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Research Article

Coastal Waterbirds Diversity and Structure under Land Use Changes in the Northern Coast of Situbondo Regency, East Java

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ABSTRACT

The coast is a suitable habitat for waterbirds, but changes in land use could negatively affect the life of these birds. The northern coast of Situbondo Regency, East Java Province, showed variations in land use quality. This study aims to analyze the interaction between changes in coastal land use that affect waterbird diversity and community structure on the coast. Waterbird density was recorded based on the point counts along a 100 m^2 transect at six stations, including Kampung Blekok, Tanjung Pecinan, Dubibir, Cemara, Banyuglugur, and Baluran National Park as the reference site. Land use quality in the coastal areas was determined by satellite imagery. Waterbird diversity was determined by the Shannon-Wiener index, and habitat preference was determined by the Neu index. The results showed that Tanjung Pecinan and Kampung Blekok stations had characteristics similar to Baluran and provided favorable habitats for waterbirds. Dominated by high mangrove forests as well as agricultural and industrial areas, these stations supported waterbird life. The reference site (H' 2.26) and Kampung Blekok (H'1.39) showed medium diversity. Kampung Blekok (*wi* 3.25), Cemara, and Tanjung Pecinan (*wi* 1.16 to 1.20) were favorable habitats for waterbirds. These mangrove stations should be preserved as habitats for waterbird life, including three red-listed IUCN species.

Keywords: Community Structure, Diversity, Land Use, Northern Situbondo Coast, Waterbirds

Introduction

The mangrove ecosystem is a coastal wetland and a potential habitat for waterbirds to find prey, shelter, grow, and breed [1–4]. Almost 21% of the world's mangrove forests are found in Indonesia [1, 5]. However, the increasing coastal reclamations and conversions into settlements and expansions of agriculture, aquaculture, and industry often occur in some Indonesian mangrove forests, thus reducing the world's mangrove forests. Furthermore, the conversion of coastal areas into shrimp ponds, industrial areas, agricultural lands, and settlements causes changes in the mangrove ecosystem as a habitat for various wild creatures, including waterbirds [6, 7].

Most waterbird activities occur in wetlands [8]. Their role is important in maintaining the balance and stability of the ecosystem, shown by their ecological niche as top consumer birds in the food chain [9]. As predators, they prevent pest outbreaks in agricultural areas and also serve as sensitive bioindicators [2]. Coastal areas, where mangrove forests have varying mud thickness, are optimal habitats for several wild animals, including waterbirds [10]. However, the coastal mangrove ecosystem integrity is vulnerably disturbed by human activities and land use changes [11].

Land use changes along the coast of Northern Situbondo Regency were reported to decrease the diversity and structure of mangroves. Earlier

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studies showed that the mangrove forests' conversion into settlements, ponds, and industries had increased mangrove forest degradations, caused abrasion and intrusion, and decreased the wildlife diversity [12–14]. However, no information exists about their impacts on waterbird diversity and community structure. Therefore, this study is urgently needed. This study aims to analyze the relationship between coastal land use changes, waterbird diversity, and community structure on the Situbondo Regency coast. Additionally, this study will provide recent information on waterbird diversity, habitat preference, and limiting factors to support better coastal development planning and sustainable birdwatching ecotourism.

Material and Methods

Study area

The study was conducted along the northern coast of the mangrove vegetation in Situbondo Regency, East Java, Indonesia, covering 725.25 ha of mangrove [15]. It included six stations: Banyuglugur District (Banyuglugur Beach), Suboh District (Dubibir Beach), Kendit District (Kampung Blekok Beach), Panarukan District (Cemara Beach), Mangaran District (Tanjung Pecinan Beach), and Banyuputih District (Baluran Beach, as a reference site), from December 2020 to April 2021 (Figure 1). These stations showed a high variation of land use. Baluran Coast, located in the Banyuputih District, is a national park conservation area in the eastern part of Situbondo Regency, a reference site in this study. Kendit, Panarukan, and Mangaran Districts are in the center of Situbondo Regency, where mangrove areas are close to the estuary. Suboh and Banyuglugur Districts are in the western Situbondo Regency and the mangrove area is close to the industrial area.

Determination of land use changes, mangrove, and waterbirds structure

Land use changes in the coastal area were determined using the Landsat 8 imagery and then processed by ArcGIS 10.7 [16, 17]. Based on the imagery, land use categories were determined as mangrove (forest and plantation), agriculture (rice field and field), aquaculture, open field (mud flat), settlement, and industrial area [18].

