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Mangrove ecosystem provisioning services for the sustainability and diversity of bird species in the coastal region of Lombok Island, Indonesia

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Abstract. *Syukur A, Zulkifli L, Mahrus H. 2021. Mangrove ecosystem provisioning services for the sustainability and diversity of bird species in the coastal region of Lombok Island, Indonesia. Biodiversitas 24: 1589-1599.* Ecological services offered by mangroves are imperative for various faunal species. The present study is focused on assessing the role of mangroves in the sustainability and diversity of bird species in the coastal region of Lombok Island, Indonesia. The aims of the study are (i) to describe the conservation status of bird species and (ii) to describe the value of the ecological index of birds as an indicator of mangrove conservation. The species diversity of birds is assessed by observation, whereas the quadratic transect method is used to assess mangrove vegetation structure. Data analysis has been carried out using univariate statistical analysis, namely the Shanon-Wiener index (H'), Simpson Index (d), Evenness Index (E), Richness Index (R), and linear regression analysis. The genus *Rhizophora* and *Avicennia* species have an even distribution in the study area. *Rhizophora* species in the study area result from revegetation, whereas Avicennia species grow naturally. Altogether, a total of 19 bird species have been observed in the present study. Of these, eight species have a limited distribution, four bird species are Near Threatened (NT), and others are Least Concern (LC) concerning their conservation status. The estimated Diversity Index (H') is ranged between 3.09-3.67, whereas Evenness (E) and Richness (R) index are ranged between 0.72-0.85 and 7.09-10.33, respectively. The ecological index value shows that the research locations have high species diversity and richness, and species are evenly distributed across the sites. Therefore, the value of the index of bird ecology and the distribution of bird species are indicators of mangrove supply services for the preservation of birds at the study site. The study concluded that the diversity of ecological indices and the conservation status of birds are important information for the success of mangrove conservation through revegetation at the study site. However, a comprehensive study is needed on the functional relationship of mangrove supply services with the diversity of bird species to obtain validity and rehabilitation as conservation indicators.

Keywords: Birds, conservation status, ecological index, Lombok Island, mangrove services

INTRODUCTION

The protection and preservation of faunal diversity are among mangroves' highly appreciated ecological services (Nagelkerken et al. 2008). Furthermore, the complex structure of mangrove vegetation is an attribute that functions for protection, food supply and biodiversity maintenance, disaster mitigation, and carbon storage (Gnansounou et al. 2022; Kelleway et al. 2017; Zulhalifah et al. 2021). Therefore, conserving the mangroves is very important to preserve the valuable provision, regulation, and cultural services they offer (Burkhard et al. 2012; Mulyana et al. 2021). In this context, integrating the value of the mangrove ecosystem services through a participatory approach is imperative (Basyuni et al. 2019; Nugroho et al. 2022). Further, the provision of mangrove ecosystem services is an indicator of management (Friess et al. 2020; Uddin et al. 2021) and has a relationship with the needs of fauna to survive (Nurokhmah et al. 2019), such as Egrets (*Egretta* spp.), Charadriidae and Scolopacidae (Purify et al. 2019). Furthermore, birds often use the morphological parts of mangroves, stems, roots, and canopies as resting places (Nagelkerken et al. 2008). In addition, mangrove areas are places for birds to forage for food during low tide (Ginantra et al. 2020). Therefore, mangrove conservation is essential for protecting bird species diversity (Abdillah et al. 2020; Cita et al. 2019; Tjiong et al. 2021).

Deforestation and land conversion processes seriously threaten mangrove vegetation and surrounding areas (Basyuni et al. 2022). For example, in Southeast Asia, including eastern Indonesia, the main threat of mangrove damage is conversion to aquaculture land (Worthington and Spalding 2018). The rate of damage from the deforestation process, especially in Indonesia, reaches 52,000 ha/year (Murdiyarso et al. 2015), and most of the reclaimed mangrove areas are at low productivity (Ilman et al. 2016). As a result, the ecological services of mangroves are lost in many areas and affected coastal communities' income and food security (Reyes-Arroyo et al. 2021).

Birds need the natural integrity of mangroves for their mobility, especially migratory birds (Buelow and Sheaves 2015; Salahuddin et al. 2021), and the heterogeneous characteristics of mangrove habitats are the main factors in the diversity and density of birds in mangrove areas

(Mohd-Azlan et al. 2015). Therefore, the Indonesian government has developed programs for environmental improvement, especially mangrove areas, which pertain to conservation and restoration and are quite effective for the restoration of mangrove environmental services (Temmerman et al. 2013). In addition, restoration programs can assist mangrove conservation planning and become a solution for accelerating the return of natural mangrove supply services (Abidin et al. 2021; Maza et al. 2021). For example, mangrove restoration results can help increase niche availability for different bird unions, including waterbird species (Canales-Delgadillo et al. 2019). However, mangroves are not the only factor influencing bird diversity in coastal areas (Nurrofik et al. 2021). Be that as it may, the distribution and species richness of the restored mangroves is favorable for migratory bird species (Huang et al. 2012).

