Species diversity of birds as bioindicators for mangroves damage at Special Economic Zones (SEZ) Mandalika in Central of Lombok, Indonesia

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Abstract. The Mandalika Special Economic Zone (SEZ) was designated as a tourist area in 2015. The development of the Mandalika area directly impacts the sustainability, diversity of species, especially birds that make mangroves their habitat. The study aims to investigate the value of bird species diversity in mangrove habitats as bioindicators. Furthermore, the research has been carried out for three months, from March to May 2021. Research data collection uses the roaming method, and data analysis uses bird community structure analysis (Diversity Index). In this study, 33 species of birds were found. Furthermore, it was found that six species of birds are protected wildlife. In addition, 16 are migratory birds, and 27 are Least Concern (LC) bird species; four species have Near Threatened (NT) status. Meanwhile, the Index of bird community structure is H' 2.7, uniformity E 0.8, and dominance C 0.9. The value of the bird community structure in the Mandalika SEZ shows the condition of mangrove habitat in the moderate damage category. Therefore, there needs to be an effort to preserve mangroves involving the community, government, and Indonesia Tourism Development Corporation (ITDC) area managers.

Keywords: Mandalika Special Economic Zone; Environment; Mangroves; Birds

1. Introduction
The Mangroves are natural ecosystems that have an essential role in the dynamics of coastal and marine ecosystems [1]. The mangrove ecosystem has a function as ecological support for the life of biota associated with mangroves [2]. Furthermore, the environmental process of the mangrove ecosystem is carbon sequestration, remediation of pollutants, and forming land [3]. In addition, according to [4], the ecological function of mangrove ecosystems is as a place to live, shelter, and breed several types of biota such as fish, shrimp, and birds. Birds use mangroves as habitats such as nesting, foraging, and breeding [5]. Furthermore, birds have high mobility, so that the interaction of bird communities affects mangrove vegetation [6]. Birds have a role in changing the structure of the vegetation composition of habitat [7]. Birds have an ecological function in a habitat as seed dispersers and natural pollinators [8]. In addition, birds can help control invertebrate and vertebrate pest populations by spreading and pollinating plants [9]. Birds also have essential services for human life by providing ecosystem services such as game meat for food, feathers for clothing, and manure for fertilizer [10]. Furthermore, according to[11], birds can be used as indicators of habitat quality because they have important characteristics such as being sensitive to environmental changes, and their distribution is easy to find. The Mandalika Special Economic Zone is a tourism center development area for West Nusa Tenggara which was established in [12]. The area's development resulted in rapid habitat exploration, resulting in damaged mangrove habitat conditions [13]. This can cause a decrease in the diversity of bird
species that have ecological functions [14], because birds have sensitivity to environmental changes [15]. The results of research conducted by Iswandaru [16], that mangrove forest degradation in KPHL affects bird species diversity and is used as a bioindicator of habitat destruction. In addition, the results of research on the mangrove ecosystem in the Aopa Watumohai Swamp National Park suffered minor damage, and the bird community was used as a bioindicator of environmental damage [17]. This study aims to look at changes in mangrove habitat conditions to bird communities to conserve the area. Therefore, this research needs to be done to see the damage to the mangrove habitat in The Mandalika SEZ.

2. Materials and Methods

2.1 Time and Location of Research
This research was conducted for three months, from March to May 2021. The research location was carried out in the mangrove Habitat of The Mandalika Special Economic Zone, Central Lombok, West Nusa Tenggara Indonesia (Figure 1).

![Figure 1. Research location map.](image)

2.2 Research Method
The tools used include binoculars for observing birds at a distance, monocular binoculars for observing waterbirds at a distance, and DSLR cameras taking pictures of birds for easy identification. The research materials used were, among others, the Bird Field Guidebook in the Wallacea Region [18], the bird field guidebook in the Sumatra, Java, and Bali Regions [19].