Mangrove analysis was conducted using the line transect and purposive sampling. The sampling site coordinates were recorded using the GPS (Global Positioning System). The distance

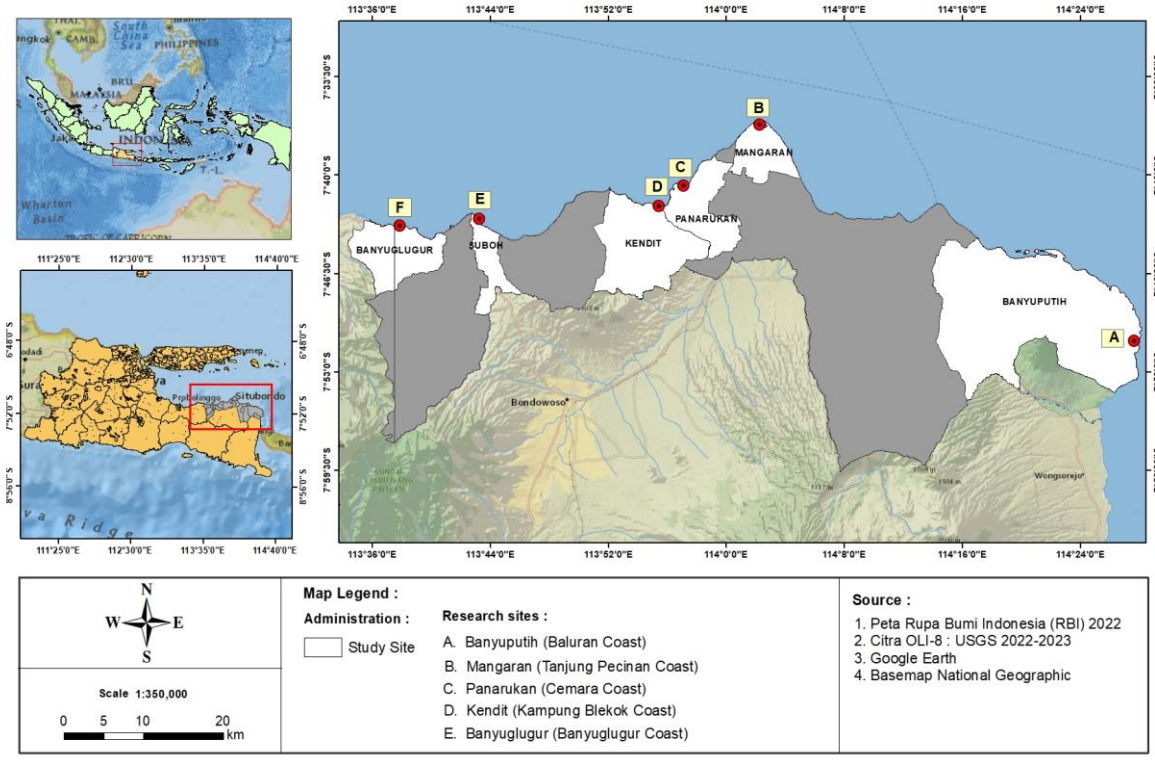

Figure 1. The study sites in the Northern Situbondo Regency

between the two transects was 100 m, and between plots (100 m^2) was 10 m. The waterbird density was examined using the cruising method along the transects in three to four plots as replications based on the point count and audiovisual method for 30 minutes from 05.30 to 8.30 am and from 2.30 to 5.30 pm [1]. Bird species were then identified using the field guide identification books [1, 19] and Burungnesia 2.0 [20].

Data analysis

The waterbird community structure data were analyzed using some ecological indices such as Shannon-Wiener diversity [21], evenness [21], species richness (determined based on the cumulative number of mangroves or waterbird species recorded in the area) [22], density, Whittaker's beta diversity (describes the amount of differentiation between species communities) [22, 23], and Neu index with the following formula:

Shannon-Wiener diversity index (H')

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

Note:
ni = ∑ number of species
N = ∑ total species

Evenness index (E)

$$E = \frac{H'}{\ln S}$$

note:
H'= diversity
S = total species

Density

$$D = \frac{\text{individual number of species}}{\text{area of the plots}}$$

Whittaker's beta diversity

$$\beta = \gamma / \alpha$$

Note:
γ = the total species diversity in all stations
α = the species diversity in each station.

Neu index (*wi*)

$$wi = [(ni/N)/(ai/A)]$$

Note:
ni= the number of waterbird encounters in i-habitat
N= the total of waterbird encounters in all habitats
ai= the wide of i-habitat
A= the wide of all habitats

Habitat data should be processed into a 1×1 km^2 before calculation so that the Neu index can represent it. The criteria of Neu index were classified into two levels: favored habitat ($wi \geq 1$) and less favorable habitat ($wi < 1$) [24]. The anthropogenic disturbance was determined by the Hemeroby index through direct observations [25]. The community structure and diversity of waterbirds were analyzed by using univariate correlation. The data were then analyzed using clustering, principal component analysis and biplots by using the PAST ver. 4.12 [25].

