

Diversity and abundance of water birds in the mangrove area of south coast of Bangkalan, Madura Island, Indonesia

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Abstract. Ramadhani A, Ambarwati R, Gumilang RS. 2022. Diversity and abundance of water birds in the mangrove area of south coast of Bangkalan, Madura Island, Indonesia. *Biodiversitas* 23: 3277-3284. The southern coastal mangrove area of Bangkalan, Madura Island, Indonesia, is an important bird habitat, especially for water birds. This study aimed to analyze the diversity and abundance of water birds in the southern coastal mangrove area of Bangkalan, Indonesia, as well as the environmental carrying capacity of this area as their habitat. Sampling was carried out using a birdwatching approach at four research stations. The diversity of water birds was analyzed using the Shannon-Wiener diversity index, while the abundance of water birds was calculated based on the abundance index. Environmental carrying capacity was analyzed descriptive-quantitatively based on the habitat profile. The results indicated that there were 15 species of water birds in the mangrove area belonging to five families in four orders, namely Charadriiformes, Ciconiiformes, Pelecaniformes, and Suliformes, with a diversity index of 1.547. There were three abundant species of water birds, namely the little egret (*Egretta garzetta*), Javan Pond-heron (*Ardeola speciosa*), and Great Egret (*Ardea alba*). In addition to water birds, there were nine species of arboreal birds in this area. The areas with dense mangroves provide better habitat carrying capacity for water birds compared to other coastal areas.

Keywords: Ardeidae, *Egretta garzetta*, migratory birds, wetlands

INTRODUCTION

Water birds are a group of birds that are identical to the wetland ecosystem because wetlands support their activities. Water birds have major functional roles in wetlands, including mangroves (Almeida et al. 2018; Purify et al. 2019, 2020) for instance as predators, herbivores, vectors of seeds, providing nutrients in the ecosystem (Green and Elmberg 2014), dispersal agents of aquatic organisms (Figuerola and Green 2002; Charalambidou and Santamaría 2005; Frisch et al. 2007; Reynolds and Cumming 2015) as well as vectors of invasive species (Reynolds et al. 2015; Green 2016). Water birds play a vital function in the nutrient dynamics of mangroves (McFadden et al. 2016; Morkune et al. 2020). In addition, water birds also have an essential role on the food webs of the marine ecosystem (Bestley et al. 2020). Generally, the morphological characteristics possessed by water birds are long legs and long beaks. These characteristics have a role in the wetland ecosystem in the foraging process (Howes et al. 2003). The typical characteristics of water birds have long bodies and legs, straight beaks that are tapered or curved. Some species of water birds have membranes on their feet. The habitat also supports water bird activities such as making nests, incubating eggs, and caring for chicks (Ma et al. 2010; Pérez-Crespo et al. 2013). The water bird habitat is combined. The combined habitat is a mixed aquatic ecosystem consisting of fresh, brackish, and marine waters.

One of the combined habitats for water birds is the mangrove area (Nagelkerken et al. 2008; Sandilyan and Kathiresan 2012; Mohd-Azlan et al. 2015).

The mangrove area is a wetland area that has important value in coastal ecosystems. This important value supports the preservation of biodiversity, such as animals and plants that include mangrove areas. In addition, mangrove areas play a role in protecting coastal abrasion or erosion, resisting sea waves, as well as reducing and protecting against strong winds (Kurniadi and Koeslulat 2020). Besides, mangrove is an important habitat for water birds (Nagelkerken et al. 2008; Asri et al. 2020). Purify et al. (2019) stated that water birds have a vital role in the mangrove ecosystem because they have a significant portion in the integrity of the ecosystem. In addition to being a nesting place for water birds, the mangrove area acts as a place for shelter, breeding, and providing food (Rajpar and Zakaria 2010).

The southern coast of Bangkalan, Indonesia, is a wetland area located in the southern part of Madura Island. Coastal ecosystems are ecosystems located between land and sea. According to Crick (2004) and Sandilyan and Kathiresan (2012) this kind of ecosystem has the potential high biodiversity. One of the potentials of high biodiversity is located in the mangrove are birds. Some parts of the southern coast of Bangkalan are comprised of mangrove areas. Mangrove areas provide space for roosting activities and abundant food sources (Nagelkerken et al. 2008; Sandilyan and Kathiresan 2012).