Other evidence is that the mangrove area and the number of mangrove species are naturally increasing and have contributed to the richness of fauna, especially in the mangrove area on the southern coast of East Lombok (Idrus et al. 2021a; Idrus et al. 2019a). In addition, the results of mangrove conservation, such as in the Mandalika Special Economic Zone on Lombok Island, are habitats for a diversity of bird species, particularly for 27 species of Least Concern (LC) birds and four species of birds with Near T (NT) status, as well as migratory birds (Salahuddin et al. 2021). However, research on the provision of mangrove services due to the conservation of bird species diversity on a wider scale, especially on the island of Lombok, has not been carried out. Furthermore, scientific information on the diversity of bird species is needed to sustain mangrove conservation at the study site. Therefore, the objectives of this study are: (i) to describe the conservation status of the diversity of bird species associated with mangroves at the study site and (ii) to describe the value of the ecological index of birds as an indicator of mangrove conservation at the study site. Furthermore, the benefits of research are providing scientific information for policies in mangrove conservation on Lombok Island and other similar locations.

MATERIALS AND METHOD

Study area

The study was carried out in selected locations of West Lombok, Central Lombok, and East Lombok, West Nusa Tenggara, Indonesia (Figure 1) from April to August 2022. The mangrove vegetation at the study site is the result of revegetation and has contributed significantly to the livelihoods of local communities (Idrus et al. 2019b); it has become an important instrument in disaster mitigation at a local scale (Idrus et al. 2021b). In addition, their use has developed as ecotourism objects, such as bird watching (Abdillah et al. 2020).

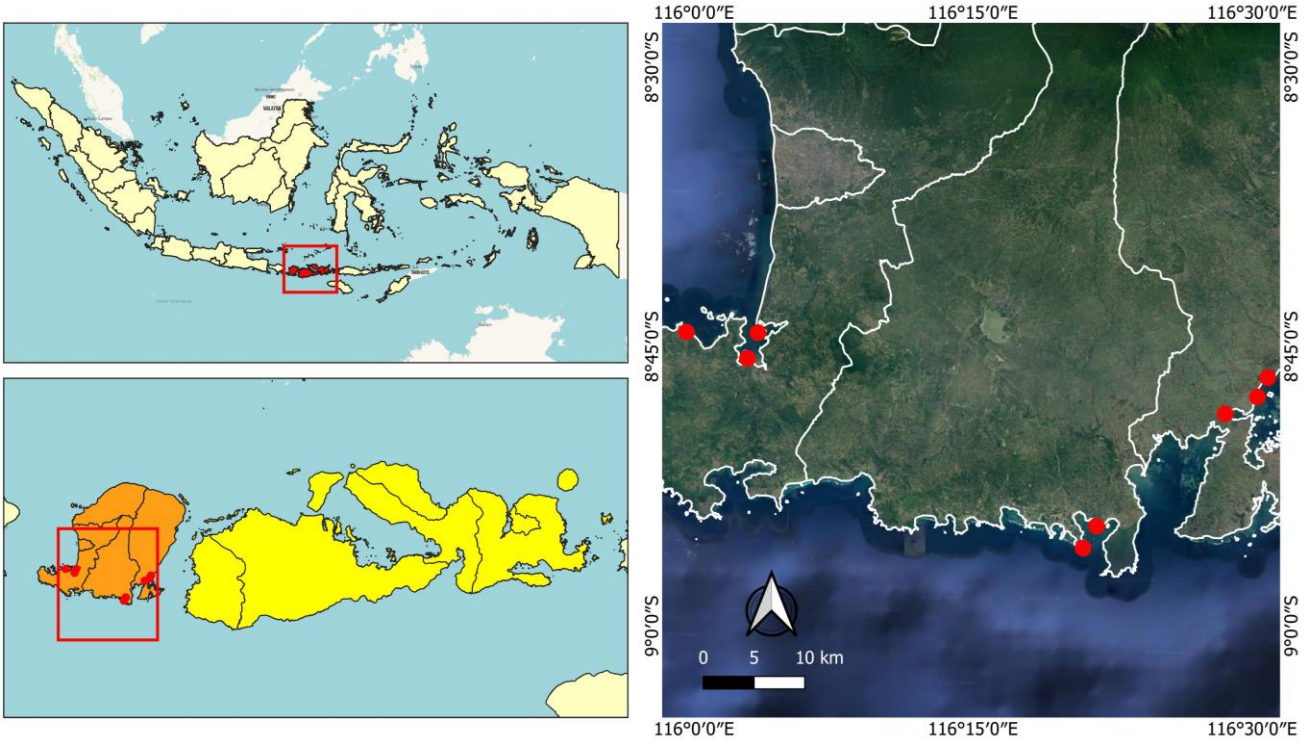

Figure 1. Map showing the selected study areas of West Lombok, Central Lombok, and East Lombok Districts, West Nusa Tenggara Province, Indonesia

Data collection and analysis

Mangrove vegetation data have been taken using the transect and quadrant method (Mueller-Dombois & Ellenberg 1974). The transects are placed perpendicular to the shoreline, and quadrants are made on the transect line with dimensions of 20 m × 20 m. In each site, 5 line transects were laid perpendicular to the waterfront at a minimum of 50 m intervals between adjacent transects. Quantitative data on mangrove vegetative structure was collected by laying quadrats along each line transect at a minimum of 25 m intervals between adjacent quadrants. The mangrove vegetation variables collected within each quadrat are the name of the species, number of individuals/species, and size and number of individuals in each stand (trees, saplings, and springs). Bird species diversity and the number of individuals per species were collected as described by Bismark (2011), and the collection was carried out between 07.00-09.00 WITA and 17.00-18.00 WITA (Central Indonesian Time). Bird species observed in the study were identified by using a bird field guidebook (MacKinnon et al. 2010), books on the introduction of bird species (Coates and Bishop 2000), IUCN Redlist.org (IUCN 2016), and Birdlife International (birdlife.org 2016). Furthermore, documentation or taking photos to identify bird species observed in detail is guided by Jhenkhar et al. (2016).