Results and Discussion

Land use area

The land use classification based on satellite imagery in each selected district is presented in Table 1 and Figure 2. Baluran, as a reference site, showed the highest mangrove area (263.23 ha), and agriculture (8947.4 ha) is dominant in this area. All districts were dominated by agriculture areas, but Tanjung Pecinan showed the highest open field, whereas Cemara showed the highest aquaculture area. Finally, Banyuglugur showed the highest industrial and settlement areas.

The Landsat 8 imagery showed that five stations comprised mangrove vegetation ranging from 29.99 ha to 52.21 ha. It was smaller than those in Baluran as a reference station, where the mangrove forest area reached 263.23 ha and showed the narrowest open area (19.08 ha). In 1980, the government established Baluran National Park as a conservation area in the Banyuputih District. The naturalness of this station was well-maintained [26]. This district showed the largest mangrove forest and agricultural area compared to other stations.

The land use of the Tanjung Pecinan coast was dominated by agricultural areas (3,033.69 ha) and showed the highest mud open field (116.71 ha). There were no industrial areas in Mangaran District. Almost all coastal areas were dominated by agricultural use which provided more food for waterbirds. The open field is a comfortable feeding area for water birds during low tide [27, 28]. Cemara Coast in the Panarukan District was dominated by aquaculture areas, including conventional and modern aquaculture ponds. The coast of Kampung Blekok in Kendit

District and Dubibir coast in Suboh District showed a large mud open field area (25.47 ha to 38.85 ha). Both were close to the estuaries. In contrast, the Banyuglugur coast in the Banyuglugur District showed the largest industrial area (26.08 ha). The mangrove area in this station was polluted by domestic and industrial wastes [14]. The negative impacts were indicated by decreasing diversity, evenness, richness, and population density of waterbirds (Table 2).

A wide area of agriculture and mud open fields was found in the districts of Mangaran, Panarukan, Kendit, and Suboh. These land uses were suitable for waterbirds such as *Bulbucus ibis* with long legs and beaks to catch their prey rather than mangrove areas. This waterbird belongs to the Ardeidae family and dominates in these districts. The declining populations of herons and migratory waterbirds are related to the loss of mangrove forests and anthropogenic disturbances.[29].

Community Structure of Waterbirds

19 waterbird species were recorded in this research (Table 2). Among them, there were three species in the 202 IUCN red list, such as *Leptoptilos javanicus* and *Ciconia episcopus* belonging to Ciconidae family, and *Charadius javanicus* of Charadriidae. Long legs and fingers characterize Ciconidae so that they can walk through shallow water searching for prey, including fishes, small vertebrates, or invertebrates in wetland or mangrove ecosystem [1, 21]. Therefore, these areas were very suitable for feeding ground and providing shelter during high tide [2, 21, 30]. Their beak's presence in the muddy, soft, and moist substrate makes it easier for shorebirds to catch prey at certain depths [31].

Table 1. Area of land use based on satellite imagery analysis

No	Stations	Area (ha)					
		Mangrove	Agriculture	Aquaculture	Open field	Settlement	Industry
1	Baluran	263.23	8,947.40	128.59	19.08	738.01	13.58
2	Tanjung Pecinan	38.39	3,033.69	327.32	116.71	543.41	0.00
3	Cemara	32.24	4,976.94	383.98	23.49	653.83	11.99
4	Kampung Blekok	29.99	1,382.19	28.45	25.47	295.15	10.60
5	Dubibir	33.41	2,201.29	79.91	38.85	373.37	8.15
6	Banyuglugur	52.21	3,140.08	28.79	26.75	349.51	26.08