2.3 Research procedure
The research was conducted using the roaming method. When data were collected, it explored the entire area in the mangrove habitat of The Mandalika SEZ by circling the edges of the mangrove habitat, stopping at potential points for bird watching, and entering the mangrove forest at low tide. Furthermore, bird observations were carried out in the morning at 07:00-10:00, and at 3:00-6:00 p.m. when the birds were looking for food and breeding to get maximum data. Along the observation path, birds passed, flew, and perched were recorded and photographed based on morphological characteristics, and the number was found.

2.4 Data analysis
The research data that has been collected is then tabulated based on the nature of the data and data sources. Furthermore, for the structure of the bird community in the mangrove habitat using the following data analysis.

2.4.1.1 Species diversity index
The diversity index shows the species richness in a community and also shows the balance of the number of individuals per species. The species diversity index is calculated based on the Shannon & Wiener formula [20]:

\[ H' = -\sum Pi \ln Pi \]

Information:
- \( Pi \): \( n_i/N \)
- \( H' \): Index of species diversity
- \( N_i \): Number of individuals of the \( i \)th species
- \( N \): Total Number of individuals

2.4.1.2 Bird Uniform
The subsequent analysis is the similarity of the individual distribution of each bird species, using the Evenness Index, with the formula:

\[ E = H' \ln(N)/\ln(S) \]

Information:
- \( E \): Evenness index
- \( H' \): Diversity index Shannon Wiener
- \( S \): Number of species

2.4.1.3 Bird Dominance
The dominance index is calculated using the Simpson dominance index with the formula:

\[ Pi = n_i/N \]

Information:
- \( Pi \): Dominance Index
- \( n_i \): Number of individual species
- \( N \): Total Number of individuals

3. Results and discussion
3.1 Bird community structure
The diversity of bird species in the mangrove habitat of The Mandalika SEZ found 33 bird species from 9 families. The bird species with the highest abundance found was *Taeniopygia guttata*, with an abundance value of 20%. Furthermore, the index value of bird species diversity in mangrove habitat is 2.7 (\( H' \)). The value is in the medium category because it is less than three and more than 2.5. This is inseparable from the condition of the mangrove vegetation structure in the area. Bird breeding is closely related to the vegetation structure in a particular habitat [21]. This makes the vegetation structure an important factor in the availability of feed for birds in the habitat [22]. The index value of bird species uniformity in mangrove habitat is 0.8 (E). Bird communities can be said to be stable if the
value is close to 1. The smaller the uniformity value of bird species, the pattern of bird distribution is not evenly distributed throughout the habitat. Homogeneous factors influence this condition in the mangrove habitat, which inhibits the distribution of bird species. In addition, the distribution of bird species is closely related to the dominance of bird species. The index value of bird dominance in mangrove habitat is 0.9 (C). If the index value is close to 1, then a species dominates the other species. The existence of a species that dominates indicates that the environmental conditions in the area favor certain species to grow. More details can be seen in (Figure 2).

Figure 2. Bird community structure index

3.2 Diversity of bird species as a bioindicator
The diversity of bird species in the mangrove habitat of The Mandalika SEZ found 33 bird species from 9 families (Table. 1) The variety of bird species protected in government regulation (PP) no. 106 of 2018 concerning the Second Amendment to the Regulation of the Minister of Environment and Forestry on mangrove habitats found six species of birds, and there were also migratory birds in mangrove habitats in The Mandalika SEZ as many as 16 bird species (Table. 1) Bird species in the mangrove habitat in The Mandalika SEZ were found from March, April, and May; the bird species found were almost the same. The addition of the number of bird species found only two bird species. More details in Table 1 Diversity of bird species in the mangrove habitat of The Mandalika SEZ.