Apart from this, the following univariate measure, viz., Diversity Index (H'), Evenness (E), and the Richness index (R) analysis, were also carried out (Ludwig and Reynolds 1988). A regression analysis is also conducted to assess the providing mangroves service from the value of its stand on the diversity of bird species. In this case, the number of individual mangrove stands is the independent variable (Y), and the number of bird species is the dependent variable (X). The linear regression formulation is guided by Ludwig and Reynolds (1988). All statistical analyses were performed in IBM SPSS Statistics 25.

RESULTS AND DISCUSSION

Mangrove species richness in the study site

A total of 11 mangrove species have been identified in the present study. Five species, namely Avicennia marina, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, and Sonneratia alba, are common. In contrast, *Avicennia lanata*, *Bruguiera gymnorrhiza*, and *Ceriops decandra* are rare in the study location. Considering the percentage of life form structure of mangrove vegetation, seedling (54-84.7%) is dominant, followed by sapling (12.5-44%) and tree (0.8-2.9%). The average mangrove tree density varies from 2.48-37.77/10 m^2. Among the eight sites studied, Teluk Jor has the highest mangrove tree density, whereas the lowest tree density is found in Cemare (Table 1). Maximum species have been found in Teluk Jor (eight species), followed by Sheets, which has seven species. Gerupuk, Dodon, and Sekotong have six species, and Tanjung Luar has five.

The even distribution of species of the genus *Rhizhopra* in all research sites indicates the success of the mangrove revegetation program at the study site. That is supported by interviews with community leaders which revealed that the mangrove species planted between 1980 and 1995 were species of *Rhizhopora*. Therefore, the revegetation/ reforestation concept is a solution for natural recovery in a damaged environment (Mi et al. 2019). Studies have also reported that mangrove revegetation can increase the abundance of crustaceans (41%) and polychaetes (13%). Also, lead to a higher number of gastropods and bivalves, and be an indicator of natural recovery in increasing the value of benthic biodiversity and restoration of coastal ecosystem services (Gorman and Turra 2016). Mangrove restoration through revegetation/reforestation can even promote natural species' return comparable to natural stands (Bosire et al. 2008). Didik and Syukur (2021) have also noted that the revegetation of *Rhizopora apiculata* and *Rhizopora stylosa* species significantly affects the natural growth and development of mangrove vegetation in Teluk Jor and East Lombok. However, it is necessary to understand the main variables, such as propagule-sediment-tidal, to increase revegetation yields in degraded coastal ecosystems (Ge et al. 2019). Hence, it is pertinent to note that indicators used in the present study (structure of vegetation, individual density, and the presence of species other than revegetated) for the success of mangrove revegetation still require the study of other variables. Those variables, such as the involvement of local communities and extreme environmental specifications due to seasonal influences, increase its success in future masses.

Bird species composition at the study site

In the present study, 1,337 birds were observed, including 74 species belonging to 26 families. Out of the 26 families, the Scolopacidae has the highest number of species (nine species), followed by the Charadriidae, with eight species. Considering the number of individuals observed Apodidae family has the highest number of individuals (25.93%), followed by the Estrildidae (18.45%); the lowest number of individuals was observed in Anatidae and Rallidae, with 0.22% each (Figure 2). Among the eight sites surveyed, the maximum number of individuals were found in Gerupuk (274), followed by Dondon (250). However, a maximum number of species was also observed from the eight locations (Table 2). Out of the 74 species observed, 19 were found in all surveyed sites, and eight were found only in one site. Therefore, the maximum number of individuals observed is *Apus pacificus* (357 individuals), followed by *Lonchura leucogastroides* (257 species).

The observed diversity of bird species in all research locations is functional evidence of the services provided by mangroves and their environment for the preservation of birds. Therefore, the conservation of mangroves and their habitat is really needed for protecting biodiversity, especially birds. As Sandilyan and Kathiresan (2015) reported, the high diversity and density of birds in mangrove ecosystems are often attributed to the abundance of food in mangroves. Nonetheless, the presence of several species of birds, such as crows and pigeons, indicates anthropogenic influences, but the presence of highly

protected birds may indicate the result of conservation value supporting the mangrove zone (Mohd-Taib et al. 2020). Therefore, the presence of *Anas gibberifrons* in Jor bays, Poton Bakau, and *Heteroscelus brevipes*, *Charadrius leschenaultia*, *Charadrius veredus* in Gerupuk and Dondon (Table 2) is an indicator of the success of mangrove conservation through revegetation on Lombok Island.

