biodiversity”, “mangrove association” and “mangrove composition”. A total of 261 articles were collected, including two books providing insights into mangrove distribution in Indonesia. The total articles obtained are classified in each region based on the year published, namely 2001–2005, 2006–2010, 2011–2015, 2016–2020, and > 2020

Fig. 1 Seven major regions as representative of mangrove distribution in Indonesia

(Fig. 2). Detailed information on some of the main articles published after > 2016 is presented in Table 1.

Information about mangrove types in each literature was presented in the distribution table in each region and classified based on criteria (true or associate mangrove) and flora habitus (tree, shrubs, herbs, palm, epiphyte, lianas, fern, and parasites). According to Wang et al. (2010), true mangrove comprises halophytes (tolerant of high salt levels), while associates include glycophytes (only tolerates certain salt concentration levels).

The exploration of fauna diversity was carried out within three years, from August 2020 to February 2023. The keywords used in the search included "fish diversity in mangrove", "macrozoobenthos diversity", "fauna in mangrove ecosystems", as well as other keywords tailored to the objectives of the study. A total of 50 articles were collected including one

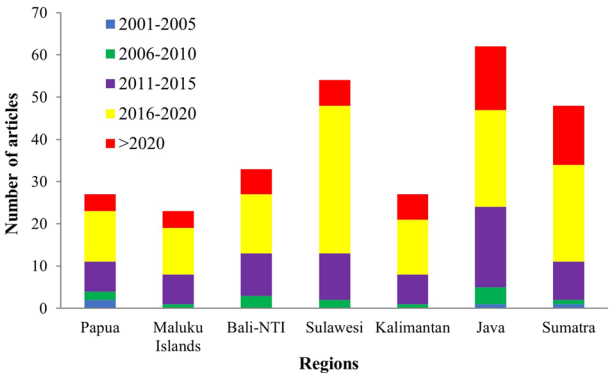

Fig. 2 Number of articles on mangrove diversity in 2001–2023 in Indonesia

Table 1 Main references related to studies on mangrove diversity (2016–2023) by region in Indonesia

Regions	2016–2020	> 2020
Papua	Warpur (2016); Mayor et al. (2017); Hamuna and Tanjung (2018); Hamuna et al. (2018); Lekito and Tambing (2018); Schaduw (2019); Heatubun et al. (2019); Sunarni et al. (2019); Wanaputra and Poedjirahajoe (2019); Dharmawan and Pramudji (2020); Pannell et al. (2020)	Marasabessy et al. (2021); Nurdiansah and Dharmawan (2021); Samori et al. (2021); Setyadi et al. (2021); Divinubun et al. (2022)
Maluku Island	Akbar et al. (2016); Madiama et al. (2016); Tolangara and Ahmad 2017); Akbar et al. (2017); Tahir et al. (2017); Akbar et al. (2018); Baksir et al. (2018); Lewerissa et al. (2018); Abubakar et al. (2019); Sipahelut et al. (2020);Tuasikal (2020)	Gabi et al. (2021); Namakule and Melsasail (2021); Suyadi and Sitepu (2021); Sabar et al. (2022)
Bali Nusa Tenggara Island	Imran and Efendi (2016); Anwar and Mertha (2017); Imamsyah (2017); Palguna et al. (2017); Zamroni (2017); Andikam et al. (2019); Aminuddin and Sunarto (2019Irwansah and Mahajoeno (2019); Japa and Santoso (2019); Rizal (2019); Seran (2019); Sani et al. (2019); Prinasti et al. (2020); Ronavia et al. (2020)	Farista and Virgota (2021); Janiarta and Safnowandi (2021); BKKPN – Kupang (2022); Dewi and Maharani (2022); Lestariningsih et al. (2022); Rahmani et al. (2023)
Sulawesi	Baderan (2016); Hartati 2016); Osmar (2016); Sasauw et al. (2016); Annisa et al. (2017); Anthoni et al. (2017); Arifin (2017); Baderan (2017); Haerul (2016); Lisna and Toknok (2017); Ndede et al. (2017); Paruntu et al. (2017); Rahim et al. (2017); Saman (2017); Saru et al. (2017) Auliyah and Blongkod (2018); Djamaluddin (2018a, b); Momo and Rahayu (2018); Rahim et al. (2018); Schadaw (2018); Setiawan and Mursidin (2018); Syahrial (2018); Baderan (2019); Djamaluddin et al. (2019); Jacobs et al. (2019); Opa et al. (2019); Rahman et al. (2019); Rahim and Baderan (2019); Saru et al. (2019); Asman et al. (2020); Babo et al. (2020); Naharuddin (2020); Rahman et al. (2020a); Rahman et al. (2020b)	Ruruh and Ernikawati (2021); Situmorang et al. (2021); Makawaehe et al. (2022); Moha et al. (2022); Yunus et al. (2020); Daud et al. (2023)
Kalimantan	Dekky and Wardoyo (2016); Khairuddin (2016); Irpan et al. (2017); Prastomo et al. (2017); Ratnasari and Dirhamsyah (2017); Wantoro et al. (2017); Warsidi and Endayani (2017); Marini and Nurrahman (2018); Arifanti et al. (2019); Kuncoro et al. (2019); Meidiana and Apriansyah (2019); Muharamsyah et al. (2019); Rumalean et al. (2019); Hadinata et al. (2020)	Setiawan et al. (2021); Yasser et al. (2021); Wantoro et al. (2021); Khaliza and Abdunnur (2022); Putra et al. (2022); Rafdinal et al. (2022); Rifanjani et al. (2022); Tony et al. (2022); Zuswiryati et al. (2022)

Table 1 (continued)

Regions	2016–2020	> 2020
Java	Agustini et al. (2016); Kusmana and Ningrum (2016); Noveliyana (2016); Renta et al. (2016); Siska (2016); Ula and Suhadi (2016); Acik and Sumardji (2017); Amaliyah (2017); Buwono (2017); Martuti (2017); Martuti et al. (2018); Poedjirahajoe et al. (2017); Pribadi et al. (2017); Setiawan and Mursidin (2018); Syahrial et al. (2017); Ali and Sulistiono (2018); Susanto et al. (2018); Mughofar et al. (2018); Rahayu and Syuhriatin (2018); Ashari et al.(2019); Batoro (2019); Hariyanto et al. (2019); Khorimatun et al. (2019); Oni et al. (2019); Tefarani et al. (2019); Nopiana et al (2020)	Hakim et al. (2021); Ilana and Cintamulya (2021); Kresnasari and Gitarama (2021); Rofi'I et al. (2021); Sukmarani et al. (2021); Ajiningrum and Dewangga (2022); Farid et al. (2022); Darmarini et el. (2022); Hakim (2022); Hapsari et al. (2022); Sari and Pratama (2022)); Pratiwi et al. (2022); Ulyah et al. (2022); Efriyeldi et al. (2023); Kurniawansyah et al. (2022)
Sumatra	Hanggara (2016); Karnanda et al. (2016); Mariati (2016); Parmadi et al. (2016); Rizwany and Yunasfi (2016); Theresia (2016); Umroh and Sari (2016); Onrizal and Afifuddin (2016); Zamdial (2016); Awn (2017); Hutasoit and Melki (2017); Mendrofa (2017); Rivilgo et al. (2017); Sitinjak (2017); Siringoringo et al. (2017); Febriansyah et al. (2018); Pratama (2018); Suryani (2018); Syahrial et al. (2018); Akhrianti et al. (2019); Zamdial and Johan (2019); Alvareza and Leilani (2020); Sarnubi et al. (2020)	Eni (2021); Jufia et al. (2021); Putra et al. (2021); Wiryono et al. (2021); Anita et al. (2022); Halim et al. (2022); Komalasari et al. (2022); Octavina et al. (2022); Siahaan et al. (2022); Hasyim et al. (2022); Syarif et al. (2022); Utami (2022); Yoswaty et al. (2022); Ardiansyah et al. (2023)

book, and family classifications were grouped into two main categories: "fishes" and "macrozoobenthos".

The same digital databases were also used to obtain data on the management of mangrove ecosystems in Indonesia. The keywords used were "mangrove ecosystem management", "mangrove ecosystem conservation", "mangrove management", and "mangrove conservation".

The literature review also focused on how mangrove conservation efforts were carried out and the impact on biodiversity in each region. Management practices that successfully preserved biodiversity will be reconstructed as a reference for other regions.

Result and discussions

Mangrove distribution

Indonesia has a very high diversity of mangrove flora, with the literature review results showing a total number of 240 species, consisting of 48 true and 192 associated mangrove (Fig. 3). The region with the most diverse flora was Java, with 180 species of 42 true and 138 associated mangrove. On the other hand, the region with the most minor diversity was the Maluku Islands, with 145 species of 36 true and 109 associated mangrove. These results can be attributed to the fact that mangrove exploration in Java was more intense than in eastern Indonesia, such as Papua and Maluku (Table 1). However, mangrove extent in Papua has greater potential for diversity than other regions with an area of 1.63 million hectares (50.37%), while Java has only 0.034 million hectares (1.06%) of the total mangrove area in Indonesia (MoEF 2021).

The diversity in this study was greater than that of Soemodihardjo et al. (1993) and Kusmana (2014), stating that Indonesia has 157 and 202 mangrove species. The higher value was because the data analyzed in this study covered almost all regions in Indonesia, from the mainland to the coast of remote islands.

The diversity of mangrove flora habitus on the Indonesian coast consisted of 74 trees, 36 shrubs, 52 herbs, six palms, 43 epiphytes, 23 lianas, three ferns, and three parasites (Table 2). This category differed from the report of Soemodihardjo et al. (1993), who reported species such as 52 trees, 21 shrubs, 13 lianas, seven palms, 14 grasses, eight

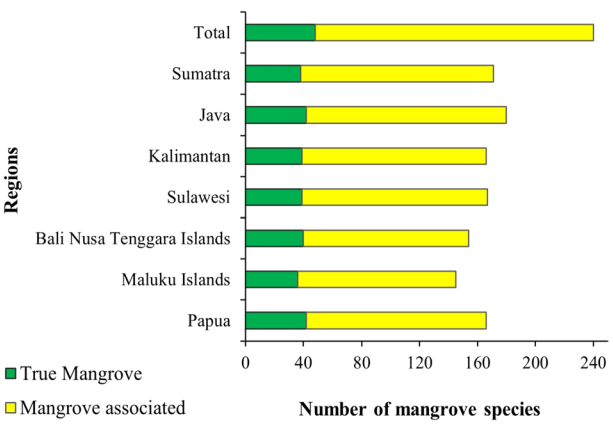

Fig. 3 The number of mangrove species by type in the region of Indonesia

Table 2 Distribution of mangrove species by region in Indonesia

Regions	Tree	Shrubs	Herbs	Palm	Epiphyte	Lianas	Fern	Parasites	Total
Papua	53	25	34	3	26	20	2	3	166
Maluku Islands	54	20	25	4	22	16	3	1	145
Bali Nusa Tenggara Islands	53	26	30	2	25	14	2	2	154
Sulawesi	57	27	39	2	23	14	3	2	167
Kalimantan	54	21	34	5	31	16	3	2	166
Jawa	60	26	43	3	29	14	2	3	180
Sumatra	56	21	35	4	30	22	2	1	171
Indonesia	74	36	52	6	43	23	3	3	240

herbs, three parasites, 36 epiphytes, and three species of fern. In addition, Kusmana (2014) stated that the number of mangrove species in Indonesia had reached 157, consisting of 89 trees, five palms, 19 liana, 44 herbs, and one fern. The distribution of mangrove species by type and classification is presented in supplementary files.

True mangrove

The diversity of true mangrove comprised 48 species consisting of 34 trees, two herbs, four shrubs, two lianas, three parasites, two ferns, and one palm. About 42 species were found in Papua and Java, 39 in Sulawesi and Kalimantan, 40 in the Bali-Nusa Tenggara, 38 in Sumatra, and 36 in the Maluku Islands region (Table 3). The herbaceous mangrove species included *Acanthus ebracteatus* and *Acanthus ilicifolius*, while the shrubs consisted of *Aegialitis annulate*, *Kandelia candel*, *Scyphiphora hydrophyllacea*, and the only palm-type species was *Nypa fruticans.*

A total of 25 true mangrove species were also found throughout the coastal areas (Table 3). In some areas, there were true mangrove, identified as new record species, including *Avicennia rumphiana* which was only found in Java, Kalimantan and Sumatra (Khaliza and Abdunnur 2022; Sulmartiwi et al. 2018; Wantoro et al. 2017). This species is an endemic mangrove in tropical regions, especially Malaysia, the Philippines, Indonesia, and Papua New Guinea (Dahdouh-Guebas 2023). *Aglaia mackiana* was only identified in Papua, according to the report by Pannell et al. (2020) on a mangrove expedition in the West Papua region. On the other hand, Sheue (2009) reported that *Ceriops australis* was newly identified in the region of Papua, Bali—Nusa Tenggara (Timor, Flores, Sumbawa), Java, and Sumatra (Pulau Bilinton). It is an endemic species in Australian waters (Huang et al. 2008), and the presence in the regions can be attributed to the spread of propagules carried by currents from Australia to Papua and further to Timor, Flores, Sumbawa, Java, and Sumatra. Moreover, it is closely related to South Pacific currents that enter Papua New Guinea (New Guinea Coastal Current/NGCC) (Kuroda 2000).