Table. 1 Diversity of bird species in the mangrove habitat of The Mandalika SEZ

| Bird Species | Indonesian Name | Conservation Status |
|--------------|----------------|---------------------|
| Ardea purpurea | Cangak merah | LC |
| Haliastus indus | Elang bondol | LC |
| Alcedo coerulescens | Raja udang biru | LC |
| Todiramphus chloris | Cekakak sungai | LC |
| Todiramphus sanctus | Cekakak Australia* | LC |
| Ardea intermedia | Kuntul perak* | LC |
| Butorides striata | Kokokan laut | LC |
| Egretta garzetta | Kuntul kecil | LC |
| Ixobrychus cinnamomus | Bambangan merah | LC |
| Caprimulgus macrurus | Cabak maling | LC |
### Advanced Table 1 Diversity of bird species in the mangrove habitat of The Mandalika SEZ

| Family         | Latin Name            | Indonesian Name       | Conservation Status |
|----------------|-----------------------|-----------------------|---------------------|
| Charadriidae   | Charadrius alexandrinus | Cerek tilil*            | LC                  |
| Charadriidae   | Charadrius leschenaultia | Cerek pasir besar*       | LC                  |
| Charadriidae   | Charadrius veredus     | Cerek asia*             | LC                  |
| Charadriidae   | Pluvialis fulva        | Cerek kernyut*          | LC                  |
| Charadriidae   | Pluvialis squatarola   | Cerek besar             | LC                  |
| Estrildidae    | Lonchura leucogastroides | Bondol jawa            | LC                  |
| Estrildidae    | Lonchura pallida       | Bondol kepala pucat     | LC                  |
| Estrildidae    | Lonchura punchutalata  | Bondol peking           | LC                  |
| Estrildidae    | Lonchura quincticolor  | Bondol pancawarna       | LC                  |
| Estrildidae    | Taeniopygia guttata    | Pipit zebra             | LC                  |
| Hirundinidae   | Hirundo rustica        | layang-layang asia*     | LC                  |
| Hirundinidae   | Cercops striolata      | Layang-layang loreng    | LC                  |
| Scolopacidae   | Actitis hypoleucus     | Trinil pantai*          | LC                  |
| Scolopacidae   | Arenaria interpres     | Trinil pembalik batu*   | LC                  |
| Scolopacidae   | Numenius minutus       | Gajahan kecil*          | LC                  |
| Scolopacidae   | Numenius phaeopus      | Gajahan penggala*       | LC                  |
| Scolopacidae   | Tringa glareola        | Trinil semak*           | LC                  |
| Scolopacidae   | Tringa nebeclaria      | Trinil kaki hijau*      | LC                  |
| Turnicidae     | Turnix suscitator      | Gemak loreng            | LC                  |
| Charadriidae   | Charadrius javanicus   | Cerek jawa              | NT                  |
| Charadriidae   | Charadrius peronii     | Cerek melayu*           | NT                  |
| Charadriidae   | Numenius arquata       | Gajahan besar*          | NT                  |
| Charadriidae   | Tringa brevipes        | Trinil ekor kelabu*     | NT                  |

Information:
IUCN: Status according to IUCN Red List of Threatened Species: LC=Least Concern. NT=Near Threatened Near Threatened
Permen: Status according to the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.106/MENLHK/SETJEN/KUM.1/12/2018, concerning the Second Amendment to the Regulation of the Minister of Environment and Forestry Number P.20/MENLHK/SETJEN/KUM.1/6/2018, regarding Protected Types of Plants and Animals: L=Protected, TL=Not Protected.
*: Migratory birds.