Several previous researches have been conducted in the northern coastal mangrove areas in East Java regarding the diversity and abundance of water birds, for example, in the Wonorejo Mangrove Area, there were species of water birds such as the Little Egret (*Egretta garzetta*), the Javan Pond-heron (*Ardeola speciosa*), the Great-billed Heron (*Ardea sumatrana*), the Black-crowned Night-heron (*Nycticorax nycticorax*) and the Green-backed Heron (*Butorides striata*) (Diana and Binawati 2019). In the mangrove area of Sidoarjo Mud Island, water birds such as the purple heron (*Ardea purpurea*) and the milky stork (*Mycteria cinerea*) were found (Prasinja et al. 2017). In addition, in the Banyuurip mangrove area, Ujungpangkah, Gresik Regency, species of water birds were found, such as the Javan Plover (*Charadrius javanicus*), the Pacific Golden Plover (*Pluvialis fulva*), and the Whiskered Tern (*Chlidonias hybrida*) (Mubarrok and Ambarwati 2019), Little Egret, the Javan Pond-heron (Ilmar and Santoso 2019; Mubarrok and Ambarwati 2019; Ali et al. 2021; Budiman et al. 2021). The coastal mangrove area of Randutatah, Probolinggo Regency, was habitat for families of water birds such as Ardeidae, Charadriidae, and Scolopacidae (Syamsuddin et al. 2019).

However, until now, there is no data regarding the diversity of water birds in Bangkalan, Madura. Therefore, exploratory research regarding water birds in the southern

coastal mangrove area of Bangkalan, Madura, is needed. This study aimed to analyze the diversity and abundance of water birds, as well as analyze the environmental carrying capacity of the southern coastal mangrove area of Bangkalan.

MATERIALS AND METHODS

Study area

The research was carried out in the southern coastal mangrove area of Bangkalan (in Madura Island), East Java Province, Indonesia. There were four research stations in the mangrove area of the southern coast of Bangkalan, namely the south coast of Sukolilo Barat Village, Labang Sub-district (Station I), Kejawan Village, Kwanyar Sub-district (Station II), Pesanggrahan Village, Kwanyar Sub-district (Station III), and Karanganyar Village, Kwanyar Sub-district (Station IV) (Figure 1). The research stations were determined based on the condition of vegetation cover of the mangrove area. Station I has relatively thin mangrove vegetation. Station II has thin mangrove vegetation. Station III has thick mangrove vegetation. Station IV has moderate mangrove vegetation.