Different mangrove species dominated each region in Indonesia, for example, Java was dominated by *Sonneratia alba* (Donato et al 2011). Other cases of dominance included Kalimantan (*Rhizophora* spp., *Avicennia* spp., and *Nypa fruticans)* (Arifanti et al. 2019; Murdiyarso et al. 2015), Papua (*Bruguiera gymnorrhiza* and *R. apiculata)* (Murdiyarso et al. 2015), Sulawesi and Sumatra (*Rhizophora mucronata* and *Rhizophora apiculata)*

Table 3 Distribution of true mangrove species by region in Indonesia

Species	Papua	Maluku Island	Bali NTI	Sulawesi	Kalimantan	Java	Sumatra	Types
Acanthus ebrecteatus	+	+	+	+	+	+	+	Herbs
Acanthus ilicifolius	+	+	+	+	+	+	+	Herbs
Acrostichum aureum	+	+	+	+	+	+	+	Fern
Acrostichum speciosum	+	+	+	+	+	+	+	Fern
Aegialitis annulata	+	+	+	+		+		Shrubs
Aegiceras corniculatum	+	+	+	+	+	+	+	Tree
Aegiceras floridum	+	+	+	+	+	+	+	Tree
Amyema anisomeres	+		+	+	+	+		Parasites
Amyema gravis	+	+			+	+		Parasites
Amyema mackayense	+		+	+		+	+	Parasites
Avicennia alba	+	+	+	+	+	+	+	Tree
Avicennia eucalyptifolia	+			+		+	+	Tree
Avicennia lanata			+	+	+		+	Tree
Avicennia marina	+	+	+	+	+	+	+	Tree
Avicennia officinalis	+	+	+	+	+	+	+	Tree
Avicennia rumphiana					+	+	+	Tree
Bruguiera cylindrica	+	+	+	+	+	+	+	Tree
Bruguiera exaristata	+	+		+		+	+	Tree
Bruguiera gymnorrhiza	+	+	+	+	+	+	+	Tree
Bruguiera hainesii	+			+	+		+	Tree
Bruguiera parviflora	+		+	+	+	+	+	Tree
Bruguiera sexangula	+	+		+	+	+		Tree
Camptostemon schultzii	+	+	+		+	+		Tree
*Ceriops australis**	+							Tree
Ceriops decandra	+	+	+	+	+	+	+	Tree
Ceriops tagal	+	+	+	+	+	+	+	Tree
Ceriops zippeliana		+	+	+		+		Tree
Excoecaria agallocha	+	+	+	+	+	+	+	Herbs
Finlaysonia maritima	+	+	+	+	+	+	+	Lianas
Finlaysonia obovata	+		+		+		+	Lianas
Kandelia candel	+		+		+		+	Shrubs
Lumnitzera littorea	+	+		+	+		+	Tree
Lumnitzera recemosa	+	+	+	+	+	+	+	Tree
Nypa fruticans	+	+	+	+	+	+	+	Palm
Osbornia octodonta	+	+	+	+	+	+	+	Tree
Pemphis acidula		+	+	+		+		Tree
Rhizophora apiculata	+	+	+	+	+	+	+	Tree
Rhizophora lamarckii		+	+			+		Tree
Rhizophora mucronata	+	+	+	+	+	+	+	Tree
Rhizophora stylosa	+	+	+	+	+	+	+	Tree
Scyphiphora hydrophyllacea	+		+	+	+		+	Shrubs
Sonneratia alba	+	+	+	+	+	+	+	Tree
Sonneratia caseolaris	+	+	+	+	+	+	+	Tree
Sonneratia ovata	+	+	+	+	+	+	+	Tree
Xylocarpus granatum	+	+	+	+	+	+	+	Tree
Xylocarpus mekogensis		+			+	+		Tree
Xylocarpus moluccensis	+	+	+	+	+	+	+	Tree
Xylocarpus rumphii	+		+			+		Tree

+present; *NTI* Nusa Tenggara Island; *new record species; green colors: found in all regions; blue color: only found in one region

(Murdiyarso et al. 2015). These differences were attributed to habitat characteristics such as bays, deltas, lagoons, open coasts, and estuary waters. Bay and estuary habitats were dominated by *Rhizophora* spp and *Sonneratia* spp. (Suyadi 2009; Lekitoo and Tambing 2018), while the Delta was dominated by *Avicennia* spp and *Nypa fruticans* (Sidik 2010; Rahman et al. 2017). *Avicennia* spp. and *Sonneratia* spp were predominant in the lagoon (Suryono 2012), while the open coast was dominated by *Rhizophora* spp. and *Avicennia marina* (Ulyah et al. 2022).

Diversity of mangrove fauna in Indonesia

The diversity of fauna in mangrove ecosystems can be classified into marine and terrestrial. This study classified fish, shrimp, macrozoobenthos, and other marine organisms as marine fauna, while birds, reptiles, mammals, and other species were considered terrestrial.

Mangrove marine fauna in Indonesia

The diversity of marine fauna in the mangrove ecosystems consisted of fish species and macrozoobenthos. The results showed 125 fish species from 47 families and 169 macrozoobenthos from 52 families. The macrozoobenthos consisted of 92 Gastropods, 24 Bivalves, 48 Crustaceans, two Polychaeta, and three species of Maxillopods (Table 4). The existence of marine fauna was closely related to the ecological function of mangrove as a provider of nutrients.

According to Nordhaus et al. (2006), mangrove ecosystems provide nutrients to support marine biota's life, such as fish, shrimp, crabs, shellfish, and others. The availability of these nutrients stems from the production of litter in the form of fallen leaves or fruit deposited in the sediments (Rahman et al. 2020c). Hulopi et al (2022) also stated that the presence of gastropods in mangrove ecosystems was closely related to the availability of food and the type of substrate in the habitat. As stated by Rahman et al (2020d), gastropods are perfectly associated with mangrove ecosystems in terms of spawning, nurturing, and foraging, while other biota, such as fish and shrimp, are partially associated. Partial associations are formed when the marine biota only uses mangrove ecosystems as a feeding ground or only as a spawning ground.

Diversity of terrestrial mangrove fauna in Indonesia

The diversity of terrestrial fauna in the mangrove ecosystems comprised 161 species, including 80 birds, 38 squamata, four crocodiles, six amphibians, 11 testudinate, and 21 mammals (Table 5). There were three species of decreasing aves classified as Least Concern (LC) according to the International Union for Conservation of Nature (IUCN), including *Ardea cinerea, Ardea purpurea*, and *Halcyon cyanoventrism*. Meanwhile, one species was classified as Near Threatened (NT), namely *Anhinga melanogaster* (BirdLife International 2016a, b). As stated in previous studies, mammal species including *Lutra sumatrana, Macaca fascicularis, Macaca ochreata,* and *Nasalis larvatus* had an Endangered (EN) status (Boonratana et al. 2021; Hansen et al. 2022; Sasaki et al. 2021), while *Lutra perspicillata* was in the Vulnerable Status (VU) (Khoo et al. 2021). *Crocodylus siamensis* and *Tomistoma schlegeli* were in the Critical Endangered (CR) and VU status, respectively (Bezuijen et al. 2012; 2014).

Biodiversity preservation through mangrove conservation strategies

Generally, the management of mangrove ecosystems in Indonesia predominantly focuses on conservation. Most conservation areas were integrated with ecotourism to increase community participation. Institutions or agencies entrusted with the mandate of conserving mangrove, include the Ministry of Environment and Forestry (MoEF), and the Ministry of Marine Affairs and Fisheries (MMAF). The mandate was outlined through the Presidential

Table 4 The diversity of mangrove marine fauna in Indonesia

Fishes		Macrozoobenthos	
Ariidae	*Arius maculatus* *Hexanematichthys sagor*	Gastropods Assimineidae	*Assiminaea* sp. *S. miniata*
Altherinidae	*Hypoatherina temincki*	Buccinidae	*B. bucinini*
Apogonidae	*Archamia fucata*	Cassidae	*B. littorinoides*
Ambassidae	*Ambassis nalua*	Cerithidae	*Cantharus* sp. *Phalium* sp.
Bagridae	*Mystus gulio* *M. nigriceps*		*Cerithium kobelti* *C. echinatum*
Belonidae	*Tylosurus crocodilus* *T. leiurus* *Strongylura strongylura*	Clavatulidae Ellobiidae	*C. coralium* *Clypeomorus pellucida* *Clypeomorus moniliferus*
Caesionidae	*Pristipomoides multides*		*Turricula javana* *Auriculastra subula*
Carangidae	*Blepharis indicus* *Selar boops* *Chomberoides tala* *C. tol* *Scomber cordyla* *Parastromateus niger* *Seriola dumerilli* *Serolina nigrofasciata* *Caranx hippos* *C. melampygus* *C. tille* *C. sexfasciatus*	Epitonidae Littorinidae	*A. elongate* *Cassidula aurisfelis* *C. lutescens Butot* *C. mustelina Deshayes* *C. triparietalis (Martens)* *C. sulculosa (Musson)* *C. nucleus* *Ellobium aurisjudae* Linnaeus *E. aurismidae* (Linnaeus)
Centropomidae	*Ambassis kopsi*		*Epitonium* sp
Chanidae	*Chanos chanos*		*Janttina janthina*
Chaetodontidae	*Scatophagus argu*		*Littoraria articulata*
Cichlidae	*Oreochromis mossambicus*		*L. carinifera* *L. philippiana*
Cyprinidae	*Rasbora tornieri* *Barbodes binotatus* *Barbonymus schwanenfeldii*	Mitridae	*L. meritoides* *L. pintado* *L. Scabra* *L. nebolusa*
Cygnoglossidae	*Cynoglossus arel* *C. waandersii*	Muricidae	*L. melanostoma* *Littorina* sp. 1
Clupeidae	*Tenualosa toli* *Ethmalosa fimbriata* *Anadontostoma chacunda* *Pellona ditchoa* *Thyrssa hamiltonii*		*Nodilittorina pyramidalis* *Domiporta filaris* *Pterygia conus* *Chicoreus capucinus* *Maculotriton serriale*
Eleotridae	*Oxyeleotris marmorata* *Butis gymnopomus* *B. butis*	Nassaridae	*Murex s*p. *Drupela margariticola* *Cronia margariticola* *Morula* sp. *Semiricinula muricina*
Elopsidae	*Elops hawaensis*		*Alectrion taenia*

Table 4 (continued)

Fishes		Macrozoobenthos	
Engraulidae	*Engraulis grayi* *Thryssa malabarica* *T. mystax* *Setipinna melanochir* *S. taty* *Engraulis zollingeri* *Stelophorus heterolobus* *S. commersonii* *S. indicus*	Neritidae	*Hebra corticata* *Nassarius hirtus* *N. arcularius—arcularius* *N. coronatus* *N. margaritifer* *N. olivaceus* *N. venustus* *Clithon oualaniensis* *Nerita* sp.
Gobiidae	*Actinogobius ommaturus* *Glossobius biocellatus* *G. giuris* *G. brachypterus* *Gobius paganellus* *Boleophthalmus boddarti* *Pseudogobius javanicus* *Periopthalmus variabilis* *Periophthalmodon schlosseri* *Sicyopus zosterophorum*	Pachychilidae Potamididae	*N. undata* *N. planospira* *N. costata* *N. chamaeleon* *N. oualaniens* *N. albicia* *N. axuvia* *N. balteata* *N. squamulata* *N. politinnaeus* *Faunus ater* *Cerithidea alata* *C. cingulata* *C. djadjarensis* *C. sinensis* *C. obtusa*
Haemulidae	*Pomadasys maculates*		*C. quadrata*
Hemiramphidae	*Hyporhampus dussumieri* *Hemiramphus* sp.	Planaxidae Pyrenidae Spondylidae	*C. weyersi* Datzjenberg *Telescopium telescopium*
Holocentridae	*Sargocentron diadema*	Tetraclitidae	*Telebralia* sp.
Lactariidae	*Pseudorhombus arsius*	Thiaridae	*T. palustris*
Lethrinidae	*Letrinus ornatus*		*T. sulcata*
Leiognathidae	*Gazza minuta* *Leiognathus splendens* *L. equulus* *L. dussumieri*	Trochidae Turbinidae	*T. mauritsi* Butot *Quoyia decollate* *Pyrene varians* *Spondylus hystrix*

Table 4 (continued)