The family group with the most number of bird species found is Scolopacidae (Figure 3). The community of the Scolocidea family is a type of water bird that is often found in mangrove habitats. In addition, the family bird species found in the mangrove habitat of The Mandalika SEZ are migratory birds. According to [23], the presence of migratory birds in an area indicates that new food sources are found, and environmental conditions are not extreme. Suppose the number of bird species in the Scolocidea family decreases. In that case, the mangrove habitat's disease can be damaged so that the presence of the Scolopacidae family in the mangrove habitat can be used as a bioindicator of...
environmental conditions. Furthermore, the families with the few bird species found include Accipitridae, Caprimulgidae, and Turnicidae (Figure.3). Meanwhile, the family group of raptor species found was Haliastus indus. The presence of birds of prey in an ecosystem shows that interactions between communities associated with mangroves are still maintained. In an ecosystem, birds of prey occupy the highest order in food webs and food chains. So the presence of Haliastus indus for the balance of the ecosystem is very much needed. If the population of Haliastus indus is disturbed, the balance of the ecosystem is disturbed [24]. The study results [25], the proliferation of Haliastus indus in a habitat indicates the presence of abundant fish species found in the area, indicating that the components of the ecosystem are still stable. Based on this role, birds of prey are categorized as protected wildlife in the government regulation of the Republic of Indonesia Number P.92/MENLHK/SETJEN/KUM.1/8/2018, so the presence of the Haliastus indus bird species indicates that habitat conditions are still stable [26]. Therefore, the bird species Haliastus indus can be used as a bioindicator of environmental damage. Based on the results of this study, the condition of damage to mangrove habitat in The Mandalika SEZ is in the moderate damage category.

![Figure 3. Histogram of the Number of bird species in each family in mangrove habitat](image)

3.3 Conservation area

The most recognized conservation status in the world is the IUCN Red List. The IUCN Red List is a list of wild plants and animals that have an endangered status in the world and aims to focus attention on endangered species. The conservation status of a threatened species indicates the likelihood that this species will continue to survive. Healthy environmental conditions allow IUCN conservation status bird species to be found. Furthermore, from the data from the study, 29 species were found to be in the Least Concern (Low Risk) category, and four species were in the Near Threatened (Almost Threatened) category (Figure.4). The existence of 4 bird species with Near Threatened status shows that the environmental conditions in the area are good for breeding bird species that are globally threatened with extinction. More details in Fig.4 Number of bird species IUCN status.
Mangroves in The Mandalika SEZ can be considered Important Bird Areas (IBA), from the number of migratory bird species found. An area can be classified as IBA if two or more migratory birds gather and forage in the area. The mangrove area in The Mandalika SEZ should receive special attention related to the presence of migratory birds. Therefore, community-based protection measures may be more effective in preventing disturbance to the company of these birds. Sementara area mangrove di sekitar lokasi penelitian telah berhasil di konservasi melalui vegaetasi [27,28]. In addition, the results of the mangrove vegetation area have become a source of local livelihoods [29]. Another indicator of the success of mangrove conservation on the southern coast of Lombok island is the value of carbon content [30]. With local wisdom from the local community, such as making a wig-a wig for bird protection and forming a community of environmentalists, it will be able to foster a sense of love and care for the environment, especially for the presence of migratory birds. These migratory birds can also be used as an object of birdwatching ecotourism to bring additional income for the environmentalist community that manages the area.

4. Conclusion
The fish family composition based on the number of species in Kuta consists of sixteen species, with the fish species having the highest number of individuals being Sardinella gibbosa, Herklotsichthys quadrimaculatus, Epinephelus bontoides, and Sphyraena flavicauda. The regression analysis results showed that seagrass density had the highest contribution to the number of species $R^2$ 73.7% and the highest contribution to the number of individuals was seagrass cover $R^2$ 90.8%. Therefore, the fauna diversity in seagrass beds in the Kuta Mandalika SEZ can be an indicator in the design of seagrass conservation and ecotourism development for the presence of fauna through environmentally friendly ecotourism in their fishing activities. The potential of the seagrass can support the existence of marine fauna associated with seagrass.

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Author's Contributions
Muhammad Al Awali Salahuddin, Immy Suci Rohayani, Dining Aidil Chandri. We conducted all experiments, observation, analysis, and paper manuscript preparation.
References

[1] Tefarani, R. (2018). Keanekaragaman Spesies Mangrove Dan Zonasi di Wilayah Mangunharjo Kecamatan Tugu Kota Semarang (Doctoral dissertation, Universitas Negeri Semarang).