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The mangrove environment is also vital for migratory birds for their food requirement (Rourke and Debus 2016; Salahuddin et al. 2021), thereby ensuring ecosystem connectivity. The presence of migratory bird species in several research locations in Table 2 can explain the role of mangroves in ecosystem connectivity since ecosystem connectivity is a very important spatial ecological aspect in conservation actions (Buelow and Sheaves 2015). Moreover, mangroves are a crucial indicator of habitat for their services, especially as a source of mega-biodiversity (Ghasemi et al. 2012). Therefore, mangrove degradation due to industrialization, urbanization, and human growth population is a serious challenge to their sustainability (Basyuni et al. 2022; Worthington and Spalding 2018). Therefore, the effort to conserve mangroves at the research site has positive implications for local communities and fauna diversity (Idrus et al. 2019a). In addition, due to revegetation, the mangrove area has developed into an ecotourism area and includes observing birds (Abdillah et al. 2020). Furthermore, the results of conservation assessments through revegetation, such as those obtained in the study sites, have shown positive mangrove vegetation development (Table 1). The richness of bird species found in each study site is the indicator for studying the implications of successful mangrove revegetation (Table 2).

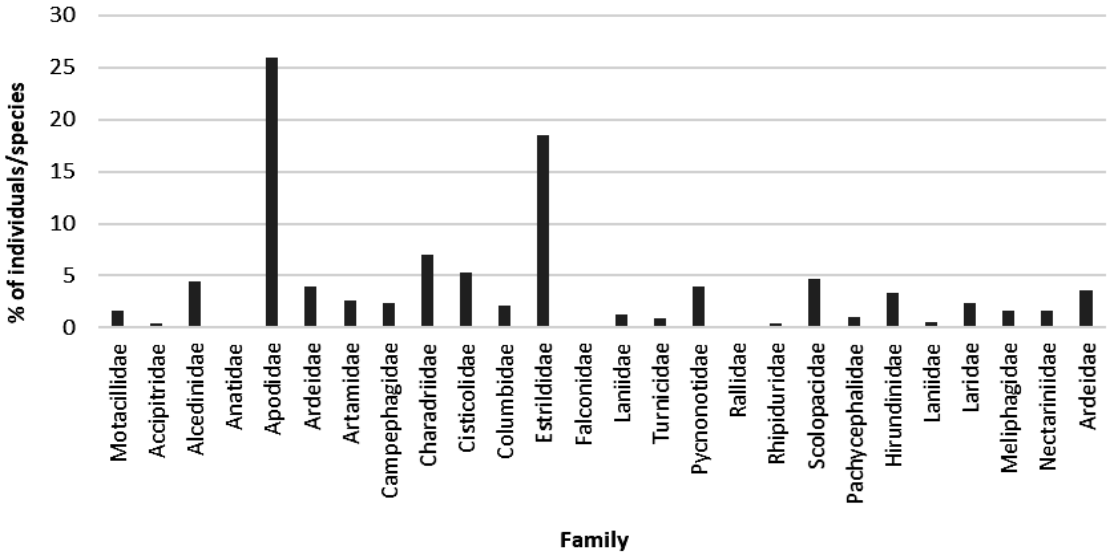

Figure 2. Bird family composition based on the number of individuals/species

Table 1. Mangrove species richness in the study site

Species of mangrove	Tanjung Luar			Poton Bako			Teluk Jor			Gerupuk			Dondon			Sekotong			Lembar			Cemare		
	Tree	Sapling	Seedling	Tree	Sapling	Seedling	Tree	Sapling	Seedling	Tree	Sapling	Seedling	Tree	Sapling	Seedling	Tree	Sapling	Seedling	Tree	Sapling	Seedling	Tree	Sapling	Seedling
Avicennia marina	3	22	74	2	16	42	4	23	106	1	44	14	1	26	67	0	28	69	2	12	32	1	15	32
Avicennia lanata	0	0	0	0	0	0	0	0	0	0	4	12	0	0	4	0	0	0	0	0	0	0	0	0
Bruguiera gymnorriza	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	34	0	0	0
Ceriops tagal	0	0	0	0	0	0	0	0	0	1	21	45	0	0	0	0	8	22	0	7	36	0	5	16
Ceriops decandra	0	0	0	0	0	0	5	56	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumnitzera racemosa	0	0	0	0	0	0	0	26	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhizophora apiculata	2	11	56	6	20	99	6	68	600	0	25	23	1	16	33	2	22	86	1	10	21	2	11	48
Rhizophora mucronata	0	0	0	3	300	900	4	80	400	2	12	56	2	14	32	3	13	98	2	39	56	3	8	64
Rhizophora stylosa	8	36	123	2	320	203	3	150	600	1	67	76	0	14	25	1	19	221	0	0	24	0	2	42
Sonneratia alba	1	16	46	4	150	412	2	250	732	1	5	14	2	9	43	1	10	46	1	8	46	2	10	56
Xylocarpus moluccensis	2	480	1050	1	12	120	2	60	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	16	565	1349	18	818	1776	26	713	3038	6	178	240	6	165	204	7	222	542	6	88	249	7	31	210
	0.8	29	69.9	1	31	68	1	19	80	1.4	42	56.6	2	44	54	0.9	29	70.3	2.9	28	69	2.8	12.5	84.7
Total all individuals		1930			2612			3777			424			375			771			343			248	
Average of Density (K)		19.30			26.12			37.77			4.24			3.75			7.71			3.43			2.48	
SD		669.94			880.18			1578.49			121.23			104.89			269.21			123.62			110.92	