Fishes		Macrozoobenthos	
Lutjanidae	*Tylosurus spp.* *Lutjanus fulvus* *L. eherenbergii* *L. johnii* *L. campechanus* *Lates Calcarifer*	Turritelidae Melampidae Fasciolaridae	*Tritip (Balanomorpha s*p.) *Melanoides torulosa* *Melanoides riqueti* (Grateloup) *M. tuberculata (Muller)* *Chrysostoma paradoxum* *Turbinella* sp. *Turbo mormoratus* *Turbo crassus* *Turitella duplicata* *Cassidula nucleus* *Cassidula nucleus* *Peristenia nassatula* *Chicoreus capucinus*
Megalopidae	*Megalops cyprinoides*	Bivalves	*Anadara artiquata Linnaeus*
Mugillidae	*Mugil dussumieri* *M. troscheli* *M. cephalus* *Valamugil cunnesius* *V. speigleri* *V. seheli* *Lethrinus* sp.	Arcidae Cardiidae Chamidae Corbiludae	*A. granosa* *Scapharca pilula* *Acanthocardia tuberculate* *Vepricardium sinense* *Chama fragum*
Muraenidae	*Thyrsoidea macrunus* *Muraena pardalis*	Cyrenidae Limidae	*Polymesoda coaxans* Gmelin *P. expansa*
Nemipteridae	*Lactarius lactarius*	Mytilidae	*Corbicula javanica*
Platycephalidae	*Cociella crocodilus* *Platycephalus scaber* *P. indicus*	Ostreidae Placunidae	*Divarrilima* sp. *Arcuatula* sp.
Plotosidae	*Plotosus canius* *Paraplotosus albabris*	Pteriidae	*Brachyodontes biloculari*
Pomatomidae	*Pomatus saltator*	Semelidae	*Saccostrea cucullata*
Polynemidae	*Eleutheronema tetradactilum*	Tellinidae	*Placuna ephippium* *Pteria s*p.
Scatophagidae	*Scatophagus argus* *Otolithes argentus* *Otolithes lateoides* *Otolithoides brunneus* *Otolithoides microdon* *Sciaena macropterus*	Spondylidae Unionidae Verenidae	*Macoma balthica* *Scrobicularia plana* *Tellina donacina* *Tellina fabula* *Tellina peltitiana* *Tellina staurella* *Spondylus hystrix* *Anodonta* sp. *Gafrarium tumidum* Roding
Serranidae	*Anthias montonii* *Ephiniphelus boenak* *Epinephelus merra* *Epinephelus sexfasciatus*	Crustacean Alpheidae Balanidae	*Alpheus crassimanus* Heller *A. bisincisus* De Man *Balanus* spp.
Siganidae	*Siganus javus* *Siganus guttatus*	Grapsidae	*Clibanarius* spp. *Sarmatium incidum*
Sillaginidae	*Sillago sihama* *Caesio cuning*		*S. crassum* *M. crassipes*

Table 4 (continued)

Fishes		Macrozoobenthos	
Soleidae	*Cynoglossus billineata* *Cynoglossus brachicephalus* *Cynoglossus grandisquamis* *Cynoglossus kaupsi* *Synaptura zebra*		*Sesarma taeniolata* White *S. meinerti* De Man *S. edwarsii* *S. bataviana* De Man *S. moeschi* *S. cumolpe* De Man *S. smithi* H. Milne-
Syngnathidae	*Doryichthys boaja*		Edwards
Sphyroenidae	*Sphyraena jello*		*S. bocourti* A. Milne-
Stromateidae	*Pampus argentus* *Pampus chinensis*		Edwards *S. fasciata* Lancherter
Tetraodontidae	*Arothron immaculatus* *Tetradon nigroviridis*	Majidae	*S. palawensis* *S. videns* De Hans *S. onychophora* De Man *S. rousseauxi* H. Milne-Edwards
Thrichiuridae	*Thrichiurus haumela* *Thrichiurus* sp.		
Teraponidae	*Terapon puta* *Terapon jarbua*		
Zenarchopteridae	*Zenarchopterus buffonis*	Diogenidae Gecarcinidae	*S. erythrodeactylum* Hess *S. longipes* (Krauss) *Metapograpsus latifrons* *Uca vocans* Linnaeus *U. lactea* (De Haan) *Maia squinado* *Clibanarius ambonensis* *Cardisoma carnifex* Ocypodidae
		Paguridae Portunidae	*Ocypoda ceratophthalamus* *O. arenaria De Man* *O. cardimana* *Ilyoplax delsmani* De Man *Tylodiplax indian*
		Penaide	*Macrophtalmus convexus*
		Thalassinidae	*M. telescopicus* Owen *M. tridentatum* *M. definitus* Adam et White *Caenobita cavipes* Stimpson *Scylla paramamosain* *Scylla olivacea* *Scylla serrata* *Uca mjorbergi* *Uca perplexa* *Uca vomeris* *Penaeus indicus* *Penaeus monodon* *Thalassina anomala* Herbst
		Polychaetes Arenicolidae Nereidae	*Arenicola marina* *Nereis* sp.
		Maxillopods Balanidae	*Balanus* sp. *Balanus perforatus* *Clibanarius* spp

Table 5 Species of terrestrial mangrove fauna in Indonesia

No	Type of species			
	Aves	Aves	Squamata	Amfibi
1	*Alcedo caerulescens*	*Parus major*	*Hemydactylus flaviviridis*	*B. melanostictus*
2	*Halcyon cyanoventris* (LC)	*Phalacrocorax niger*	*Eublephris fasciolatus*	*R. maculatus*
3	*Todirhampus chloris*	*P. sulcirostri*	*Gecko gecko*	*R. cyanophlyctia*
4	*Todirhampus sanctus*	*Picoides macei*	*Mabuya multifasciata*	*R. limnocharis*
5	*Pelargopsis capensis*	*Picoides maluccensis*	*Calotes versicolor*	*R. tigrina*
6	*Alcedo meninting*	*Lonchura punctulata*	*Chamaeleon zeylanicus*	*Microhyla ornata*
7	*Anas gibberifrons*	*L. leucogastroides*	*Varanus sp.*	
8	*Anhinga melanogaster* (NT)	*Paser montanus*	*V. salvator*	**Testudinate**
9	*Collocalia fuciphaga*	*Psittacula alexandri*	*V. flavescens*	*Pelochelys bironi*
10	*Collocalia esculenta*	*Loriculus galgulus*	*Naja naja*	*Morenia petersi*
11	*Apus affinis*	*Cacatua alba*	*Typhlops porractus*	*Batagur baska*
12	*Apus pacificus*	*Pycnonotus aurigaster*	*T. acutus*	*Lepidochelys olivaca*
13	*Ardea cinerea* (LC)	*Pycnonotus goiavier*	*Ahaetula ahaetulla*	*Chelonia mydas*
14	*Ardea purpurea* (LC)	*Amaurornis phoenicurus*	*A. cyanochloris*	*Tryonix hurun*
15	*Egretta garzetta*	*Porphyrio porphyria*	*Python reticulatus*	*T. gageticus*
16	*Egretta intermedia*	*Calidris ferruginea*	*Natrix stolata*	*Lissemys punctata*
17	*Nycticorax nycticorax*	*Tringa hypoleucos*	*Enhydris enhydris*	*Kachuga tecta*
18	*Ardeolaspeciosa*	*Prinia familiaris*	*Fordonia leucobalia*	*K. smiti*
19	*Butorides striatus*	*Prinia polychroa*	*Bungards lividus*	*K. kachuga*
20	*Bubulcus ibis*	*Orthotomus sepium*	*Acrochordus granulatus*	
21	*Artamus leucorynchus*	*Orthotomus ruficeps*	*Hydrophis obscurus*	**Mammalia**
22	*Lalage nigra*	*Orthotomus sutorius*	*H. nigrocinctus*	*Amblyonyx cinerea*
23	*Caprimulgus affinis*	*Gerygone sulphurea*	*M. cantoris*	*Calloscirus notatus*
24	*Aegithina tiphia*	*Acrocephaus stentoreus*	*Enhydrina achistoss*	*Cervus unicolor*
25	*Mycteria cinerea*	*Sterna nilotica*	*Cerberas thynchops*	*Felis vivverina*
26	*Streptopelia chinensis*	*Sterna bergii*	*Ptyas mucosus*	*Lutra perspicillata* (VU)
27	*Treron vernans*	*Acridotheres javanicus*	*Spalerosophis diadema*	*Lutra lutra*
28	*Macropygia emiliana*	*Zoothera interpres*	*Vivera russeli*	*Lutra sumatrana* (EN)
29	*Geopelia sriata*	*Zosterops chloris*	*Pligodon arnensis*	*Macaca fascicularis* (EN)
30	*Crypsirina temia*	*Zosterops palpebrosus*	*Oligodon dorsalis*	*Macaca ochreata* (EN)
31	*Cacomantis merulinus*	*Chlidonias leucopterus*	*Dryophis mycterigans*	*Nasalis larvatus* (EN)
32	*Centropus nigrorufus*	*Sterna hirundo*	*Lycondon aulicus*	*Orcella brevirostris*
33	*Centropus bengalensis*	*Gygis alba*	*Eryx conicus*	*Panthera tigris sumatranus*
34	*Dicaeum trochileum*	*Sula lencogastes*	*Psammophis condouarus*	*Pteropus vampirus*
35	*Hirundo tahitica*		*Mabouya* sp.	*Presbytis melalophos*
36	*Hirundo rustica*	**Crocodilia**	*Tiliqua* sp.	*Pteropus* spp
37	*Lanius schach*	*Crocodylus siamensis* (CR)	*Saranus salvadorii*	*Tragulus* spp
38	*Motacilla flava*	*Crocodylus novaguinea*	*Liasis* sp.	*Trachypithecus aurata*

Table 5 (continued)

No	Type of species			
	Aves	Aves	Squamata	Amfibi
39	*Rhipidura javanica*	*Crocodylus porosus*		*Tupaia javanica*
40	*Cyornis rufigastra*	*Tomistoma schlegeli* (VU)		*Ratus s*pp
41	*Muscicapa sibirica*			*Sousa chinensis*
42	*Nectarinia jugularis*			*Sus scrofa*
43	*Nectarinia calcostheta*			
44	*Anthreptes malacensis*			
45	*Anthreptes singalensis*			
46	*Oriolus chinensis*			

Bold words in Table 5 indicate terrestrial fauna groups

LC Least Concern, *NT* Near Threatened, *VU* Vulnerable, *EN* Endangered, *CR* Critical Endangered

Regulation of the Republic of Indonesia Number 73 of 2012 concerning the national strategy for the management of mangrove ecosystems. This was further detailed in the ministerial regulations through various policies such as conservation and environment, rehabilitation, silvofishery, protected forests, and ecotourism. MMAF designates conservation areas as part of the coastal and small islands zoning plan (RZWP3K), while MoEF adopts the policy of the Directorate of Conservation Areas. The mandate aims to improve community welfare by conserving and rehabilitating mangrove ecosystems.

MMAF plays a crucial role in the protection, management, restoration, and utilization of mangrove ecosystems. These functions are carried out through the Regulation of the Minister of Marine Affairs and Fisheries in Indonesia No. 24 of 2016 concerning procedures for rehabilitating coastal areas and small islands. Meanwhile, MoEF has the function of formulating policies related to mangrove protection, establishing conservation areas, granting permits, supervising utilization by the community, and conducting investigations for further development. These functions are supported by Law No. 32 of 2009 concerning environmental protection and management, as well as MoEF Minister Regulation Number P.23 of 2021 concerning forest and land rehabilitation.

In 2010, the mangrove conservation areas in Indonesia reached 22%, or the equivalent of 758,472 ha (Sidik et al. 2018). The conservation efforts aimed to preserve and enhance ecosystem services such as mangrove biodiversity, potential carbon stocks, coastal protection, and the biodiversity of marine and terrestrial fauna (Sievers et al. 2023). The government initiates mangrove conservation through MoEF and MMAF by indulging various parties such as communities, non-governmental organizations, and the private sector. Efforts to conserve mangrove ecosystems and their fauna are supported by several regulations, including Law No. 5 of 1990 concerning the conservation of natural resources and their ecosystems, Government Regulation No. 68 of 1998 regarding nature reserves and conservation, as well as Minister of Environment Regulation No. P106 of 2018 concerning protected plant and animal species. The implementation and enforcement of these regulations have not been optimal in recent decades. This was reflected in the existence of several species included in the endangered category by the IUCN, as presented in Table 5.

Several unique faunas are protected in conservation areas and have become icons in ecotourism activities (Hadinata et al. 2020; Manihuruk et al. 2021). In each region,

ecotourism-based conservation was implemented to maintain the unique diversity of fauna. According to previous studies, Crocodilus was protected in the regions of Papua, Kalimantan, Java, and Sumatra. The *Halcyon* sp. species were preserved in Papua and Java (Kusmana 2014); *Anhinga* sp. was protected in Kalimantan and Java (Kusmana 2014); while the proboscis monkey (*Nasalis larvatus*) was only found and conserved in the Kalimantan region (Kusmana 2014; Noorhidayah and Ma'ruf 2007; Sawitri et al. 2013; Widyastuti and Erianto 2017) (Table 6). Based on the results, ecotourism-based conservation and the protection of unique fauna were the main factors contributing to the high biodiversity in Indonesia. This action could also improve the economy of the community, triggering their active participation in managing the mangrove ecosystems (Wardhani 2011).