[2] Martinuzzi S, W A Gould, A Lugo dan E Medina, 2009. Conversion and Recovery of Puerto Rican Mangroves: 200 Years of Change. Journal Forest Ecology and Management 257: 75–84.

[3] Setyawon, A. D., & Winarno, K. (2006). Pemanfaatan langsung ekosistem mangrove di Jawa Tengah dan penggunaan lahan di sekitarnya; kerusakan dan upaya restorasinya. Biodiversitas, 7(3), 282-291.

[4] Yanto, R., Pratomo, A., & Irawan, H. (2016). Keanekaragaman Gastropoda pada Ekosistem Mangrove Pantai Masiran Kabupaten Bintan. Repository Umrah.

[5] Nybakken, J. W., & Eidman, H. M. (1998). Biologi laut: satu pendekatan ekologis. Gramedia.

[6] Desmawati, I. (2010). Studi Distribusi Jenis-Jenis Burung Dilindungi Perundang-Undangan Indonesia di Kawasan Wonorejo, Surabaya. Institut Teknologi Sepuluh Nopember.

[7] Ayat, A., & Tata, H. L. (2015). Diversity of birds across land use and habitat gradients in forests, rubber agroforests and rubber plantations of North Sumatra. Indonesian Journal of Forestry Research, 2(2), 103-120.

[8] Rumanasari, R. D., Saroyo, S., & Katili, D. Y. (2017). Biodiversitas burung pada beberapa tipe habitat di kampus Universitas Sam Ratulangi. Jurnal MIPA, 6(1), 43-46.

[9] Nurdin, N., Nasihin, I., & Guntara, A. Y. (2018). Pemanfaatan Keanekaragaman Jenis Burung Berkicau dan Upaya Konservasi pada Kontes Burung Berkicau di Kabupaten Kuningan Jawa Barat. Wanaraksa, 11(01).

[10] Reid, W. V., Mooney, H. A., Cropper, A., Capistrano, D., Carpenter, S. R., Chopra, K., & Zurek, M. B. (2005). Ecosystems and human well-being-Synthesis: A report of the Millennium Ecosystem Assessment. Island Press.

[11] Kinnaird, M. F., & O'Brien, T. G. (1998). Ecological effects of wildfire on lowland rainforest in Sumatra. Conservation Biology, 12(5), 954-956.

[12] Ahyadi, H., Erdin, E., Candri, D. A., Farista, B., Astuti, S. P., & Virgota, A. (2021). Keanekaragaman Jenis dan Status Kesehatan Padang Lamun di Kawasan Pesisir Mandalika, KAB. Lombok Tengah. Prosiding SAINTEK, 3, 509-513.

[13] Putri, N. A., Ramadhan, S., Fauzan, A. J. A., Utami, R. S., & Yuliawati, Y. D. Eksploitasi Reklamasi Lahan Pesisir dalam Pengaruh Pencemaran Laut dan Ancaman Habitat Pesisir Teluk Jakarta.

[14] Indriana, D.P., H. Marisa dan Zakaria. 2009. Keanekaragaman Spesies Tumbuhan pada Kawasan Mangrove Nipah (Nypa fruticans Wurmb.) di Kec. Pulau Rimau Kab. Banyuasin Sumatera Selatan. Jurnal Penelitian Sains. Vol. 12 (3D) hal 12309.1

[15] Sujatnika, Jepson P, Soehartono TR, Crosby MJ, Mardiastuti A. 1995. Melestarikan Keanekaragaman Hayat Indonesia: Pendekatan Daerah Burung Endemik. Jakarta: PHPA/Birdlife International-Indonesia Programme.

[16] Iswanderu, D. (2018). Kelimpahan dan keanekaragaman jenis burung di hutan mangrove KPHL Gunung Balak. Indonesian Journal of Conservation publish by” Universitas Negeri Semarang Vol 1 No 7 2018, 7(1), 57-62.