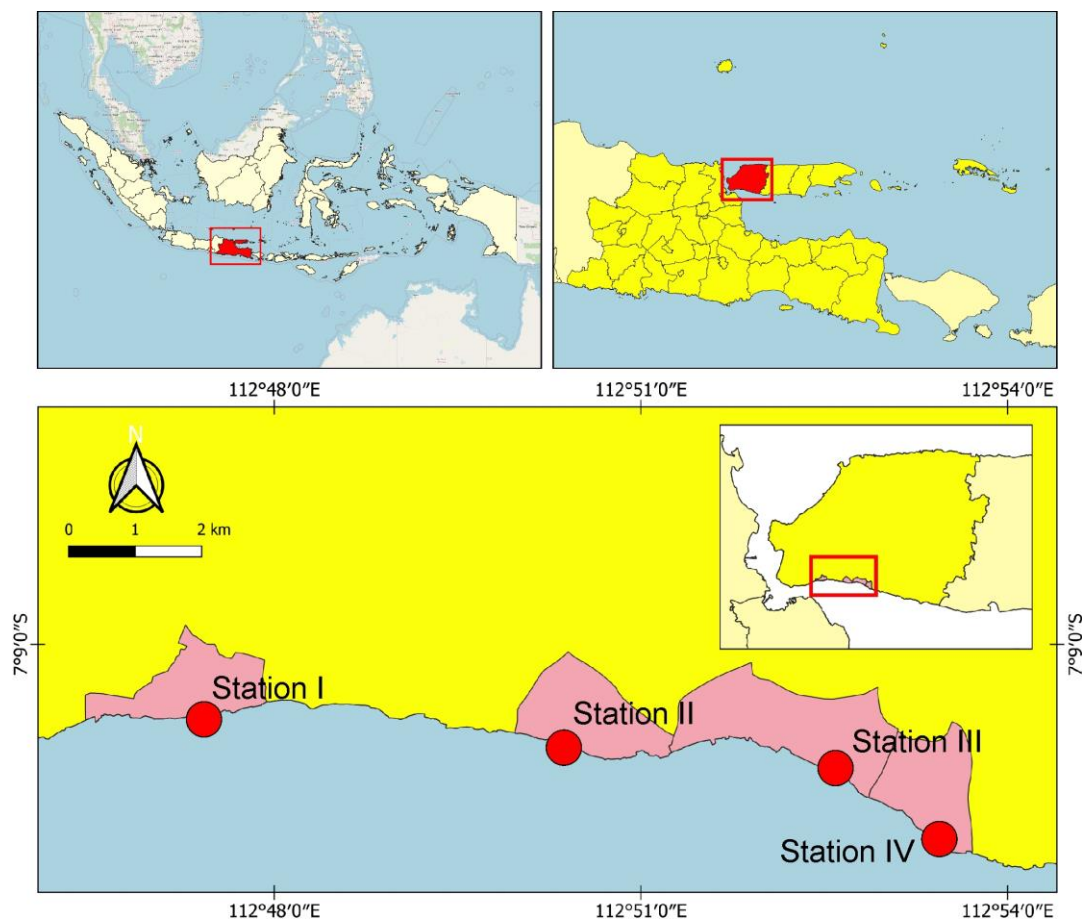


Figure 1. Map of research on the mangrove area of the southern coast of Bangkalan, Madura Island, East Java Province, Indonesia

Procedures

Sampling and observation of birds

A sampling of bird species was carried out in October 2021 during low tide. Sampling using the transect method with a birdwatching technique approach. This method was carried out by tracing along the observation track. Bird observation was conducted using the transect method carried out in the morning and afternoon at 07.30-10.30 a.m and 11.00-14.00 p.m, respectively with two repetitions of observations at each station. In each station, it was determined three observation points. The observation time for each point was 15 minutes and then moved as far as 50 meters to the next point along the transect tract. Observation activities were conducted using binoculars with a magnification of 50×50. Each bird observed was morphologically documented with a FujiFILM Corporation Digital FinePix S2980 camera with a 5.0-90.0 mm lens magnification. Observations were recorded on an observation sheet containing the name of the bird, number, time of encounter, and bird activity. In addition, the environmental carrying capacity was evaluated based on the condition of the substrate of the water bird habitat by measuring physical factors, including substrate pH, substrate temperature, substrate humidity, and water salinity. The substrate temperature was measured using a thermometer. The pH and humidity of the substrate were measured using a soil tester. The water salinity was measured using a refractometer. Meanwhile, the mangrove vegetation was recorded, including the name of the mangrove species, number, and its usage by the birds, for example, perching, feeding.

Identification of data

Identification of birds based on MacKinnon et al. (2010) and the digital application of Burungnesia. The conservation status of each species was analyzed based on the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.106/MENLHK/SETJEN/KUM.1/12/2018 (*Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia Nomor P.106/MENLHK/SETJEN/KUM.1/12/2018*), Government Regulation of the Republic of Indonesia Number 7 Year 1999 (*PP No. 7 Tahun 1999*) about Preservation of Plant and Animal Species, International Union for Conservation of Nature (IUCN), and Convention on International Trade in Endangered Species (CITES) as a guide to describe the conservation status of birds. Identification of mangrove vegetation was carried out based on morphological characteristics referred to Noor et al. (2006).

Data analysis

Data analysis was carried out with the diversity index using the Shannon-Wiener formula, as follows:

Diversity index:

$$H' = -\sum \frac{N_i}{N} \ln \frac{N_i}{N}$$

Where, H': Diversity index; N_i: Number of individuals of species i; N: Total number of individuals of all species; ln: logarithm with base e.