Table 6 Protected mangrove fauna species by region in Indonesia through ecotourism-based conservation

Region	Location	Species	Sources
Papua	Dolok Island	*Crocodylus* sp.	Kusmana (2014)
	Gunung Lorentz	*Crocodylus* sp.	Sari et al (2022)
	Youtefa Bay, Tourism Park Jayapura	*Halcyon* sp.	
		Ciconia episcopus	
		Gecko-gecko	
		Liasis sp.	
		Varanus salvadorii	
Maluku Island	n.a	n.a	n.a
Bali–NTI	Bali Barat	*Leucopsar rothschildi*	Kusmana (2014)
Sulawesi	Malili–Bone Bay	*Macaca ochreata*	Anwar and Gunawan (2006)
Kalimantan	Wain River, Samarinda	*Nasalis larvatus*	Noorhidayah and Ma'ruf 2007)
	PT. Makmur Abadi Permai	*Crocodylus porosus*	Ripai and Kamarubayana (2016)
	Tarakan, North Kalimantan	*Nasalis larvatus*	Sawitri et al (2013)
	Batu Ampar	*Nasalis larvatus*	Widyastuti and Erianto (2017)
	Teluk Kalumpang	*Nasalis larvatus*	Kusmana (2014)
	Muara Kendawangan	*Nasalis larvatus*	Rabiati et al (2016)
	Pamuka	*Nasalis larvatus*	
	Muara Kahayan	*Nasalis larvatus*	
	Tanjung Putting	*Nasalis larvatus*	
	Teluk Adeng	*Anhinga* sp	
	Kuala Lupak	*Crocodylus* sp	
		Nasalis larvatus	
Jawa	Muara Angke, Jakarta	*Egretta* spp.	Kusmana (2014)
	Semarang, Central Java	*Halcyon* spp.	Setyowati et al (2019)
	Ujung Kulon, Banten	*Anhinga* spp.	Kusmana (2014)
		Crocodylus porosus	
		Rhinoceros sondaicus	
Sumatra	Berbak	*Crocodylus* sp.	Kusmana (2014)
	Pulau Tengah, Waitambi, and Mudo	*Calloscirus notatus*	Zahdi (2022)
	Berbak National Park-Jambi	*Cervus unicolor*	Cahyo (2007)
		Lutra perspicillata	
		Lutra lutra	
		Macaca fascicularis	
		Tupaia javanica	
		*Ratus s*pp.	
		Sus scrofa	
		P. tigris sumatranus	

Notes: NTI (Nusa Tenggara Island); n.a (not available)

In 2010–2020, about 78% of mangrove without a conservation status was found to be experiencing damage threat, triggering the degradation of *Bruguiera hainesii* and *Heritera globosa* with Critically Endangered (CE) and Endangered status, according to the IUCN (Duke et al. 2010; Sukardjo 2010). In the above-mentioned decade, the mangrove deforestation rate was estimated at 182,091 ha, with a deforestation rate of 18,209 ha per year (Arifanti et al. 2021). To address this, the Indonesian government increased its commitment to conservation and restoration programs. The President assigned the Peatland and Mangrove Restoration Agency (BRGM) to restore 600,000 mangrove ecosystems by 2020–2024. BRGM collaborates with MoEF and MMAF to carry out mangrove ecosystem restoration, resulting in the achievement of 52,853 ha restored area in 2021 (Ministry of Environment and Forestry 2021). The restoration target is aimed at achieving Sustainable Development Goals (SDGs), especially SDG 14 to increase marine biodiversity. However, the target has serious challenges, specifically related to the suitability of rehabilitation land (Sasmito et al. 2023). Despite these challenges, there is optimism that strong collaboration between stakeholders, specifically with the participation of the community will lead to successful mangrove restoration, resulting in increased protection of biodiversity.

According to Nurhati and Murdiyarso (2022), crucial steps that must be taken by both the government and other stakeholders in the mangrove conservation program include (1) Strengthening the regulatory, policy, and institutional framework; (2) Enhancing data and information management as well as the use of cutting-edge science and technology; (3) Increasing the role and capacity of the community as partners; (4) Law enforcement; (5) Encouraging funding mechanisms that support conservation as a profit rather than a cost center. Optimally implementing these steps will help maintain the biodiversity of the mangrove ecosystems in Indonesia and provide many benefits for the welfare of the community.

Conclusion

In conclusion**,** mangrove ecosystems in Indonesia were found to have high biodiversity, including mangrove species as well as marine and terrestrial fauna. This was attributed to the Indonesian government's commitment expressed through conservation efforts. Conservation was carried out to preserve and improve ecosystem services including mangrove biodiversity, carbon stock potential, coastal protection, as well as the biodiversity of marine and terrestrial fauna. Based on the results, incredibly unique fauna included Crocodilus found in Papua, Kalimantan, Java, and Sumatra region, *Halcyon* sp in Papua and Java region, *Anhinga* sp in Kalimantan and Java region, as well as *Nasalis larvatus* in Kalimantan. However, in many unconserved mangrove areas, deforestation occurred in 2010–2020, triggering degradation evident in species such as *Bruguiera hainesii* and *Heritera globosa* with Critically Endangered (CE) and Endangered status. There were three species of declining aves classified as Least Concern (LC) according to the IUCN, including *Ardea cinerea, Ardea purpurea*, and *Halcyon cyanoventrism,* along with one species in the Near Threatened (NT) status, namely *Anhinga melanogaster*. Mammal species such as *Lutra sumatrana, Macaca fascicularis, Macaca ochreata,* and *Nasalis larvatus* were found to be in the Endangered (EN) status while *Lutra perspicillata* was in the Vulnerable status (VU). In addition, *Crocodylus siamensis* and *Tomistoma schlegeli* were classified as Critical Endangered (CR) and VU, respectively. Based on the results, the Indonesian government should continue to add mangrove conservation areas and optimize regulatory

enforcement on the protection of unique and rare fauna, specifically those included in the IUCN Redlist Status.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10531-023-02767-9.

Author contributions The first author collected and analyzed data and wrote the manuscript; the second author collected data and set the reference style; the third author reviewed the content of the manuscript; the fourth author reviewed the content of the manuscript; the fifth author reviewed the content of the manuscript, the sixth and seventh authors set the layout of manuscript, the last author reviewed the content of the manuscript.

Funding Not applicable.

Data availability Not applicable.

Declarations

Competing interests The authors declare no competing interests.

Ethical approval Not applicable.

References

Abubakar S, Kadir MA, Wibowo ES, Akbar N (2019) Manfaat mangrove bagi peruntukan sediaan farmasitika di Desa Mamuya Kecamatan Galela Timur Kabupaten Halmahera Timur (tinjauan etnofarmakologis). Jurnal Enggano 4:12–25. https://doi.org/10.31186/jenggano.4.112-25

Abubakar S, Rina SR, Susanto AN, Kodung FR (2022) Kesehatan mangrove berdasarkan biodiversitas fauna di Desa Bobo Kecamatan Jailolo Kabupaten Halmahera Barat. Agrikan 15:284–293

Acik R, Sudarmadji, (2017) Hubungan antara faktor ekologi terhadap struktur komunitas mangrove di Teluk Pangpang Taman Nasional Alas Purwo. J Basic Sci 18:61–64. https://doi.org/10.19184/jid.v18i1.2753

Agustini NT, Ta'alidin Z, Purnama D, (2016) Struktur komunitas mangrove di Desa Kahyapu Pulau Enggano. Jurnal Enggano 1:19–31. https://doi.org/10.31186/jenggano.1.1.19-31

Ajiningrum PS, Dewangga MA (2022) Struktur komunitas mangrove di pesisir pantai kecamatan sedati dan kecamatan jabon kabupaten sidoarjo. Florea 9:33–41

Akbar N, Baksir A, Tahir I, Arafat D (2016) Struktur komunitas mangrove di Pulau Mare, Kota Tidore Kepulauan, Maluku Utara, Indonesia. Jurnal Depik 5:133–142. https://doi.org/10.13170/depik.5.3.5578

Akbar N, Marus I, Haji I, Abdullah S, Umalekhoa S, Ibrahim FS, Ahmad M, Ibrahim A, Kahar A, Tahir I (2017) Struktur komunitas hutan mangrove di Teluk Dodinga, Kabupaten Halmahera Barat Provinsi Maluku Utara. Jurnal Enggano 2:78–89. https://doi.org/10.31186/jenggano.2.1.78-89

Akbar N, Ibrahim A, Haji I, Tahir I, Ismail F, Ahmad M, Kotta R (2018) Struktur komunitas mangrove di desa Tewe, Kecamatan Jailolo Selatan, Kabupaten Halmahera Barat, Provinsi Maluku Utara. Jurnal Enggano 3:81–97. https://doi.org/10.31186/jenggano.3.1.81-97

Akhrianti I, Nurtjahya E, Franto SIA (2019) Kondisi komunitas mangrove di pesisir utara Pulau Mendanau dan Pulau Batu Dinding, Kabupaten Belitung. Jurnal Sumberdaya Perairan 13:12–26

Ali M, Sulistiono Imran Z (2018) Mangrove vegetation: composition and structure in Bengawan Solo estuary. Indonesia. NUJ Sci Tech. 26(4):107–118. https://doi.org/10.14456/nujst.2018.27

Alvareza M, Leilani I (2020) Community structure of the mangrove forest in the tourism area of Pariaman City, West Sumatra. Bioscience 4:62–72. https://doi.org/10.24036/0202041108192-0-00

Amaliyah R (2017) Pengembangan aktivitas ekowisata mangrove berbasis konservasi di Kota Pekalongan, Jawa Tengah. Master Thesis, Institut Pertanian Bogor

Aminuddin M, Sunarto PD (2019) Mangrove forest community structure in Ekas Buana Village, East Lombok Regency, West Nusa Tenggara. In AIP Conference Proceedings 2120:040019. https://doi.org/10.1063/1.5115657

Andikam IBMB, Kusmana C, Nurjaya IW (2019) Dampak pembangunan jalan tol Bali Mandara terhadap ekosistem mangrove di Teluk Benoa Bali. JPSL 9:641–657. https://doi.org/10.29244/jpsl.9.3.641-657
Anita A, Marlian N, Zurba N (2022) Kajian konservasi mangrove di pesisir pantai sumatera barat. J Aceh Aquat Sci 6:63–75
Annisa R, Priosambodo D, Salam MA, Santosa S (2017) Struktur komunitas mangrove asosiasi di sekitar area tambak Desa Balandatu Kepulauan Tanakeke Kabupaten Takalar Sulawesi Selatan. Jurnal Biologi Makassar 2:21–35. https://doi.org/10.20956/bioma.v2i1.1496
Anthoni A, Schaduw JNW, Sondak CFA (2017) Persentase tutupan dan struktur komunitas mangrove di sepanjang pesisir Taman Nasional Bunaken bagian utara. Jurnal Pesisir dan Laut Tropis 2:13–21. https://doi.org/10.35800/jplt.5.3.2017.16909
Anwar C, Gunawan H (2006) Peranan ekologis dan sosial ekonomis hutan mangrove dalam mendukung pembangunan wilayah pesisir. Prosiding Ekspose Hasil 20:23–34
Anwar H, Mertha IG (2017) Komposisi jenis mangrove di teluk Gerupuk Kabupaten Lombok Tengah. Jurnal Sangkareang Mataram 3:25–31
Ardiansyah Z, Susiana S, Kurniawan D (2023) Struktur komunitas mangrove di perairan Muara Sungai Beladeng Kelurahan Dompak, Tanjungpinang. Akuatikisle 7:37–43. https://doi.org/10.29239/j.akuatikisle.7.1.37-43
Arifanti VB, Kauffman JB, Hadriyanto D, Murdiyarso D, Diana R (2019) Carbon dynamics and land use carbon footprints in mangrove- converted aquaculture: the case of the Mahakam Delta, Indonesia. For Ecol Manage 432:17–29. https://doi.org/10.1016/j.foreco.2018.08.047
Arifanti VB, Novita N, Subarno Tosiani A (2021) Mangrove deforestation and CO_2 emissions in Indonesia. IOP Conf Ser 874:012006. https://doi.org/10.1088/1755-1315/874/1/012006
Arifin A (2017) Struktur vegetasi mangrove berdasarkan substrat di Pantai Mara'Bombang Kecamatan Suppa Kabupaten Pinrang. Undergraduate Thesis, Universitas Hasanuddin
Ashari DP, Muhammad F, Utami S (2019) Struktur komunitas hutan mangrove di Sungai Donan Kabupaten Cilacap, Jawa Tengah. Bioma 21:65–71
Asman I, Sondak CFA, Schaduw JNW, Kumampung DRH, Ompi M, Sambali H (2020) Struktur komunitas mangrove di Desa Lesah, Kecamatan Tagulandang, Kabupaten Sitaro. Jurnal Pesisir dan Laut Tropis 8:48–60. https://doi.org/10.35800/jplt.8.2.2020.28769
Auliyah N, Blongkod A (2018) Struktur Komunitas Mangrove di Pesisir Desa Dalapuli Barat, Bolaang Mongondow Utara. Gorontalo Fish J 1:1–11. https://doi.org/10.32662/.v1i1.92
Awn MS (2017) Estimating biomass and litter leaves productivity of mangrove for management in Enggano Island, Bengkulu, Sumatera, Indonesia. Master Thesis, IPB University
Babo PP, Sondak CF, Paulus JJH, Schaduw JNW, Angmalisang PA, Wantasen AS (2020) Struktur komunitas mangrove di Desa Bone Baru, Kecamatan Banggai Utara, Kabupaten Banggai Laut, Sulawesi Tengah. Jurnal Pesisir dan Laut Tropis 8:92–103. https://doi.org/10.35800/jplt.8.2.2020.29951
Baderan DWK (2016) Keanekaragaman jenis tumbuhan mangrove di kawasan pesisir Tabulo Selatan, Kabupaten Bualemo, Provinsi Gorontalo. Prosiding Seminar Nasional Lahan Basah 1:41–44
Baderan DWK (2017) Distribusi spasial dan luas kerusakan hutan mangrove di wilayah pesisir Kwandang Kabupaten Gorontalo Utara Provinsi Gorontalo. Jurnal GeoEco 3:1–8
Baderan DWK (2019) Struktur vegetasi dan zonasi mangrove di wilayah pesisir Kecamatan Kwandang Kabupaten Gorontalo Utara Provinsi Gorontalo. Bioma 4:20–30
Baksir A, Akbar N, Tahir I, Haji I, Ahmad M, Kotta R (2018) Struktur komunitas hutan mangrove di Pulau Sibu Kota Tidore Kepulauan Provinsi Maluku Utara. Jurnal Enggano 3:178–196. https://doi.org/10.31186/jenggano.3.2.178-196
Batoro J (2019) Flora Krandan (Canavalia maritima Aubl.) Urb. In South coastal Java, Indonesia. AIP Conference Proceeding. https://doi.org/10.1063/1.5061842
Bengen DG, Yonvitner R (2022) Pedoman Teknis Pengenalan dan Pengelolaan Ekosistem Mangrove. IPB Press, Bogor
Bezuijen M, Simpson B, Behler N, Daltry J, Tempsiripong Y (2012) Crocodylus siamensis. The IUCN red list of threatened species 2012: e.T5671A3048087. https://doi.org/10.2305/IUCN.UK.2012.RLTS.T5671A3048087.en Accessed on 29 Nov 2023
Bezuijen MR, Shwedick B, Simpson BK, Staniewicz A, Stuebing R (2014) Tomistoma schlegelii.The IUCN red list of threatened species 2014: e.T21981A2780499. https://doi.org/10.2305/IUCN.UK.2014-1.RLTS.T21981A2780499.en Accessed on 29 Nov 2023
BirdLife International (2016) Anhinga melanogaster. The IUCN Red List of Threatened Species 2016: e.T22696712A93582012. https://doi.org/10.2305/IUCN.UK.20163.RLTS.T22696712A93582012.en Accessed on 29 Nov 2023