Table 2. List of bird species observed at the eight research sites

Family	Scientific name	Local name	Location								No. of species	No. of ind./sp.	% of ind./sp.	Status conserv.
			East Lombok			Central Lombok			West Lombok					
			Tanjung Luar	Poton Bako	Teluk Jor	Gerupuk	Dondon	Sekotong	Lembar	Cemare				
Motacillidae	*Anthus novaese elandia*	Apung tanah	2	3	3	8	6	0	0	0	1	22	1.6	LC
Accipitridae	*Elanus caeruleus*	Elang tikus	0	0	0	0	1	0	1	0	3	6	0.44	LC
	Haliaseetur indus	Elang bondol	1	0	0	1	0	0	0	1				LC
	Pandion haliaetus	Elang tiram	0	0	0	0	0	1	0	0				LC
Alcedinidae	*Halcyon chloris*	Raja udang biru	3	1	3	4	5	0	2	2	3	61	4.43	LC
	Halcyon sanctus	Cekakak sungai	2	7	6	2	5	3	0	0				LC
	Alcedo coerulescens	Cekakak australia	2	1	2	3	4	2	1	1				LC
Anatidae	*Anas gibberifrons*	Itik benjut	0	1	2	0	0	0	0	0	1	3	0.22	NT
Apodidae	*Apus pacificus*	Kapinis laut	2	7	6	13	6	12	3	2	4	357	25.93	LC
	Collocalia esculenta	Walet sapi	2	9	8	18	6	15	4	7				LC
	Collocalia fuchipagus	Walet sarang-putih	8	12	16	12	17	12	11	8				LC
	Collocalia linchi	Walet linci	6	13	29	29	21	23	10	10				LC
Ardeidae	*Ixobrychus cinnamomeus*	Bambangan merah	0	2	0	4	0	0	0	0	5	55	3.99	LC
	Ardeola speciosa	Blekok sawah	4	6	3	12	7	2	1	6				LC
	Ardea cinerea	Cangak abu	0	1	0	1	0	0	0	2				LC
	Ardea alba	Cangak besar	0	1	0	0	0	0	0	0				LC
	Ardea purpurea	Cangak merah	0	0	1	0	1	1	0	0				LC
Artamidae	*Artamus leucorynchus*	Kekep babi	8	2	2	5	3	11	3	2	1	36	2.61	LC
Campephagidae	*Lalage sueurii*	Kapasan sayap putih	2	1	4	2	4	1	1	2	3	32	2.32	LC
	Caprimulgus affinis	Cabak kota	2	0	0	1	3	0	1	1				LC
	Caprimulgus macrurus	Cabak maling	1	0	0	1	1	2	1	1				LC
Charadriidae	*Charadrius dubius*	Cerek kalung kecil	0	0	0	2	1	3	0	1	8	97	7.04	LC*
	Charadrius leschenaultii	Cerek pasir besar	0	0	0	4	0	0	0	0				NT*
	Charadrius javanicus	Cerek jawa	3	6	1	11	12	5	2	7				LC
	Charadrius peronii	Cerek melayu	0	0	0	2	1	0	0	0				LC*
	Charadrius veredus	Cerek asia	0	0	0	3	4	0	0	0				NT*
	Pluvialis fulva	Cerek krunyut	0	0	0	8	5	0	0	0				LC*
	Pluvialis squatarola	Cerek besar	2	1	2	2	2	1	0	1				LC
	Caradrius alexandrinus	Cerek tilil	0	0	0	3	2	0	0	0				LC*
Cisticolidae	*Cisticola exilis*	Cici merah	4	1	1	1	2	0	0	0	3	73	5.3	LC
	Cisticola juncidis	Cici padi	12	2	9	7	7	4	2	5				LC
	Orthotomus sepium	Cinenen jawa	2	3	2	1	3	2	2	1				LC
Columbidae	*Chalcophaps indica*	Delimukan zamrud	0	0	2	0	0	0	0	0	4	30	2.18	LC
	Geopelia striata	Perkutut jawa	1	0	3	1	3	1	1	0				LC
	Streptopelia chinensis	Tekukur biasa	2	4	0	2	2	4	0	0				LC
	Treron vernans	Punai gading	0	0	1	2	0	1	0	0				LC