Abundance index:

$$Di = \frac{ni}{n} \times 100\%$$

Where, Di: Bird species abundance index i; n_i: number of birds of species i; n: total number of all birds observed

Meanwhile, the environmental carrying capacity data was processed descriptively based on the habitat profile.

RESULTS AND DISCUSSION

Birdwatching results

In the mangrove area of the southern coast of Bangkalan, Madura, there were 24 species of water birds and non-water birds found. There were 15 species of water birds belonging to five families and included in four orders, namely Charadriiformes, Ciconiiformes, Pelecaniformes, and Suliformes. Among these data, there are seven species of water birds included in the migratory status, namely Pacific Golden Plover, Kentish Plover, White-Winged Tern, Black-Naped Tern, The Whimbrel, Gray-Tailed Tattler, and Common Sandpiper. In addition, there were water birds species that are protected species based on the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.106/MENLHK/SETJEN/KUM.1/12/2018 and Government Regulation of the Republic of Indonesia Number 7 Year 1999, namely The Javan Plover, Kentish Plover, White-Winged Tern, Black-Naped Tern, Whimbrel, and The Great Egret, and one species of water birds, the Gray-tailed Tattler is included in the (NT) Near Threatened according to the IUCN (Table 1).

In the mangrove area, there were also found non-water bird species. There were nine species belonging to eight families, including to five orders, namely Apodiformes, Columbiformes, Coraciiformes, Cuculiformes, and Passeriformes. One of these non-water bird species is protected under Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.106/MENLHK/SETJEN/KUM.1/12/2018, Government Regulation of the Republic of Indonesia Number 7 Year 1999, namely Sunda Pied Fantail. Overall, non-water bird species were categorized of Least Concern (LC) and non-appendix based on IUCN and CITES (Table 2).

Calculation of diversity index

Based on the results of the calculation of the bird diversity index in the southern coastal mangrove area of Bangkalan, Madura, it was 1.547. Each research station has almost the same diversity index but with different environmental conditions. The highest diversity index was station III, which is located in Pesanggrahan Village, Kwanyar Sub-district (Table 3).

Calculation of abundance index

The results of observations also with the calculation of the abundance index which shows as many as three species of water birds that are often found in the southern coastal mangrove area of Bangkalan, namely the Little Egret of 19.617%; Javan Pond-heron by 15.311%, and Great Egret by 14.354 (Table 4; Figure 2).

Environmental support data

Based on data collection, which was carried out by observation, data related to the carrying capacity of the environment were obtained, which consisted of measurements of physical factors and mangrove vegetation. The measurement results showed that the temperature, pH, humidity, and salinity ranges are almost

the same. However, in observations, there are differences in substrate conditions and the level of mangrove vegetation cover. Station I had a rocky coral substrate and muddy sand with relatively thin mangrove vegetation. Station II had a muddy sand substrate and rocky coral with thin mangrove vegetation. Station III had a muddy sand substrate with thick mangrove vegetation. Station IV was muddy sand with moderate mangrove vegetation (Table 5).

There were seven species of true mangroves dominating the coastal mangrove area of South Bangkalan, including Apple Mangrove, White Mangrove, River Mangrove, Loop-Root Mangrove, Sea Holly, Khalsi, dan Black Mangrove. These species support bird activities such as feeding, perching, and singing (Table 6).

Table 1. Water birds in mangrove area southern coastal of Bangkalan, Madura Island, Indonesia