BirdLife International (2016) Halcyon cyanoventris. The IUCN red list of threatened species 2016: e.T22683252A92980601. https://doi.org/10.2305/IUCN.UK.20163.RLTS.T22683252A92980601.en Accessed on 29 Nov 2023

BKKPN-Kupang (2022) Pendampingan Pendataan Mangrove Praktik Lapangan Mahasiswa Poltek AUP. Direktorat Jenderal Pengelolaan Laut. https://kkp.go.id/bkkpnkupang/artikel/46512-pendampingan-pendataan-mangrovepraktik-lapangan-mahasiswa-poltek-aup

Boonratana, R., Cheyne, S.M., Traeholt, C., Nijman, V., Supriatna, J (2021) Nasalis larvatus (amended version of 2020 assessment). The IUCN red list of threatened species 2021: e.T14352A195372486. https://doi.org/10.2305/IUCN.UK.2021-1.RLTS.T14352A195372486.en Accessed on 29 Nov 2023

Buwono YR (2017) Identifikasi dan kerapatan ekosistem mangrove di kawasan Teluk Pangpang Kabupaten Banyuwangi. Jurnal Ilmu Perikanan 8:32–37

Cahyo S (2007) Pendayagunaan Ekosistem Mangrove. Dahara Prize Press, Semarang

Dahdouh-Guebas F (2023) World Mangrove database. *Avicennia rumphiana* Hallier f. Accessed through: World register of marine species at: https://www.marinespecies.org/aphia.php?p=taxdetails&id=235042 on 02 Feb 2023

Darmarini AS, Wardiatno Y, Partono T, Soewardi K, Samosir AM, Zainuri M (2022) Structure of mangrove ecosystem in Lubuk Damar Coast, Seruway, Aceh Tamiang. JPSL 12:72–81

Daud F, Kusen JD, Kumampung DRH, Djamaaludin R, Darwisito R, Ompi M (2023) Struktur komunitas mangrove di pesisir Tanjung Kelapa Kecamatan Tombariri Taman Nasional Bunaken. Jurnal Ilmiah PLATAX 11:46–53

Dekky RL, Wardoyo ERP (2016) Inventarisasi jenis-jenis mangrove yang ditemukan di kawasan Tanjung Bila Kecamatan Pemangkat Kabupaten Sambas. Jurnal Protobiont 5:54–58

Dewi NLPM, Maharani SE (2022) Keanekaragaman jenis mangrove pada Tahura Ngurah Rai sekitar PLTD/G Pesanggaran. Jurnal Ecocentrism. 2:6–15. https://doi.org/10.36733/jeco.v2i1.3678

Dharmawan IWE, Pramudji (2020) Mangrove community structure in Papuan Small Islands, a case study in Biak Regency. IOP Conf Ser 550:012002. https://doi.org/10.1088/1755-1315/550/1/012002/meta

Divinubun MI, Kumalasari L, Meishah N, Ma'arif S (2022) Analisis Vegetasi Mangrove di Pulau Arar Distrik Mayamuk Kabupaten Sorong. Jurnal Aquafish Saintek 2:1–7

Djamaluddin R (2018) The mangrove flora and their physical habitat characteristics in Bunaken National Park, North Sulawesi, Indonesia. Biodivers J Biol Divers 19:1303–1312. https://doi.org/10.13057/biodiv/d190417

Djamaluddin R, Kaumbo MA, Djabar B (2019) The present condition of the mangrove environment and community structure in Tomini Gulf, Sulawesi, Indonesia. Jurnal Ilmu dan Teknologi Kelautan Tropis 11:601–614. https://doi.org/10.29244/jitkt.v11i3.21986

Djamaluddin R (2018) Mangrove-Biologi, Ekologi, Rehabilitasi, dan Konservasi

Donato DC, Kauffman JB, Murdiyarso D, Kurnianto S, Stidham M (2011) Mangrove are among the most carbon-rich forests in the tropics. Nat Geosci 4:293–297. https://doi.org/10.1038/ngeo1123

Duke N, Kathiresan K, Salmo III SG, Fernando ES, Peras JR, Sukardjo S, Miyagi T, Ellison J, Koedam NE, Wang Y, Primavera J, Jin Eong O, Wan-Hong Yong J, Ngoc Nam V (2010) *Bruguiera hainesii*. The IUCN red list of threatened species 2010: e.T178834A7621565. https://doi.org/10.2305/IUCN.UK.2010-2.RLTS.T178834A7621565.en Accessed on 01 Oct 2023

Efriyeldi S, Effendi I, Almanar IP, Syakti AD (2023) The mangrove ecosystem in a harbor-impacted city in Dumai, Indonesia: a conservation status. Reg Stud Mar Sci 65:103092. https://doi.org/10.1016/j.rsma.2023.103092

Eni K (2021) Spesies dan karakteristik tumbuhan ekosistem mangrove berdasarkan hasil survei di kawasan Teluk Bungus-Padang. Jurnal Kependudukan Dan Pembangunan Lingkungan 2:9–18

Farid A, Rosi MF, Arisandi A (2022) Struktur komunitas mangrove di Ekowisata Mangrove Lembung, Kecamatan Galis, Kabupaten Pamekasan. Jurnal Kelautan Nasional 17:231–242. https://doi.org/10.15578/jkn.v17i3.11210

Farista B, Virgota A (2021) The Assessment of Mangrove Community Based on Vegetation Structure at Cendi Manik, Sekotong District, West Lombok, West Nusa Tenggara. J. Biologi Tropis. 21:1021–1029. https://doi.org/10.29303/jbt.v21i3.3047

Febriansyah Hartono D, Negara BFSP, Renta PP, Sar YP (2018) Struktur komunitas hutan mangrovdi Pulau Baai, Kota Bengkulu. Jurnal Enggano 3:112–128. https://doi.org/10.31186/jenggano.3.1.112-128

Gabi FG, Sondak CFA, Kumampung DRH, Darwisito S, Ompi M, Rembet UNWJ (2021) Struktur komunitas mangrove Gamlamo, Kecamatan Jailolo, Halmahera Barat, Provinsi Maluku Utara. J Pesisir dan Laut Tropis 9:34–43. https://doi.org/10.35800/jplt.9.3.2021.36489

Hadinata FW, Khayani DN, Tria H, Zurba N (2020) Pengembangan ekowisata mangrove berbasis konservasi di pesisir Kabupaten Kubu Raya, Kalimantan Barat. J Aceh Aquat Sci. https://doi.org/10.35308/.v4i1.2720
Haerul (2016) Analisis faktor—faktor yang mempengaruhi efektivitas pengelolaan ekosistem mangrove berbasis masyarakat (studi kasus pesisir Kabupaten Pangkep. Provinsi Sulawesi Selatan). Master Thesis, Institut Pertanian Bogor
Hakim MR (2022) Struktur komunitas mangrove di Pulau Pemagaran, Kepulauan Seribu, DKI Jakarta. Marlin 3:295–304
Hakim MR, Krisnafi Y, Prayitno MRE (2021) Struktur komunitas mangrove di kawasan mangrove Bulaksetra, Kabupaten Pangandaran. Marlin 2:55–61
Halim TC, Adibrata S, Pratiwi FD (2022) Analisis vegetasi dan struktur komunitas mangrove di Sungai Bunting Lestari Kecamatan Belinyu, Kabupaten Bangka. Aquatic Science 4:1–10
Hamuna B, Tanjung RHR (2018) Deteksi perubahan luasan mangrove Teluk Youtefa Kota Jayapura menggunakan citra landsat multitemporal. Majalah Geografi Indones 32:115–122. https://doi.org/10.22146/mgi.33755
Hamuna B, Sari AN, Megawati R (2018) Kondisi hutan mangrove di Kawasan Taman Wisata Alam Teluk Youtefa, Kota Jayapura. Majalah Ilmiah Biologi Biosfera 35:75–83
Hanggara BB (2016) Laju sedimentasi dan akumulasi sedimen tanah hutan mangrove di Kabupaten Deli Serdang, Sumatera Utara. Undergraduate Thesis, Institut Pertanian Bogor
Hansen MF, Ang A, Trinh TTH, Sy E, Paramasivam S, Ahmed T, Dimalibot J, Jones-Engel L, Ruppert N, Griffioen C, Lwin N, Phiapalath P, Gray R, Kite S, Doak N, Nijman V, Fuentes A, Gumert MD (2022) *Macaca fascicularis* (amended version of 2022 assessment). The IUCN red list of threatened species 2022: e.T12551A221666136. https://doi.org/10.2305/IUCN.UK.2022-2.RLTS.T12551A221666136.en Accessed on 29 Nov 2023
Hapsari AS, Sugandi D, Ridwana R, Himayah S (2022) Analisis vegetasi mangrove di Kawasan Hutan Mangrove Karangsong, Kabupaten Indramayu, Jawa Barat. Jurnal Perikanan dan Kelautan 12:78–92. https://doi.org/10.33512/jpk.v12i1.14800
Hariyanto S, Fahmi AK, Soedarti T, Suwarni EE (2019) Vegetation and community structure of mangrove in Bama Resort Baluran National Park Situbondo East Java. Biosaintifika 11:132–138. https://doi.org/10.15294/biosaintifika.v11i1.19111
Hartati, Harudu L (2016) Identifikasi jenis—jenis kerusakan ekosistem hutan mangrove akibat aktivitas manusia di Kelurahan Lowu—lowu Kecamatan Lea—lea Kota Bau—bau. Jurnal Penelitian Pendidikan Geografi 1:30–45
Hasyim AF, Mulyadi A, Efriyeldi E (2022) Mangrove vegetation community structure in Sungai Sembilan Sub-District, Dumai City. J Coast Ocean Sci 3:75–84. https://doi.org/10.31258/jocos.3.1.75-84
Heatubun CD, Wanma JF, Matani OP, Batorinding E, Wanma AO (2019) Laporan struktur dan komposisi jenis mangrove—Ekspedisi mangrove Papua Barat. BPPD dan UNIPA, Papua
Huang Y, Tan F, Su G, Deng S, He H, Shi S (2008) Population genetic structure of three tree species in the mangrove genus (Rhizophoracecae) from the Indo-West Pacific. Genetica. 133:47–56. https://doi.org/10.1007/s10709-007-9182-1
Hulopi M, de Queljoe KM, Uneputty PA (2022) Keanekaragaman gastropoda di ekosistem mangrove pantai Negeri Passo Kecamatan Baguala Kota Ambon. Triton 18:121–132. https://doi.org/10.30598/TRITONvol18issue2page121-132
Hutasoit YH, Melki S (2017) Struktur vegetasi mangrove alami di areal Taman Nasional Sembilang Banyuasin Sumatera Selatan. Maspari J 9:1–8
Ilana N, Cintamulya I (2021) Identification of mangrove diversity and environmental conservation in the Tundung Musuh Conservation Area of Tuban Regency. In: Proceeding of international conference in education, science, and technology pp 431-442
Ilman M, Dargusch P, Dart P, Onrizal, (2016) A historical analysis of the drivers of loss and degradation of Indonesia's mangrove. Land Use Policy 54:448–459. https://doi.org/10.1016/j.landusepol.2016.03.010
Imamsyah A (2017) Struktur dan distribusi vegetasi mangrove di Taman Hutan Ngurai Rai, Bali. Master Thesis, Institut Pertanian Bogor
Imran A, Efendi I (2016) Inventarisasi mangrove di pesisir Pantai Cemara Lombok Barat. JUPE 1:105–112. https://doi.org/10.58258/jupe.v1i1.66
Irpan FB, Manurung TF, Muflihati, (2017) Komposisi dan struktur vegetasi penyusun zonasi hutan mangrove Tanjung Prapat Muda – Tanjung Bakau Kabupaten Kubu Raya. Jurnal Hutan Lestari 5:104–112
Irwansah Sugiyarto, Mahajoeno E (2019) Struktur komunitas ekosistem mangrove di Teluk Serewe Pulau Lombok Nusa Tenggara Barat. Bioeksperimen 5:126–130. https://doi.org/10.23917/bioeksperimen.v5i2.9242

Jacobs R, Kusen JD, Sondak CFA, Boneka FB, Worouw V, Mingkid WM (2019) Struktur komunitas ekosistem mangrove dan kepiting bakau di Desa Lamanggo dan Desa Tope, Kecamatan Biaro, Kabupaten Kepulauan Siau, Tagulandang Biaro. Jurnal Pesisir dan Laut Tropis 1:20–28. https://doi.org/10.35800/jplt.7.1.2019.22817