[17] Qiptiyah, M., Broto, B. W., & Setiawan, H. (2013). Keragaman jenis burung pada kawasan mangrove di Taman Nasional Rawa Aopa Watumohai. Jurnal Penelitian Kehutanan Wallacea, 2(1), 41-50.

[18] Coates, B.J. and Bishop, K.D. A Guide to The Birds of Wallacea: Sulawesi, The Moluccas and Lesser Sunda Island, Indonesia. Dove Publications, Australia (2000).

[19] Mackinnon, S. P., Jordan, C. H., & Wilson, A. E. (2011). Birds of a feather sit together: Physical similarity predicts seating choice. Personality and Social Psychology Bulletin, 37(7), 879-892.
[20] Akhrianti, I., Bengen, D. G., & Setyobudiandi, I. (2014). Spatial distribution and habitat preference of bivalvia in the coastal waters of simpang pesak sub district, east belitung district. Jurnal ilmu dan teknologi kelautan tropis, 6(1).

[21] Delisle, J. M., & Savidge, J. A. (1997). Avian use and vegetation characteristics of Conservation Reserve Program fields. The Journal of Wildlife Management, 318-325.

[22] Tortosa FS. 2000. Habitat Selection by Flocking Wintering Common Cranes (Grus grus) a tLos Pedroches Valley, Spain. Etologia 8: 21-24.

[23] Rouke, J., & Debus, S. J. (2016). The breeding cycle of a pair of Brahminy Kites’ Haliastur indus’ in New South Wales. Australian Field Ornithology, 33, 151-155.

[24] Wamepa, K., Purwoko, A., & Kamal, M. (2019). Studi Populasi Burung Wader (Charadriiformes) pada Akhir Musim Migrasi di Semenanjung Sembilang Banyuasin, Sumatera Selatan. Jurnal Penelitian Sains, 20(3), 77-80.

[25] Prawiradilaga, D. M., T. Muratte, A. Muzakir, T. Inoue, Kuswandono, A. A. Supriatma, D. Ekawati, M. Y. fianto, Hapsoro, T. Ozawa, dan N. Sakaguchi. (2003). Panduan Survei Lapangan dan Pemantauan Burung-burung Pemangsa. Jakarta: PT. Binamitra Mega Warna.

[26] Riefani, M. K., & Arsyad, M. (2019,). Spesies burung di Kawasan Ekowisata Mangrove Pagatan Besar, Kabupaten Tanah Laut. In Prosiding Seminar Nasional Lingkungan Lahan Basah (Vol. 4, No. 1, pp. 192-196). Research and Public Service Institute, Lambung Mangkurat University.

[27] Idrus, AA, Syukur, A., & Zulkifli, L. (2021). The Evidence of Rhizophora as a Potential Species to Improve Mangrove Recovery on the Southern Coast of East Lombok, Indonesia. ASM Science Journal. 14(2):57-54.

[28] Santoso, D., ZulHalifah , & Syukur,A., (2021, March). Impact of Revegetation of Rhizophora apiculata and Rhizophora stylosa on The Development of Mangrove Vegetation in Teluk Jor, East Lombok. In IOP Conference Series: Earth and Environmental Science (Vol. 712, No. 1, p. 012048). IOP Publishing.

[29] Idrus, AA, Syukur, A., & Zulkifli, L. (2019, December). The livelihoods of local communities: Evidence of success of mangrove conservation on the coastal of East Lombok Indonesia. In AIP Conference Proceedings (Vol. 2199, No. 1, p. 050010). AIP Publishing LLC.

[30] Zulhalifah, Z., Syukur, A., Santoso, D., & KARANAN, K. (2021). Species diversity and composition, and above-ground carbon of mangrove vegetation in Jor Bay, East Lombok, Indonesia. Biodiversity Journal of Biological Diversity, 22 (4).