| Order | Family | Scientific name | Common name | Presence in research station | | | | Conservation status | | |
|-----------------|-------------------|-----------------------------------|------------------------|------------------------------|----|-----|----|---------------------|------|-------|
| | | | | I | II | III | IV | PP | IUCN | CITES |
| Charadriiformes | Charadriidae | <i>Charadrius javanicus</i> | Javan plover* | √ | √ | - | √ | √ | LC | - |
| | | <i>Pluvialis fulva</i> | Pacific golden plover | √ | - | √ | - | - | LC | - |
| | | <i>Charadrius alexandrinus</i> | Kentish plover* | √ | - | - | - | √ | LC | - |
| | Laridae | <i>Chlidonias leucopterus</i> | White-winged tern* | - | √ | √ | √ | √ | LC | - |
| | | <i>Sterna sumatrana</i> | Black-naped tern* | - | - | √ | - | √ | LC | - |
| | Scolopacidae | <i>Numenius phaeopus</i> | Whimbrel* | √ | - | √ | - | √ | LC | - |
| | | <i>Tringa brevipes</i> | Gray-tailed tattler | - | - | √ | - | - | NT | - |
| Ciconiiformes | Ardeidae | <i>Actitis hypoleucos</i> | Common sandpiper | - | √ | √ | √ | - | LC | - |
| | | <i>Ardea cinerea</i> | Grey heron | - | - | - | √ | - | LC | - |
| | | <i>Egretta garzetta</i> | Little egret | - | - | √ | √ | - | LC | - |
| Pelecaniiformes | Ardeidae | <i>Ardeola speciosa</i> | Javan pond-heron | - | - | √ | √ | - | LC | - |
| | | <i>Ardea alba</i> | Great egret* | - | - | √ | √ | √ | LC | - |
| | | <i>Ardea purpurea</i> | Purple heron | - | √ | - | - | - | LC | - |
| | | <i>Butorides striata</i> | Green-backed heron | √ | √ | - | - | - | LC | - |
| Suliformes | Phalacrocoracidae | <i>Phalacrocorax sulcirostris</i> | Little black cormorant | - | - | - | √ | - | LC | - |

Note: *: Conservation status based on Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.106/MENLHK/SETJEN/KUM.1/12/2018, Government Regulation of the Republic of Indonesia Number 7 Year 1999 (PP)

Table 2. Non-water birds in mangrove area southern coastal of Bangkalan, Madura Indonesia

| Order | Family | Scientific Name | Common Name | Presence in Station | | | | Conservation status | | |
|---------------|--------------|------------------------------|-----------------------|---------------------|----|-----|----|---------------------|------|-------|
| | | | | I | II | III | IV | PP | IUCN | CITES |
| Apodiformes | Apodidae | <i>Collocalia linchi</i> | Cave swiftlet | √ | √ | √ | √ | - | LC | - |
| Columbiformes | Columbidae | <i>Geopelia striata</i> | Zebra dove | - | - | √ | - | - | LC | - |
| Coraciiformes | Alcedinidae | <i>Todiramphus chloris</i> | Collared kingfisher | √ | √ | - | √ | - | LC | - |
| Cuculiformes | Cuculidae | <i>Centropus sinensis</i> | Greater coual | - | √ | - | - | - | LC | - |
| Passeriformes | Laniidae | <i>Lanius schach</i> | Long-tailed shrike | - | - | √ | - | - | LC | - |
| | Passeridae | <i>Passer montanus</i> | Eurasian tree sparrow | √ | - | - | - | - | LC | - |
| | Pycnonotidae | <i>Pycnonotus goiavier</i> | Yellow-vented bulbul | - | √ | - | - | - | LC | - |
| | | <i>Pycnonotus aurigaster</i> | Sooty-headed bulbul | - | - | √ | - | - | LC | - |
| | Rhipiduridae | <i>Rhipidura javanica</i> | Sunda pied fantail* | - | - | √ | √ | √ | LC | - |

Note: *: Conservation status based on Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.106/MENLHK/SETJEN/KUM.1/12/2018, Government Regulation of the Republic of Indonesia Number 7 Year 1999 (PP)

Table 5. Physical factors for each station in mangrove area southern coastal of Bangkalan, Madura Indonesia

| Station | Temp. (°C) | Humidity(%) | pH | Salinity (%) |
|--------------------------------------|------------|-------------|---------|--------------|
| Sukolilo Barat (Labang Sub-district) | 36-37 | 78-85 | 5.9-6.8 | 2.9-3.0 |
| Kejawen (Kwanyar Sub-district) | 35-37 | 70-88 | 6.9-7.5 | 2.8-3.1 |
| Pesangrahan (Kwanyar Sub-district) | 35-36 | 76-89 | 7.4-7.2 | 2.9-3.1 |
| Karanganyar (Kwanyar Sub-district) | 34-36 | 78-82 | 6.3-7.0 | 2.8-3.0 |