Janiarta MA, Safnowandi Armiani S (2021) Struktur komunitas mangrove di pesisir pantai Cemara Selatan Kabupaten Lombok Barat sebagai bahan penyusunan modul ekologi. BIOMA 3:60–71. https://doi.org/10.31605/bioma.v3i1.1030

Japa L, Santoso D (2019) Analisis komunitas mangrove di Kecamatan Sekotong Lombok Barat NTB. Jurnal Biologi Tropis 19:25–33. https://doi.org/10.29303/jbt.v19i1.1001

Jufia TO, Gazali M, Marlian N (2021) Struktur komunitas mangrove di Pesisir Lhok Bubon, Aceh Barat. Jurnal La'ot Ilmu Kelautan 3:99–115

Karnanda M, Muchlisin ZA, Sarong MA (2016) Struktur komunitas mangrove dan strategi pengelolaannya di Kecamatan Pidie, Provinsi Aceh, Indonesia. Depik 5:113–127. https://doi.org/10.13170/depik.5.3.5577

Kathiersan K, Bingham BL (2001) Biology of mangrove and their ecosystems. Academic Press, Cambridge

Khairuddin B (2016) Strategi pengelolaan ekosistem mangrove yang terpadu dan berkelanjutan di Kabupaten Mempawah Provinsi Kalimantan Barat. Master Thesis, Institut Pertanian Bogor

Khaliza N, Abdunnur RA (2022) Analisis vegetasi mangrove di Desa Kersik Kabupaten Kutai Kartanegara. Kalimantan Timur Tropic Aqua Scie 1:98–103

Khoo M, Basak S, Sivasothi N, de Silva PK, Reza Lubis I (2021) *Lutrogale perspicillata*. The IUCN red list of threatened species 2021: e.T12427A164579961. https://doi.org/10.2305/IUCN.UK.2021-3.RLTS.T12427A164579961.en Accessed on 29 Nov 2023

Khorimatun S, Takarina ND, Soedjiarti T (2019) The community structure of plant-associated mangrove at Blanakan Fishpond Area, Subang, West Java. In AIP Conference Proceedings 2168:1–9. https://doi.org/10.1063/1.5132512

Komalasari IN, Diantari R, Maharani HW (2022) Dinamika Nitrat (NO_3) dan Fosfat (PO_4) Pada Kerapatan Mangrove Yang Berbeda di Pantai Ringgung, Pesawaran, Lampung. AQUACOASTMARINE 1:16–25. https://doi.org/10.32734/jafs.v1i1.8613

Kresnasari D, Gitarama AM (2021) Struktur Dan Komposisi Vegetasi Mangrove Di Kawasan Laguna Segara Anakan Cilacap. Jurnal Bioterdidik 9:202–216. https://doi.org/10.23960/jbt.v9i3.23026

Kuncoro I, Arotonang AB, Helena S (2019) Analisis vegetasi mangrove di Muara Sungai Peniti, Kabupaten Mempawah. Jurnal Laut Khatulistiwa 2:32–38. https://doi.org/10.26418/lkuntan.v2i1.30191

Kurniawansyah A, Manessa MD, Hartati AP (2022) Luasan dan Kerapatan ekosistem mangrove di Kecamatan Cilamaya Wetan Kabupaten Karawang. Majalah Geografi Indones. https://doi.org/10.22146/mgi.75345

Kuroda Y (2000) Variability of currents of the Northern Coastal of New Guinea. J Oceanogr 56:103–116. https://doi.org/10.1023/A:1011122810354

Kusmana C (2014) Distribution and current status of mangrove forest in Indonesia. In: Hanum IF, Hakeem ALKR, Ozturk M (eds) Mangrove ecosystems of Asia: status, challenges, and management strategies. Springer, New York, pp 37–60

Kusmana C, Ningrum DRP (2016) Tipologi dan kondisi vegetasi kawasan mangrove Bulaksetra Kabupaten Pangandaran Provinsi Jawa Barat. Jurnal Silvikultur Tropika 7:137–145

Lekitoo K, Tambing Y (2018) Struktur vegetasi mangrove di pesisir Sumuri, Teluk Bintuni. Papua Barat Vogelklop 1(1):76–81

Lestariningsih WA, Rahman I, Buhari N (2022) Kerapatan dan tutupan kanopi ekosistem mangrove di Desa Wisata Pare Mas Lombok Timur. J Mar Res 11:367–373. https://doi.org/10.14710/jmr.v11i3.34903

Lewerissa YA, Sangaji M, Latumahina MB (2018) Pengelolaan mangrove berdasarkan tipe substrat di perairan Negeri Ihamahu Pulau Saparua. Jurnal Triton 14:1–9

Lisna MA, Toknok B (2017) Potensi vegetasi hutan mangrove di wilayah pesisir pantai Desa Khatulistiwa Kecamatan Tinombo Selatan Kabupaten Parigi Moutong. Warta Rimba 5:3–70

Madiama S, Muryani C, Santoso S (2016) Kajian perubahan luas dan pemanfaatan serta persepsi masyarakat terhadap pelestarian hutan mangrove di Kecamatan Teluk Ambon Baguala. Jurnal GeoEco 2:170–183

Makawaehe VV, Sondak CF, Rumengan AP, Kaligis EJ, Roeroe KA, Kondoy CI (2022) Struktur komunitas kawasan mangrove di Desa Talengen Kecamatan Tabukan Tengah Kabupaten Kepulauan Sangihe. Jurnal Pesisir Dan Laut Tropis 10:67–78

Manihuruk AQT, Restu IW, Kartika IWD (2021) Strategi pengelolaan ekowisata berbasis konservasi pada obyek wisata alam trekking di Tahura, Ngurah Rai. Bali Cur Trend Aqua Scie 4:133–140

Marasabessy I, Badarudin I, Rumlus A (2021) Tingkat kerapatan dan tutupan relatif mangrove di Taman Wisata Klawalu Kota Sorong Papua Barat. Grouper 12:1–10

Mariati W (2016) Pengembangan ekowisata di kawasan mangrove Desa Anak Setatah Kabupaten Kepulauan Meranti Provinsi Riau. Master Thesis, Institut Pertanian Bogor
Marini KAA, Nurrahman YA (2018) Struktur komunitas hutan mangrove di Desa Bakau Kecil Kabupaten Mempawah Kalimantan Barat. Jurnal Laut Khatulistiwa 1:73–80
Martuti NKT (2017) Keanekaragaman mangrove di wilayah tapak, Tugurejo Semarang. Jurnal MIPA 36:123–130
Martuti NKT, Hidayah I, Margunani (2018) The role of mangrove in the development of Batik on the coast of Semarang City. National seminar on conservation and using natural diversity to national welfare pp 45–52
Mayor T, Simbala HEI, Koneri R (2017) Keragaman mangrove di Pulau Mansuar Kabupaten Raja Ampat Provinsi Papua Barat. J of Bioslogos 7:41–48. https://doi.org/10.35799/jbl.7.2.2017.18576
Meidiana V, Apriansyah Safitri I (2019) Struktur komunitas dan estimasi karbon sedimen mangrove di Desa Sebubus Kabupaten Sambas Kalimantan Barat. Jurnal Laut Khatulistiwa 2:107–117. https://doi.org/10.26418/lkuntan.v2i3.35842
Mendrofa S (2017) Potensi dan strategi pengelolaan ekosistem mangrove di Kecamatan Sawo, Kabupaten Nias Utara, Provinsi Sumatera Utara. Master Thesis, Institut Pertanian Bogor
Ministry of Environment and Forestry (2021) Peta Mangrove Nasional Tahun 2021. Direktorat Konservasi Tanah dan Air. Jakarta p 181
Moha Y, Bay MKA, Sentia S, Kasim F (2022) Analisis kondisi eksisting struktur komunitas mangrove Kawasan Pesisir Bolihutuo Kabupaten Boalemo Provinsi Gorontalo. Acta Aquat 9:65–71. https://doi.org/10.29103/aa.v9i2.8122
Momo LH, Rahayu WS (2018) Analisis vegetasi hutan mangrove di Desa Wambona Kecamatan Wakorumba Selatan, Kabupaten Muna, Indonesia. Jurnal Akuakultur, Pesisir dan Pulau-pulau Kecil 2:10–16. https://doi.org/10.29239/j.akuatikisle.2.1.10-16
Mughofar A, Masykuri M, Setyono P (2018) Zonasi dan komposisi hutan mangrove di pantai Cengkrong Desa Karanggandu Kabupaten Trenggalek Propinsi Jawa Timur. Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan 8:77–85
Muharamsyah S, Anwari MS, Ardian H (2019) Keanekaragaman jenis mangrove di Desa Mendalok Kecamatan Sungai Kunyit Kabupaten Mempawah. Jurnal Hutan Lestari 7:189–197. https://doi.org/10.26418/jhl.v7i3.35903
Murdiyarso D, Purbopuspito J, Kauffman JB, Warren MW, Sasmito SD, Donat DC, Kurnianto S (2015) The potential of Indonesian mangrove forests for global climate change mitigation. Nat Clim Chang 5:8–11. https://doi.org/10.1038/nclimate2734
Naharuddin N (2020) Struktur dan asosiasi vegetasi mangrove di Hilir DAS Torue, Parigi Moutong, Sulawesi Tengah. Jurnal Sylva Lestari 8:378–389. https://doi.org/10.23960/jsl38378-389
Namakule U, Melsasail KM (2021) Struktur komunitas mangrove di perairan pantai Desa Sehati Kabupaten Maluku Tengah. Jurnal Biologi Udayana 25:100–110. https://doi.org/10.24843/JBIOUNUD.2021.v25.i02.p01
Ndede IG, Tasirin JS, Sumakud MYMA (2017) Komposisi dan struktur vegetasi hutan mangrove di Desa Sapa Kabupaten Minahasa Selatan. Cocos 1:79–84
Noorhidayah SK, Ma'ruf A, (2007) Struktur dan komposisi vegetasi habitat bekantan pada hutan mangrove di bagian hilir Sungai Wain Kalimantan Timur. Jurnal Penelitian Hutan Dan Konservasi Alam 4:107–116
Nopiana M, Yulianda F, Sulistiono FA (2020) Condition of shore and mangrove area in the coastal area of Karawang Regency, Indonesia. AACL Bioflux 13:553–569
Nordhaus I, Wolff M, Diele K (2006) Litter processing and food intake of the mangrove crab *Ucides cordatus* in the high intertidal forest in Northern Brazil. Estua, Coast, Shelf Scie 67:239–250
Noveliyana Y (2016) Pengelolaan ekosistem mangrove berkelanjutan di pesisir Kabupaten Tanggerang, Provinsi Banten. Master Thesis, Institut Pertanian Bogor
Nuraya T, Zuswiryati Z, Sari DW (2022) Identifikasi dan keanekaragaman mangrove di Desa Bakau Besar dan Bakau Kecil Kabupaten Mempawah Kalimantan Barat. Jurnal Laut Khatulistiwa 5:138–149. https://doi.org/10.26418/lkuntan.v5i3.57019
Nurdiansah D, Dharmawan IWE (2021) Struktur komunitas dan kondisi kesehatan mangrove di Pulau Middleburg-Miossu, Papua Barat. Jurnal Ilmu dan Teknologi Kelautan Tropis 13:81–96. https://doi.org/10.29244/jitkt.v13i1.34484
Nurhati IS, Murdiyarso D (2022). Strategi Nasional Pengelolaan Ekosistem Mangrove: Sebagai Rujukan Konservasi dan Rehabilitasi Kawasan Pesisir untuk Tujuan Pembangunan Berkelanjutan dan Pembangunan Rendah Karbon. Working Paper 10. Bogor, Indonesia: CIFOR