Estrildidae	*Lonchura leucogastroides*	Bondol jawa	14	11	7	18	10	2	3	11	5	254	18.45	LC
	Lonchura pallida	Bondol kepala-pucat	5	9	23	9	13	0	2	6				LC
	Lonchura punctulata	Bondol peking	11	7	8	10	7	2	1	3				LC
	Lonchura quinticolor	Bondol panca warna	0	0	0	3	4	0	0	0				LC
	Taeniopygia guttata	Pipit zebra	4	5	6	14	13	3	6	4				LC
Falconidae	*Falco moluccensis*	Elang alap sapi	0	0	0	0	1	0	0	0	1	1	0.07	LC
Laniidae	*Lanius schach*	Bentet kelabu	3	0	1	5	3	2	1	3	1	18	1.31	LC
Turnicidae	*Turnix suscitator*	Gemak loreng	2	1	4	1	2	0	1	1	1	12	0.87	LC
Pycnonotidae	*Pycnonotus aurigaster*	Cucak kutilang	1	0	4	2	6	2	1	3	2	55	3.99	LC
	Pycnonotus goiavier	Merbah cerucuk	2	11	3	2	7	4	2	5				LC
Rallidae	*Amaurornis phoenicurus*	Kareo padi	0	0	1	0	1	0	0	0	2	3	0.22	LC
	Porzana fusca	Tikusan merah	0	0	1	0	0	0	0	0				LC
Rhipiduridae	*Rhipidura rufifrons*	Kipasan dada hitam	0	1	1	0	3	0	0	0	1	5	0.36	LC
Scolopacidae	*Actitis hypoleucos*	Trinil pantai	2	2	4	4	7	2	0	7	9	65	4.72	LC*
	Arenaria interpres	Trinil pembalik -batu	0	0	0	4	2	0	0	0				LC*
	Heteroscelus brevipes	Trinil ekor-kelabu	0	0	0	3	1	0	1	1				NT*
	Numenius arquata	Gajahan erasia	0	0	2	1	0	0	0	0				LC*
	Numenius minutus	Gajahan kecil	0	0	0	1	1	1	0	0				LC*
	Numenius phaeopus	Gajahan penggala	0	0	0	1	2	0	0	1				LC*
	Tringa glareola	Trinil semak	0	0	2	3	0	0	0	0				LC*
	Tringa nebularia	Trinil kaki hijau	1	2	1	0	0	0	0	0				LC*
	Tringa totanus	Trinil kaki-merah	2	1	3	0	0	0	0	0				LC*
Pachycephalidae	*Pachycephala grisola*	Kancilan bakau	1	2	2	0	3	2	0	1	2	14	1.02	LC
	Himantopus leucocephalus	Gagang-bayam timur	0	1	2	0	0	0	0	0				LC
Hirundinidae	*Hirundo rustica*	Layang-layang asia	1	5	2	2	5	1	2	2	3	46	3.34	LC
	Hirundo striolata	Layang-layang loreng	3	1	1	2	4	0	2	3				LC
	Hirundo tahittica	Layang-layang batu	1	1	1	3	1	0	0	3				LC
Laniidae	*Lanius schach*	Bentet kelabu	1	0	1	3	0	0	0	2	1	7	0.51	LC
Laridae	*Thalasseus bergii*	Dara laut jambul	0	3	0	1	1	2	1	2	4	32	2.32	LC*
	Sternula albifrons	Dara laut kecil	0	0	0	0	0	0	0	5				LC*
	Chlidonias hybrida	Dara laut biasa	0	3	0	0	0	0	0	7				LC*
	Sterna hirundo	Dara laut kumis	0	2	0	0	0	0	5	0				LC*
Meliphagidae	*Lichmera indistincta*	Isap madu Australia	1	1	6	5	6	3	0	0	1	22	1.6	LC
Nectariniidae	*Nectarinia jugularis*	Burungmadu sriganti	2	3	1	4	5	3	2	2	1	22	1.6	LC
Ardeidae	*Butorides striata*	Kokokan laut	1	0	1	2	2	1	1	0	4	49	3.56	LC
	Egretta intermedia	Kuntul perak	1	2	2	1	3	1	1	1				LC
	Egretta garzetta	Kuntul kecil	3	2	2	5	3	2	1	2				LC
	Egretta sacra	Kuntul karang	0	0	1	0	0	0	0	0				LC
Total			133	160	199	274	250	139	79	135	74	1377	100	

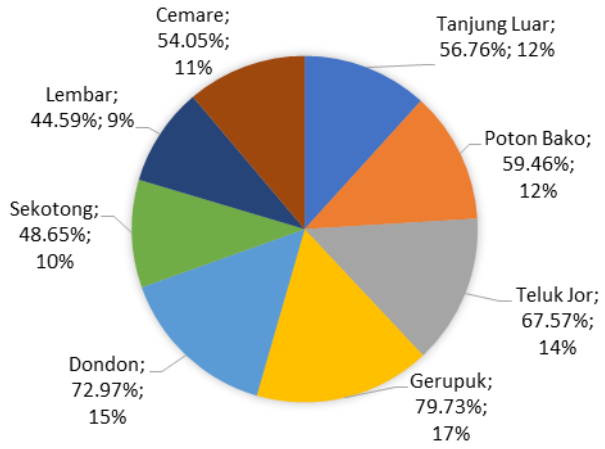

Figure 3. Percentage number of bird species per location based on the total number of species in all locations

The bird species composition at each research location shows differences between locations (Figure 3). The highest number of bird species has been found in Gerupuk (79.73%), followed by Lembar (44.59%) (Table 2). The composition of bird species at each research location can provide information about the first location of mangroves. Those geographically closer together have a wealth of different bird species, such as the location of mangroves in three districts (East Lombok, Central Lombok, and West Lombok). Further, all mangrove locations at the study site are of functional value in providing habitat and food for the diversity of bird species. Furthermore, birds' species composition can be explained by the number of locations found. In this regard, out of 74 bird species at all study sites, 19 species (25.56%) were found at all sites, and 8 (10.81%) at only one site (Table 4).