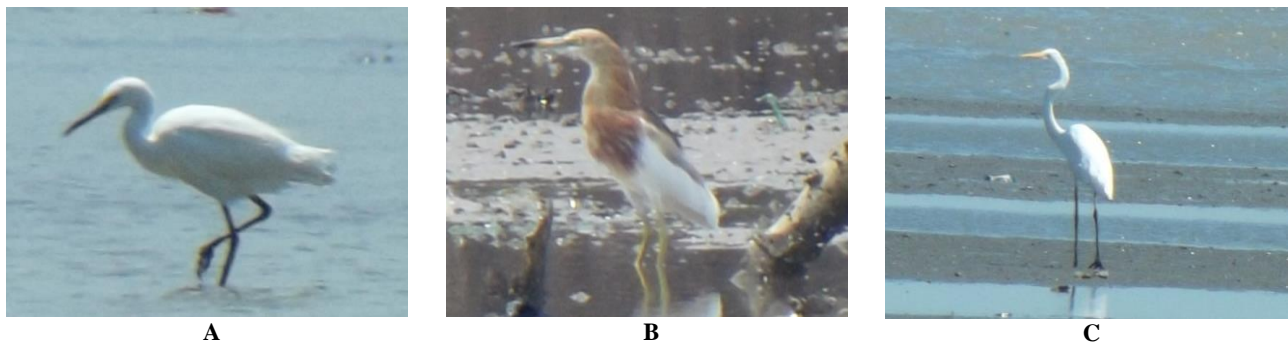


Figure 2. Abundant water birds in the southern coastal mangrove area of Bangkalan, Madura A. Little Egret; B. Javan Pond-heron; and C. Great Egret

Table 3. Diversity index of each research station in mangrove area southern coastal of Bangkalan, Madura Indonesia

| Station | Diversity Index (H') |
|--------------------------------------|----------------------|
| Sukolilo Barat (Labang Sub-district) | 1.313 |
| Kejawen (Kwanyar Sub-district) | 1.414 |
| Pesanggrahan (Kwanyar Sub-district) | 1.744 |
| Karanganyar (Kwanyar Sub-district) | 1.718 |
| Average (H') | 1.547 |

Table 4. Abundance index of water birds in mangrove area southern coastal of Bangkalan, Madura Indonesia

| Scientific name | Common name | Abundance Index/Di (%) |
|-----------------------------------|------------------------|------------------------|
| <i>Ardeola speciosa</i> | Javan pond-heron (M) | 15.311 |
| <i>Ardea cinerea</i> | Grey heron | 0.957 |
| <i>Ardea alba</i> | Great egret (M) | 14.354 |
| <i>Ardea purpurea</i> | Purple heron | 0.957 |
| <i>Charadrius javanicus</i> | Javan plover | 5.742 |
| <i>Pluvialis fulva</i> | Pacific golden plover | 5.263 |
| <i>Charadrius alexandrinus</i> | Kentish plover | 0.957 |
| <i>Chlidonias leucopterus</i> | White-winged tern | 9.091 |
| <i>Sterna sumatrana</i> | Black-naped tern | 0.957 |
| <i>Numenius phaeopus</i> | Whimbrel | 7.656 |
| <i>Butorides striata</i> | Green-backed heron | 3.828 |
| <i>Egretta garzetta</i> | Little egret (M) | 19.617 |
| <i>Phalacrocorax sulcirostris</i> | Little black cormorant | 1.914 |
| <i>Tringa brevipes</i> | Grey-tailed tattler | 6.699 |
| <i>Actitis hypoleucos</i> | Common sandpiper | 6.699 |

Note: M= The most abundant water birds species based on abundance index calculation