Octavina C, Ulfah M, Sakinah R, Azis SA, Razi NM, Fazillah MR, Agustiar M (2022) Community structure of mangrove in Lambadeuk village, Aceh Besar regency, Indonesia. In: E3S Web of Conferences 339:03005
Oni Kusmana C, Basuni S (2019) Succes story rehabilitasi ekosistem mangrove di Pantai Karangsong Kabupaten Indramayu. JPSL 9:447–487. https://doi.org/10.29244/jpsl.9.3.477-487
Onrizal SN, Afifuddin Y (2016) Keanekaragaman komunitas mangrove di sekitar Kawasan Wisata Mangrove Kampoeng Nipah Sumatera Utara. J Universitas Sumatera Utara 1:64–69
Opa ET, Kusen JD, Kepel RC, Jusuf A, Lumingas LJ (2019) Community structure of mangrove in Mantehage Island and Paniki Island, North Sulawesi, Indonesia. Aquac Aquar Conserv Legis 12:1388–1403
Osmar M (2016) Studi analisis komposisi dan struktur tegakan hutan mangrove di Desa Tanjung Bunga Kabupaten Konawe Utara. Master Thesis, Universitas Halu Oleo
Palguna IBA, Ardhana IPG, Arthana IW (2017) Struktur dan keanekaragaman jenis mangrove di Kawasan Hutan Mangrove Nusa Lembongan, Kecamatan Nusa Penida, Kabupaten Klungkung. Ecothropic 11:108–115. https://doi.org/10.24843/EJES.2017.v11.i02.p07
Pannell CM, Schnitzler J, Muellner-Riehl AN (2020) Two new species and a new species record of *Aglaia* (Meliaceae) from Indonesia. PhytoKeys 155:33–51. https://doi.org/10.3897/phytokeys.155.53833
Paruntu CP, Windarto AB, Rumengan AP (2017) Karakteristik komunitas mangrove Desa Matondai Kecamatan Pinolosian Timur Kabupaten Bolaang Mongondow Selatan Provinsi Sulawesi Utara. Jurnal Pesisir dan Laut Tropis 1:53–65. https://doi.org/10.35800/jplt.5.2.2017.16619
Poedjirahajoe E, Marsono D, Wardani FK (2017) Penggunaan principal component analysis dalam distribusi spasial vegetasi mangrove di Pantai Utara Pemalang. Jurnal Ilmu Kehutanan 11:29–42. https://doi.org/10.22146/jik.24885
Prastomo RH, Herawatingsih R, Latifah S (2017) Keanekaragaman vegetasi di kawasan hutan mangrove Desa Nusapati Kabupaten Mempawah. Jurnal Hutan Lestari 5:556–562
Pratama SS (2018) Analisis vegetasi mangrove di muara Desa Kurau Kecamatan Koba Kabupaten Bangka Tengah Provinsi Kepulauan Bangka Belitung. Undergraduate Thesis, Universitas Islam Negeri Raden Fatah
Pratiwi R, Maharani HW, Delis PC, Mahardika AH (2022) Karakteristik struktur komunitas mangrove di wilayah pesisir Kabupaten Tangerang, Banten. JFMR 6:9–18. https://doi.org/10.21776/ub.jfmr.2022.006.02.2
Pribadi R, Khakim A, Nurdianto F (2017) Structure and composition of mangrove vegetation in Pantai Mekar and Pantai Harapan Jaya Village, District of Muara Gembong, Bekasi Regency, West Java Province. The 6th results of fisheries and marine research of Diponegoro University 819–828
Prinasti NKD, Dharma IGBS, Suteja Y (2020) Struktur komunitas vegetasi mangrove berdasarkan karakteristik substrat di Taman Hutan Raya Ngurah Rai, Bali. J Mar Aquat Sci 6:90–99. https://doi.org/10.24843/jmas.2020.v06.i01.p11
Putra A, Salim D, Tony F, Fitrianto I (2022) Analisis vegetasi mangrove di Desa Mekarsari Kabupaten Tanah Laut(Studi Kasus PT. Arutmin Indonesia Tambang Mekarsari). Environ Pollut J 2:311–316. https://doi.org/10.58954/epj.v2i1.84
Rabiati M, Kartono AP, Masyud B (2016) Populasi bekantan di Suaka Margasatwa Kuala Lupak, Kalimantan Selatan, Indonesia. Media Konservasi 20:242–251
Rafdinal R, Linda R, Raynaldo A (2022) Community structure and potential carbon stock of mangrove forest in Malek Village, Paloh District, Sambas Regency, Indonesia. Aquat Sci Manag 10:16–22
Rahayu SM, Syuhriatin W (2018) Keanekaragaman mangrove di Desa Gedangan, Kecamatan Purwodadi, Kabupaten Purworejo Jawa Tengah. Enviroscienteae 14:62–69
Rahim S, Baderan DWK (2019) Komposisi jenis, struktur komunitas, dan keanekaragaman mangrove asosiasi Langge Kabupaten Gorontalo Utara – provinsi Gorontalo. Jurnal Ilmu Lingkungan 7:181–188
Rahim S, Baderan DWK, Hamidun MS (2017) The density, composition, and mangrove forest habitat in Torosiaje Jaya village, Gorontalo Indonesia coastal area. Bonorowo Wetl 7:38–42. https://doi.org/10.13057/bonorowo/w070108
Rahim S, Baderan DWK, Hamidun MS (2018) Keanekaragaman spesies, biomassa dan stok karbon pada hutan mangrove Torosiaje Kabupaten Pohuwato-Provinsi Gorontalo. Jurnal Pro-Life 5:650–665
Rahman, Effendi H, Rusmana I (2017) Estimation of stock and carbon absorption of mangroves in Tallo River Makassar. J For Sci 11:19–28
Rahman Yulianda F, Rusmana I, Wardiatno Y (2019) Production ratio of seedlings and density status of mangrove ecosystem in coastal areas of Indonesia. Adv Environ Biol 13:13–20. https://doi.org/10.22587/aeb.2019.13.6.3

Rahman Wardiatno Y, Yulianda F, Rusmana I (2020) Sebaran spesies dan status kerapatan ekosistem mangrove di pesisir Kabupaten Muna Barat, Sulawesi Tenggara. JPSL 10:461–478. https://doi.org/10.29244/jpsl.10.3.461-478
Rahman WY, Yulianda F, Rusmana I (2020b) Socio-ecological system of carbon-based mangrove ecosystem on the coast of West Muna Regency, Southeast Sulawesi, Indonesia. AACL Bioflux 13:518–528
Rahman WY, Yulianda F, Rusmana I (2020c) Produksi serasah musiman pada berbagai spesies mangrove di pesisir Kabupaten Muna Barat—Sulawesi Tenggara. Jurnal Ilmu Pertanian Indonesia 25:325–335
Rahman WY, Yulianda F, Rusmana I, Bengen DG (2020d) Metode dan Analisis Studi Ekosistem Mangrove. IPB Press, Bogor
Rahmani AV, Idrus AA, Mertha IG (2023) The mangrove community structure in Regional Marine Conservation Area Gili Sulat West Nusa Tenggara. Jurnal Biologi Tropis 23:42–51. https://doi.org/10.29303/jbt.v23i1.4597
Ratnasari Fahrizal, Dirhamsyah M (2017) Pemanfaatan vegetasi mangrove di Pulau Padang Tikar Kecamatan Batu Ampar Kabupaten Kubu Raya. Jurnal Tengkawang 7:110–115. https://doi.org/10.26418/jt.v7i2.23783
Renta PP, Pribadi R, Zainuri M, Anggraini M, Utami F (2016) Struktur komunitas mangrove di Desa Mojo Kabupaten Pemalang Jawa Tengah. Jurnal Enggano 1:1–10. https://doi.org/10.31186/jenggano.1.2.1-10
Rifanjani S, Lugita E, Anwari MS, Darwati H, Munadian M (2022) Keanekaragaman jenis vegetasi di kawasan hutan mangrove muara Sungai Kakap Kabupaten Kubu Raya. Jurnal Hutan Lestari 10:436–446. https://doi.org/10.31186/jenggano.1.2.1-10
Ripai A, Kamarubayana L (2016) Penangkaran buaya muara *(Crocodylus porosus*) di PT. Makmur Abadi Permai Samarinda Kalimantan Timur. Jurnal Agrifor 15:155–170
Rivilgo W, Tanjung A, Ghalib M (2017) Struktur komunitas mangrove di perairan Desa Kuala Alam Kecamatan Bengkalis Kabupaten Bengkalis Provinsi Riau. Undergraduate Thesis, Universitas Riau
Rizal LS (2019) Identifikasi jenis mangrove di Kawasan Konservasi Laut Daerah (KKLD) Gili Sulat – Gili Lawang Kabupaten Lombok Timur. JUPE 5:354–363. https://doi.org/10.58258/jupe.v4i5.1093
Rizwany Y, Yunasfi MA (2016) Struktur dan komposisi vegetasi mangrove di dusun II desa Pulau Sembilan, Kecamatan Pangkalan Susu, Kabupaten Langkat, Provinsi Sumatera Utara. J Aquacoastmarine 13:1–11
Rofi'i I, Poedjirahajoe E, Marsono D (2021) Keanekaragaman dan pola sebaran jenis mangrove di SPTN Wilayah I Bekol, Taman Nasional Baluran. Jurnal Kelautan 14:210–222. https://doi.org/10.21107/jk.v14i3.9293
Ronavia A, Restu IW, Wijanegara IK (2020) Potensi Dan sebaran jenis Pidada (Sonneratia caseolaris) berdasarkan jenis tanah di Tahura Ngurah Rai-Bali. J Mar Aquat Sci 6:185–195. https://doi.org/10.24843/jmas.2020.v06.i02.p5
Rumalean AS, Purwanti F, Hendrarto B, Hutabarat S (2019) Struktur komunitas hutan mangrove pada kawasan Mempawah Mangrove Park di Desa Pasir Mempawah Hilir. Jurnal Ilmu Dan Teknologi Kelautan Tropis 11:221–230
Ruruh A, Ernikawati E (2021) Struktur vegetasi mangrove di pesisir Pantai Desa Dambalo Kecamatan Tomilito Kabupaten Gorontalo Utara. Jurnal Penelitian Kehutanan BONITA 3:1–8. https://doi.org/10.55285/bonita.v3i1.537
Sabar M, Samman A, Serosero RH, Kadir MA (2022) Mangrove species density and dynamics of Nitrate (NO_3) on sediments in the Manumadehe Island, South Jailolo District, West Halmahera Regency. Jurnal Agrikan (agribisnis Perikanan) 15:370–380
Saman RU (2017) Keberlanjutan pengelolaan ekosistem mangrove di Kecamatan Bolaang Mongondow Selatan, Provinsi Sulawesi Utara. Master Thesis, Institut Pertanian Bogor
Samori F, Bawole R, Tebay S (2021) Struktur dan vegetasi mangrove di Warambui Distrik Oransabari Manokwari Selatan Provinsi Papua Barat. JRPK 3:347–357
Sani LH, Candri DA, Ahyadi H, Farista B (2019) Struktur vegetasi mangrove alami dan rehabilitasi pesisir selatan Pulau Lombok. Jurnal Biologi Tropis 19:268–276. https://doi.org/10.29303/jbt.v19i2.1363
Sari QW, Pratama FAP (2022) Analisis struktur dan komunitas vegetasi ekosistem mangrove di Pantai Cipatujah Tasikmalaya Jawa Barat. Maspari J 14:25–35. https://doi.org/10.56064/maspari.v14i1.15935
Sari A, Tuwo A, Saru A, Rani C (2022) Diversity of fauna species in the mangrove ecosystem of Youtefa Bay Tourism Park, Papua, Indonesia. Biodiversitas 23:4490–4500. https://doi.org/10.13057/biodiv/d230915
Sarnubi S, Sarno S, Marisa H (2020) Struktur dan komposisi mangrove di arboretum Taman Nasional Berbak dan Sembilang Kabupaten Banyuasin Provinsi Sumatera Selatan. Sriwijaya Bioscientia 1:21–30. https://doi.org/10.56064/maspari.v14i1.15935

Saru A, Amri K, Mardi, (2017) Konektivitas struktur vegetasi mangrove dengan keasaman dan bahan organik total pada sedimen di Kecamatan Wonomulyo Kabupaten Polewali Mandar. Spermonde 3:1–6

Saru A, Idrus R, Ilham M (2019) The mangrove ecosystem has the potential for educational tour development around pond education of Hasanuddin Univeristy (UNHAS) in Mallusteasi District, Barru Regency. Jurnal Ilmu Kelautan Spermonde 5:70–76. https://doi.org/10.20956/jiks.v5i2.8934

Sasaki, H, Aadrean A, Kanchanasaka B, Reza Lubis I, Basak, S (2021) *Lutra sumatrana.* The IUCN red list of threatened species 2021: e.T12421A164579488. https://doi.org/10.2305/IUCN.UK.2021-3.RLTS.T12421A164579488.en Accessed on 29 Nov 2023

Sasauw J, Kusen JD, Schaduw JNW (2016) Struktur komunitas mangrove di Desa Tongkaina, Manado. Jurnal Pesisir dan Laut Tropis 2:17–22. https://doi.org/10.35800/jplt.4.2.2016.13929

Sasmito SD, Basyuni M, Kridalaksana A et al (2023) Challenges and opportunities for achieving sustainable development goals through restoration of Indonesia's mangrove. Nat Ecol Evol 7:62–70. https://doi.org/10.1038/s41559-022-01926-5

Sawitri R, Bismark M, Karlina E (2013) Ekosistem mangrove sebagai objek ekowisata alam di kawasan konservasi mangrove dan bekantan di Kota Tarakan. Jurnal Penelitian Hutan dan Konservasi Alam 10:297–314. https://doi.org/10.20886/jphka.2013.10.3.297-314

Schaduw JNW (2018) Struktur komunitas dan keberlanjutan pengelolaan ekosistem mangrove pulau-pulau kecil (kasus pada Pulau Nain Kabupaten Minahasa Utara Provinsi Sulawesi Utara). Jurnal Ilmu Lingkungan 16:120–129. https://doi.org/10.14710/jil.16.2.120-129

Schaduw JNW (2019) Struktur komunitas dan persentase penutupan kanopi mangrove Pulau Sulawati Kabupaten Kepulauan Raja Ampat Provinsi Papua Barat. Majalah Geografi Indonesia 33:26–34. https://doi.org/10.22146/mgi.34745

Seran W (2019) Struktur dan komposisi hutan mangrove di Pantai Paradiso, Kota Kupang NTT. Jurnal Agribisnis Perikanan 12:34–42. https://doi.org/10.29239/j.agrikan.12.1.34-42

Setiawan H, Mursidin (2018) Karakteristik ekologi dan kesehatan hutan mangrove di Pulau Tanakeke Sulawesi Selatan. Jurnal Penelitian Kehutanan Wallacea 7:47–58

Setiawan MAN, Syahdan M, Hamdani H (2021) Analisis vegetasi mangrove dan hubungannya dengan parameter lingkungan di Kecamatan Takisung Kabupaten Tanah Laut. Mar Coast Small Islands J 1:32–43