This can explain the distribution pattern of different bird species, with some distributed broadly while some are limited. Both mangrove areas provide the needs of more than one bird species. Therefore, maintaining the integrity of mangroves and the environment is a strategy that has positive value for bird conservation.

Bird ecological index at study site

The diversity of bird species in the study area (Table 2) is evidence of the contribution of mangrove conservation. Furthermore, the integrity of the ecological value of mangroves to the diversity of bird species can be expressed as an ecological index of birds associated with mangroves. The results of the analysis of the three ecological indices of birds at all research sites are presented in Table 3. The estimated Diversity Index (H') ranged between 3.09-3.67, whereas Evenness (E) and Richness (R) index ranged between 0.72-0.85 and 7.09-10.33, respectively. The value of the ecological index, especially the bird diversity index, explains the structure of the bird community and its relationship with the mangrove environment. The structure of the bird community based on the diversity index value can be explained through two main variables - the number of entire species and the number of individuals/species. The functional relationship between the two that contributed to the high and low values of the bird diversity index was different between locations. In addition, its function is to explain the relationship between mangrove ecosystems and the function of providing services for habitats and foraging for bird communities. Meanwhile, the Richness Index (R) describes the size of the total number of species in the community. The location with the highest species richness is Grupuk, while the lowest is Sekotong. On the other hand, the Evennes Index (E) describes the even distribution of individuals in communities of different species.

The ecological index value shows that the research locations have high species diversity and richness and are evenly distributed across the sites. This observed high bird species diversity can indicate the success of mangrove conservation through revegetation at the study site. However, the value of the ecological index for its use as a conservation indicator requires a time factor, especially for conservation areas with a revegetation or planting-approach model (Lindenmayer et al. 2015). Another factor that is difficult to contain in conservation efforts is habitat variation, and levels of disturbance, especially those which serve as important drivers of bird responses (Drapeau et al. 2016). Therefore, an important factor in biodiversity conservation strategies is the resilience of ecosystem functions in addition to species richness (Chapman et al. 2018). In this case, the functional aspects of all environmental elements can be integrated with the value of species diversity (Arruda-Almeida et al. 2018). Therefore, concerning the level of conservation complexity, the possible mangrove conservation strategy in the study area is to integrate the value of the ecological index of birds with the functional aspects of mangrove supply services, such as habitat, food, and bird comfort.

The strategy conservation of mangroves for the protection of bird communities in study locations

The existence of mangrove areas, especially in Indonesia, has a strategic meaning from an ecological and economic perspective. Moreover, an estimate is that Indonesia's mangrove rehabilitation and conservation efforts have benefits for 74 million coastal people and can contribute to reducing national land sector emissions by up to 16% (Sasmito et al. 2023). Meanwhile, aspects of ecosystem services that contribute significantly to basic human needs are provisioning and cultural services, but regulatory services, are stronger on environmental needs (Ruslan et al. 2022). Therefore, mangrove conservation efforts are to maintain the value of mangroves by providing essential services, particularly for the conservation of fauna diversity, such as birds. Furthermore, mangrove conservation efforts through revegetation at the study site have been significantly successful. The indicators are the addition of the mangrove area and the growth of new species of true mangroves (Idrus et al. 2021a). The result is that the mangrove area, from its provision of services, has a positive impact on macro-fauna groups, such as birds. For example, the results of research at eight mangrove locations in the coastal area of Lombok Island were that the composition and number of bird species differed between locations, but 25.67% of bird species were present in all

locations, and 10.81% of bird species were only present in one location (Table 3). Furthermore, the importance is first to explain the spatial distribution of each bird species, second, the priority of mangrove locations as habitats, and third, to explain the connectivity between mangrove ecosystems using the four functional indicators of mangrove supply services for birds to survive. Meanwhile, from 74 bird species, 19 species (25.67%) were migratory birds consisting of three families, namely Charadriidae with six species, Scolopacida with nine species, and Laridae with four species. The location with the highest number of migratory bird species is Gerupuk, and the lowest is Tanjung Luar and Lembar (Table 2).

Furthermore, the presence of bird species in all research locations is the implication of the mangrove vegetation structure as a service for providing mangroves for bird habitat. Meanwhile, the regression analysis results between mangrove vegetation density as the independent variable (y), and the number of bird species as the dependent variable (x), obtained an R^2 value of 96.55%. Therefore, mangrove stands can indicate the presence of several bird species in the study area. Furthermore, the regression equation is presented in Figure 4. On the other hand, it was found that mangrove locations with a lower average density, such as in Gerupuk, had more bird species than Tanjung Luar, Poton Bakau, and Teluk Jor, where mangrove stands were higher (Table 1). In this regard, mangrove stands are not independent determinants of the assemblages of bird species in mangrove areas or the influence of bird distribution patterns and high bird mobility (Mohd-Azlan and Lawes 2011). another determining factor is the type and diversity of zones: mangroves and the surrounding environment (Mohd-Azlan and Noske 2012). However, the minimum presence of mangrove vegetation significantly affects the scarcity of protected bird species, such as birds of the *Ardea alba* and *Glareola maldivarum* species. It is thought to result from the loss of mangrove supply services as a place for foraging, breeding, and resting places (Isworo and Oetari 2020). In addition, mangrove density and habitat heterogeneity are important components that play a role in maintaining diverse assemblages of bird species (Mohd-Azlan et al. 2015).