Table 6. Species of mangrove vegetation and their use on bird activity in mangrove area southern coastal of Bangkalan, Madura Indonesia

| Common Name | Scientific Name | Bird activities |
|--------------------|-------------------------------|-----------------|
| Apple mangrove | <i>Sonneratia alba</i> | Feeding |
| White mangrove | <i>Avicennia marina</i> | Perching |
| River mangrove | <i>Aegiceras corniculatum</i> | Perching |
| Loop-root mangrove | <i>Rhizophora mucronata</i> | Feeding |
| Sea holly | <i>Acanthus ebracteatus</i> | Perching, Chirp |
| Khalsi | <i>Aegiceras floridum</i> | Perching |
| Black mangrove | <i>Avicennia alba</i> | Perching |

Discussion

Based on the results of the study, 15 water bird species were found in the mangrove area of the southern coast of Bangkalan, Madura. Water birds can be identified morphologically. Morphological characteristics of water birds include the characteristics of feathers, beaks, and feet. The various characteristics of the beak that are owned by water birds are wide and flat and long beaks that form a hard or sagging cone. These characteristics indicate that the beak of water birds has a relationship with the type of feed and the process of foraging for food. In addition, the characteristics of the feet of water birds are long and webbed in some species. These characteristics are related to bird habitat. The habitat of water birds is generally in wetland areas. Péron et al. (2013) stated that water birds prefer wetlands because they support the migration process. Some of the water birds found in the mangrove area of the southern coast of Bangkalan are classified as migratory birds, namely the Pacific Golden Plover, the Kentish Plover, the White-winged Tern, the Black-naped Tern, the Whimbrel, the Gray-tailed Tattler, and the Common Sandpiper. Migratory birds are birds that travel long distances by moving to safer habitats. In this case, migration aims to avoid extreme weather conditions. The distance traveled by water birds is influenced by the seasonal conditions of an area and the bird population (Howes et al. 2003).

In its conservation, birds are the most common wild animal species side by side with humans, but there are human activities that threaten their existence, for instance, hunting and trading. Hunting activities can affect the number of bird populations (Young et al. 2005; Greenwood 2007; Brooks et al. 2008; Zuberogoitia et al. 2008; Magige et al. 2009; Ilmar and Santoso 2019). Several regulations and guidelines related to the conservation status of birds are contained in the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.106/MENLHK/SETJEN/KUM.1/12/2018, Government Regulation of the Republic of Indonesia Number 7 Year 1999 (PP), IUCN, and CITES. The conservation status of birds supports the population of bird species because if there is an imbalance in the population, it will have an impact on the threat to a species (Brooks et al. 2008). Based on the number, distribution, and threat, IUCN has criteria that support the level of conservation of each species. The criteria consist of extinct (Extinct; EX),

extinct in the wild (Extinct in The Wild; EW), critically (Critically Endangered; CR), critical (Endangered; EN), vulnerable (Vulnerable; VU), near threatened (Near Threatened; NT), low risk (Least Concern; LC), lacking information (Data Deficient; DD), and not evaluated (Not Evaluated; NE). Both of these conservation statuses are related to international level regulations that play a role in protecting endangered species as a result of illegal trade (Lanchbery 2006; Boitani et al. 2008; D'Cruze and Macdonald 2016; McGowan et al. 2017; Betts et al. 2019; Maulany et al. 2021)

Overall, the results of research on water birds found in the mangrove area of the southern coast of Bangkalan, Madura, almost have similarities with the studies conducted in the mangrove area of the northern coast of East Java. The bird species found were the Javan Pond-heron, the Little Egret, the Purple Heron, the Javan Plover, and the Pacific Golden Plover. This finding is related to the condition of habitats. Ma et al. (2010) reported that the habitat variables affected the use of wetlands by water birds. Besides, the species richness and the species density were associated with plant species in the mangrove area (Mohd-Azlan et al. 2015). Meanwhile, Mubarrok and Ambarwati (2019) stated that the distribution of birds is influenced by the availability of feed and nesting places. In addition, environmental conditions owned by each region can affect bird diversity.

Based on data in the southern coastal mangrove area of Bangkalan, a diversity index was obtained at each of the four research stations. Each research station has a different diversity index. Differences in diversity index values can be influenced by habitat characteristics, chemical factors, and physical factors in certain ecosystems (Martins et al. 2019). The value of species diversity is related to species density (Paracuellos and Tellería 2004; Eeva et al. 2012). Species density is a description of the level of species diversity in a particular community related to the evenness of individuals in each species. If the distribution of individuals in a community is not evenly distributed, the value of the density of the species is low.