Setyadi G, Pribadi R, Wijayanti DP, Sugianto DN (2021) Mangrove diversity and community structure of Mimika District, Papua, Indonesia. Biodivers J Biol Divers 22:3562–3570. https://doi.org/10.13057/biodiv/d220857

Setyowati E, Ngabekti S, Priyono B (2019) Konservasi buaya muara di Taman Margasatwa Semarang. Life Sci 8:34–40. https://doi.org/10.15294/lifesci.v8i1.29988

Siahaan VR, Handoko E, Barat WOB (2022) Struktur komunitas pohon mangrove Di Kawasan Desa Bagan Asahan Kecamatan Tanjung Balai Kabupaten Asahan. BEST J 5:440–445

Sidik AS (2010) The changes of mangrove ecosystems in Mahakam Delta, Indonesia: a complex socio-oenvironmental pattern of linkages in resources utilization. Borneo Res J 4:27–46

Sidik F, Supriyanto B, Krisnawati H, Muttaqin MZ (2018) Mangrove conservation for climate change mitigation in Indonesia. Wires Clim Change. https://doi.org/10.1002/wcc.529

Sievers M, Brown JJ, McGowan J, Turschwell MP, Buelow CA, Holgate B, Pearson RM, Adame MF, Andradi-Brown DA, Arnell A, Mackey BG et al (2023) Co-occurrence of biodiversity, carbon storage, coastal protection, and fish and invertebrate production to inform global mangrove conservation planning. Sci Total Environ 905:166357. https://doi.org/10.1016/j.scitotenv.2023.166357

Sipahelut P, Wakano D, Sahertian DE (2020) Keanekaragaman jenis dan dominansi mangrove di pesisir Pantai Desa Sehati Kecamatan Amahai, Kabupaten Maluku Tengah. Biosel 8:160–170. https://doi.org/10.33477/bs.v8i2.1145

Siringoringo YN, Djayus Y, Desrita, (2017) Struktur komunitas mangrove di hutan mangrove, Desa Belawan Sicanang, Kabupaten Medan Belawan, Provinsi Sumatera Utara. J Aquacoastmarine 5(2):1–7

Siska F (2016) Produktivitas dan laju dekomposisi serasah *Avicennia marina* dan R*hizophora apiculata* di Cagar Alam Pulau Dua Banten. Master Thesis, Institut Pertanian Bogor

Sitinjak FN (2017) Struktur komunitas hutan mangrove di Desa Mengkapan, Kecamatan Sungai Apit, Kabupaten Siak. Master Thesis, Universitas Riau

Situmorang ME, Alex DK, Meiske SS, Ridwan L, Joudy RRS, Rignolda D (2021) Struktur komunitas mangrove di Pantai Meras Kecamatan Bunaken Kota Manado Sulawesi Utara. JIP 9:271–280. https://doi.org/10.35800/jip.9.2.2021.35323

Soemodihardjo S, Wiroatmodjo P, Abdullah A, Tantra IGM, Soegiarto A (1993). In: Clough BF (ed) The economic and environmental values of mangrove forests and their present state of conservation in the South-East Asia/Pasific region. Jepang, ISME-ITTO-JIAM, pp 17–40

Sukardjo S (2010) *Heritiera globosa*. The IUCN red list of threatened species 2010: e.T178807A7612712. https://doi.org/10.2305/IUCN.UK.2010-2.RLTS.T178807A7612712.en Accessed on 01 Oct 2023.

Sukmarani D, Proklamasiningsih E, Susanto AH, Ardli ER, Sudiana E, Yani E (2021) Superoxide dismutase (SOD) activity of Ceriops zippeliana in Segara Anakan Cilacap (Indonesia) under heavy metal accumulation. Biodiv J Biol Divers 22:5627–5635. https://doi.org/10.13057/biodiv/d221259

Sulmartiwi L, Pujiastuti DY, Tjahjaningsih W, Jariyah, (2018) Potential of mangrove *Avicennia rumphiana* extract as an antioxidant agent using multilevel extraction. IOP Conf Ser. https://doi.org/10.1088/1755-1315/137/1/012075

Sunarni Maturbongs MR, Arifin T, Rahmania R (2019) Zonasi dan struktur komunitas mangrove di pesisir Kabupaten Merauke. Jurnal Kelautan Nasional 14:165–178. https://doi.org/10.15578/jkn.v14i3.7961

Suryani N (2018) Kajian ekosistem hutan mangrove di Muara Sungai Batang Manggung Kecamatan Pariaman Utara Kota Pariaman Provinsi Sumatera Barat. Jurnal Geografi 10:144–156. https://doi.org/10.24114/jg.v10i2.10411

Suryono CA (2012) Struktur populasi vegetasi mangrove di Laguna Segara Anakan Cilacap, Jawa Tengah. Indones J Mar Sci 11:112–118. https://doi.org/10.14710/ik.ijms.11.2.112-118

Susanto AH, Soedarti T, Purnobasuki H (2018) Mangrove community structure of Surabaya east coast. Vegetos 31:09–12. https://doi.org/10.5958/2229-4473.2018.00085.X

Suyadi NI, Sitepu AB (2021) Karakteristik vegetasi mangrove dan pemanfaatannya: Studi kasus di Seram Timur. Maluku J Kelautan Dan Perikanan Terapan 4:37–45

Suyadi, (2009) Kondisi hutan mangrove di Teluk Ambon: prospek dan tantangan. Berita Biologi 9:481–490

Syahrial LMK, Pranata E, Hamdani R, Syahrian W, Purnama DP, Kaprisai HMD (2017) Variasi geografik kerapatan mangrove dan kepadatan gastropoda serta keterkaitannya di Pulau Tunda Serang Banten, Indonesia. Biowallacea 4:591–601

Syahrial Bengen DG, Prartono T, Amin B (2018) Struktur demografi populasi *Rhizophora apiculata* di kawasan industri perminyakan Provinsi Riau. Jurnal Perikanan Tropis 5(2):189–197

Syahrial, (2018) Keadaan hutan mangrove di utara Indonesia berdasarkan indikator kualitas lingkungan dan indikator ekologi komunitas. Maspari J 10:89–96

Syarif W, Nasution S, Mubarak M (2022) Structure of the mangrove community in Batang Masang Beach Tiku V Jorong Tanjung Mutiara District Agam Regency West Sumatera. J Coast Ocean Sci 3:85–93. https://doi.org/10.31258/jocos.3.2.85-93

Tahir I, Paembonan RE, Harahap ZA, Akbar N, Wibowo ES (2017) Sebaran kondisi ekosistem hutan mangrove di kawasan Teluk Jailolo Kabupaten Halmahera Barat Provinsi Maluku Utara. Jurnal Enggano 2:143–155. https://doi.org/10.20886/jwas.v2i2.880

Tefarani R, Martuti NKT, Ngabekti S (2019) Keanearagaman spesies mangrove dan zonasi di wilayah Kelurahan Mangunharjo Kecamatan Tugu Kota Semarang. Life Sci 8:41–53. https://doi.org/10.15294/lifesci.v8i1.29989

Theresia (2016) Pengelolaan ekosistem mangrove di Taman Nasional Sembilang Kabupaten Banyuasin Provinsi Sumatera Selatan. Master Thesis, Institut Pertanian Bogor

Tolangara A, Ahmad H (2017) Kerapatan mangrove dan konservasinya di Bacan Kabupaten Halmahera Selatan, Provinsi Maluku Utara. Technol 6:22–29

Tony FTF, Putra A, Salim D, Fitrianto I (2022) Analisis vegetasi mangrove di Desa Mekarsari, Kabupaten Tanah Laut (Studi kasus PT. Arutmin Indonesia Tambang Mekarsari). Environ Pollut J 2:311–316

Tuasikal T (2020) Kerapatan ekosistem mangrove di Dusun Wael, Kabupaten Seram Bagian Barat. Jurnal Agrohut 11:25–32

Ula ED, Suhadi, Rohman F (2016) Struktur komunitas mangrove di Desa Mangunharjo Kecamatan Mayangan, Kota Probolinggo. In "Proceedings of biologi national seminar 96–102

Ulyah F, Hastuti ED, Prihastanti E (2022) Struktur komunitas vegetasi mangrove di pesisir Pantai Kepulauan Karimunjawa. Jurnal Ilmu Lingkungan 20:176–186. https://doi.org/10.14710/jil.20.1.176-186

Umroh AW, Sari SP (2016) Detection of mangrove distribution in Pongok Island. Proc. Environ Ser 33:253–257. https://doi.org/10.1016/j.proenv.2016.03.076

Utami AA (2022) Analisis vegetasi mangrove di Suaka Margasatwa Karang Gading dan Langkat Timur Laut. Jurnal Lingkungan Almuslim 1:8–15
Wanaputra AA, Poedjirahajoe E (2019) Struktur dan komposisi hutan mangrove di IUPHHK-HA PT. Bintuni Utama Murni Wood Industries Kabupaten Teluk Bintuni Provinsi Papua Barat. Jurnal Kehutanan Papuasia 5:111–123. https://doi.org/10.46703/jurnalpapuasia.Vol5.Iss2.142
Wang l, Mu M, Li X, Lin P, Wang W, (2010) Differentiation between true mangrove and mangrove associates based on leaf traits and salt contents. J Plant Ecol 4:292–301. https://doi.org/10.1093/jpe/rtq008
Wantoro W, Syahdan M, Salim D (2017) Struktur komunitas jenis mangrove di Kabupaten Tanah Laut Provinsi Kalimantan Selatan. Mar Coast Small Islands J 1:2–10
Wantoro W, Syahdan M, Salim D (2021) Struktur komunitas jenis mangrove di Kabupaten Tanah Laut Provinsi Kalimantan Selatan. Mar Coast Small Islands J 1:1–10
Wardhani MK (2011) Kawasan konservasi mangrove: suatu potensi ekowisata. Jurnal Kelautan. 4:60–76. https://journal.trunojoyo.ac.id/jurnalkelautan/article/view/891/784
Warpur M (2016) Struktur vegetasi hutan mangrove dan pemanfaatannya di kampung Ababiaidi Distrik Supiori Selatan Kabupaten Supiori. Jurnal Biodjati 1:19–26. https://doi.org/10.15575/biodjati.v1i1.1040
Warsidi ES (2017) Komposisi vegetasi mangrove di Teluk Balikpapan Provinsi Kalimantan Timur. J Argifor 16:115–124
Widyastuti F, Erianto RS (2017) Habitat bekantan (*Nasalis larvatus* Wurmb) di dalam dan sekitar areal IUPHHK-HT PT. Bina Silva Nusa Kecamatan Batu Ampar, Kabupaten Kubu Raya Provinsi Kalimantan Barat. Jurnal Hutan Lestari 5:610–617
Wiryono W, Hidayat MF, Malau H (2021) Studi tentang tumbuhan epifit hutan mangrove di Desa Pasar Ngalam Kecamatan Air Priukan Kabupaten Seluma. J Glob For Environ Sci 1:40–50
Yasser M, Hendri ORS, Irawan A, Sari LI (2021) Indeks nilai penting ekosistem mangrove di Kelurahan Kampung Baru Kecamatan Penajam Kabupaten Penajam Paser Utara. Berkala Perikanan Terubuk 49:1123–1130
Yoswaty D, Warningsih T, Batubara UM, Wahyuni I (2022) Karakteristik Hutan Mangrove di Desa Anak Setatah Provinsi Riau untuk Pengembangan Desa Wisata Berbasis Masyarakat. Jurnal Perikanan Dan Kelautan 27:114–123
Yudha RP, Sugito YS, Sillanpaa M, Nurvianto S (2021) Impact of logging on the biodiversity and composition of flora and fauna in the mangrove forests of Bintuni Bay, West Papua. Indones For Ecol Manag 488:119038. https://doi.org/10.1016/j.foreco.2021.119038
Yunus B, Omar SBA, Parawansa BS (2020) Study of mangrove community structure in Ujung Batu Beach Water, Flores Sea, Jeneponto District. Intl J Res-Granthaalayah 8:108–120. https://doi.org/10.29121/granthaalayah.v8.i5.2020.97
Zahdi FRM (2022) Biodiversity of mammals inhabits mangrove in Indonesia. Working Paper pp 1-8
Zamdial HD, Johan Y (2019) Struktur komunitas ekosistem mangrove di kawasan pesisir kota Mukomuko Kabupaten Mukomuko Provinsi Bengkulu. Jurnal Enggano 4:92–104
Zamdial, (2016) Analisa struktur komunitas hutan mangrove di Desa Pasar Sebelah Kecamatan Kota Mukomuko Kabupaten Mukomuko. Jurnal Enggano 1:29–37. https://doi.org/10.31186/jenggano.1.2.29-37
Zamroni Y (2017) Ekologi mangrove di perairan Teluk Sepi Lombok Barat. Bio Wallacea 3:79–83

Authors and Affiliations

Rahman[1] · Frijona F. Lokollo[1] · Gratia D. Manuputty[1] · Ronald D. Hukubun[1] · Krisye[1] · Maryono[2] · Mintje Wawo[3] · Yusli Wardiatno[4]

✉ Rahman
rahmanrajaali@gmail.com

[1] Department of Marine Science, Faculty of Fisheries and Marine Science, Pattimura University, Ambon, Indonesia

[2] Marine and Fisheries Agribusiness, Politeknik Negeri Sambas, Pontianak, Indonesia

[3] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Pattimura University, Ambon, Indonesia

[4] Department of Aquatic Resources Management, Fisheries and Marine Science Faculty, IPB University, Bogor, Indonesia