Meanwhile, the results of the identification of bird conservation status (Table 2) show 70 species with Least Concern (LC) status and four species with Near Threatened (NT) based on the International Union for the Conservation of Nature and Natural Resources Red List of Threatened (IUCN 2016). Four species of birds with status (NT) consist of three species of migratory birds and one species of non-migratory status. Furthermore, 16 species of birds with conservation status (LC) are migratory birds. Meanwhile, 54 species of birds with conservation status (LC) are local birds with natural habitats. The key factor for the presence of birds at mangrove locations is the availability of providing services for habitat, food, and resting (Sandilyan 2011). Food is the most dominant factor affecting the presence of birds in the mangrove ecosystem (Mohd-Azlan et al. 2014). However, especially for migratory birds, mangroves are needed as a habitat, and the presence of migratory birds can help in conservation planning (Kumar et al. 2016). Therefore, mangrove conservation efforts are directed to restore the essential function of providing mangrove services.

Table 3. Ecological Diversity (H'), Evennes (E), and Richness (R) index of bird species in the study area

Ecological indexes	Name of Location							
	East Lombok			Central Lombok		West Lombok		
	Tanjung Luar	Poton Bako	Teluk Jor	Gerupuk	Dondon	Sekotong	Lembar	Cemare
Diversity Index (H')	3.39	3.40	3.36	3.58	3.67	3.09	3.15	3.41
Evenness (E)	0.79	0.79	0.78	0.83	0.85	0.72	0.73	0.79
Richness (R)	8.38	8.47	9.26	10.33	9.6	7.09	7.32	7.95

Table 4. The spatial distribution of bird species

Spatial distribution	Name of bird species	Number of species
All locations	*Alcedo coerulescens, Apus pacificus, Collocalia esculenta, Collocalia fuchipagus, Collocalia linchi, Ardeola speciosa, Artamus leucorynchus, Lalage sueurii, Charadrius javanicus, Cisticola juncidis, Orthotomus sepium, Lonchura leucogastroides, Lonchura punctulata, Taeniopygia guttata, Pycnonotus goiavier, Hirundo rustica, Nectarinia jugularis, Egretta intermedia,Egretta garzetta*	19
Seven locations	*Halcyon chloris, Pluvialis squatarola, Lonchura pallida, Lanius schach, Turnix suscitator, Pycnonotus aurigaster, Actitis hypoleucos,Hirundo striolata*	8
Six locations	*Halcyon sanctus, Caprimulgus macrurus, Geopelia striata, Hirundo tahittica, Thalasseus bergii, Lichmera indistincta,Butorides striata*	7
Five locations	*Anthus novaese elandia, Cisticola exilis, Streptopelia chinensis,Pachycephala grisola*	4
Four locations	*Caprimulgus affinis, Charadrius dubius, Heteroscelus brevipes,Lanius schach*	4
Three locations	*Haliaseetur indus, Ardea cinerea, Ardea purpurea, Treron vernans, Rhipidura rufifrons, Numenius minutus, Numenius phaeopus, Tringa nebularia,Tringa totanus*	9
Two locations	*Elanus caeruleus, Anas gibberifrons, Ixobrychus cinnamomeus, Charadrius peronii, Charadrius veredus, Pluvialis fulva, Caradrius alexandrinus, Lonchura quinticolor, Amaurornis phoenicurus, Arenaria interpres, Numenius arquata, Tringa glareola, Himantopus leucocephalus, Chlidonias hybrida,Sterna hirundo*	15
One location	*Pandion haliaetus, Ardea alba, Charadrius leschenaultii, Chalcophaps indica, Falco moluccensis, Porzana fusca, Sternula albifrons,Egretta sacra*	8
Total species		74

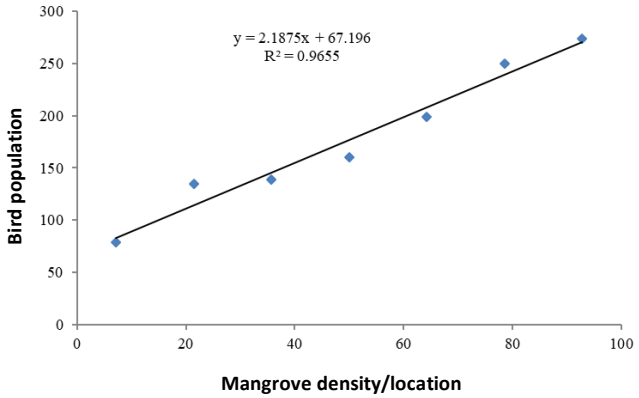

Figure 4. Linear regression between the average value of mangrove stand density and the number of bird species

The conclusion of this study recorded 74 bird species from 26 families, with a total of 1,377 individuals found in all research locations. Furthermore, the existence of four species with (NT) status is evidence of the crucial function of mangrove supply services in the study location. In addition, the value of the ecological birds' index can be an indicator of mangrove supply services. Therefore, the mangrove conservation strategy at the study site is to maintain resilience by providing mangrove ecosystem services for bird preservation. The strategy can be adopted by integrating the value of the ecological index of birds with other functions of the ecological aspect.

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