In addition to diversity, abundance is also related to a population. In the southern coastal mangrove area of Bangkalan, Madura, many species of water birds are found, such as Little Egret and the Javan Pond-heron. In addition, there were Great Egret which has a high abundance index in the southern coastal mangrove area of Bangkalan, Madura. The high population of great egrets can be caused by habitat conditions such as mangroves. Cisneros-Heredia (2006) reported the existence of great egret in the group of ten. The abundance of water birds is influenced by the condition of the mangrove (Mohd-Azlan et al. 2015) and the habitat related to mudflat conditions (Purify et al. 2019). In addition, there are many food sources for macrozoobenthos, such as the feed of the water birds and the safety place of water bird habitats. The environmental changes that occur in the habitat of a species have a relationship with diversity and abundance (Guo et al. 2017; Purify et al. 2019). In this case, the population of a species has a relationship with environmental quality.

Environmental carrying capacity is an ecosystem criterion that supports the activities of organisms and plays a role in showing the quality of an environment so that it can know and avoid if there is a decrease in environmental quality (Williams et al. 2014; Suana et al. 2020). Environmental physical factors have a relationship with bird habitat. The physical environmental factors include soil, water, temperature, and sunshine (Soendjoto and Gunawan 2003). Several parameters are used to measure environmental quality, namely temperature, pH, humidity, and salinity (Purify et al. 2019; Herawati et al. 2021). All of those habitat parameters related to the fertility of the waters (Herawati et al. 2021). In this case, it also affects the availability of food sources for water birds in waters and wetlands. In addition, water birds feed is also affected by salinity because each aquatic invertebrate has a different salinity tolerance (Liang et al. 2002; De Dios et al. 2019). Based on the results of the study, the temperature, pH, humidity, and salinity ranges were almost the same in all research stations, however they were differences between the substrate conditions and the mangrove vegetation. These parameters indicated that the ecosystem could support the life of water birds. In addition, the existence of mangroves and mudflats can provide feed for water birds.

The habitat of station III is a mangrove area in Kwanyar Sub-district. Kwanyar Sub-district has mangrove vegetation with a high level of plant density. The dense mangrove vegetation is due to government programs related to the rehabilitation of forest areas. Meanwhile, Labang Sub-district has low-level mangrove vegetation. This is due to the condition of the substrate in the Labang Sub-district, which is mostly rocky and there is land reclamation such as settlements and the construction of facilities and infrastructure. Mangrove vegetation has a role in bird activity. These activities are foraging, nesting, and breeding (Rajpar and Zakaria 2010; Asri et al. 2020). Habitat substrate conditions also affect waterbird activity (Mancini et al. 2018). Several coastal mangrove areas south of Bangkalan support the conservation area (Wardhani 2014).

Mangroves are important habitats for most groups of water birds as well as some species of terrestrial birds (Nagelkerken et al. 2008; Mancini et al. 2018; Asri et al. 2020). They make mangroves as a habitat for foraging, breeding, or just resting. For some species of water birds, such as herons (*Ardea* spp.), the mangrove habitat provides adequate space to build nests, especially because of the minimal disturbance caused by predators. For fish-eating species, such as the egrets (*Egretta* spp.), mangroves provide an abundant perch and food source, while for various species of migratory water birds (particularly the Charadriidae and Scolopacidae), mudflats are a very suitable habitat to find their prey (Purify et al. 2019). Besides, the mangrove roots are a good resting place during high tide in their wandering season (Nagelkerken et al. 2008).

Based on research that has been carried out in the mangrove area of the southern coast of Bangkalan, Madura, 15 water birds were found. The data obtained a diversity index of 1.547; and three species have the highest

abundance index, namely the Little Egret, the Javan Pondheron, and the Great Egret. In addition, the environmental carrying capacity obtained showed that the physical factors of each research station have the same range in different substrate conditions and lush vegetation, with seven mangrove species dominating in the mangrove area. Mangrove areas that have high density support the carrying capacity of the habitat environment for water birds compared to other coastal areas.

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