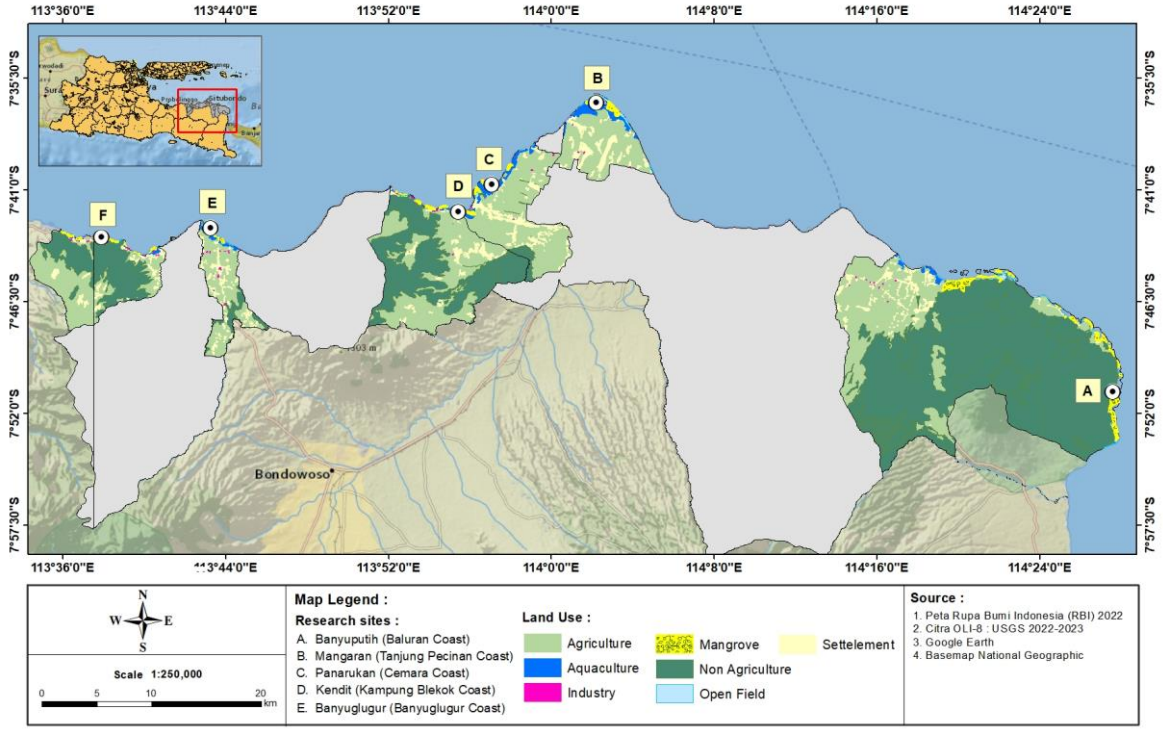

Figure 2. The land use maps each study site

Table 2. Waterbirds species found on studied area

No.	Species	English name	Density in the land use					
			Ba	Tp	Ce	Kb	Du	Bg
Ardeidae								
1	*Ardea alba*	Great White Egret	+++	+	+	++	+	-
2	*A. cinerea*	Grey Heron	+	-	-	-	-	-
3	*A. purpurea*	Purple Heron	++	+	+	+	+	-
4	*A. sumatrana*	Great-billed Heron	++	-	-	-	-	-
5	*Ardeola speciosa*	Javan Pond-heron	+	++	+	++	+	-
6	*Bubulcus ibis*	Cattle Egret	+++	++++	++++	++++	++++	-
7	*Butorides striata*	Green-backed Heron	++	++	+	++	-	-
8	*Egretta garzetta*	Little Egret	+++	++	++	++	++	-
9	*Ixobrychus sinensis*	Yellow Bittern	-	-	+	+	-	-
10	*Nycticorax nyxticorax*	Black-crowned Night-heron	+	++	++	++	++	+
Alcedinidae								
11	*Alcedo coelurenscens*	Cerulean Kingfisher	++	-	-	-	-	-
12	*Halcyon chloris*	Collared Kingfisher	++	-	-	-	-	-
Charadriidae								
13	*Charadrius javanicus*	Javan Plover	-	+	-	+	++	-
Ciconidae								
14	*Ciconia episcopus**	Asian Woollyneck	++	-	-	-	-	-
15	*Leptoptilos javanicus***	Lesser Adjutant	+	-	-	+	-	-
Meropidae								
16	*Merops philippinus*	Blue-tailed Bee-eater	+++	-	-	-	-	-
Rallidae								
17	*Amaurornis phoenicurus*	White-breasted Waterhen	-	-	-	+	-	-
Scolopacidae								
18	*Numenius phaeopus*	Whimbrel	+++	+	++	++	++	-
19	*Actitis hypoleucos*	Common Sandpiper	+++	+	++	++	++	-

Note: Ba (Baluran); Tp (Tanjung Pecinan); Ce (Cemara); Kb (Kampung Blekok; Du (Dubibir); Bg (Banyuglugur); - (not found); + (low); ++ (moderate); +++ (high); and ++++ (very high density)

In Kampung Blekok and Baluran, we also found the red list IUCN species near threatened (*C. javanicus*) and vulnerable (*L. javanicus*). Besides, in Baluran station, we recorded some abundant species such as *Ardea alba*, *Bubulcus ibis*, *Egretta garzetta* (Ardeidae), *Merops philippinus* (Meropidae), *Numenius phaeopus* and *Actitis hypoleucos* (Scolopacidae). Species *B. ibis* was dominant in Kampung Blekok, Tanjung Pecinan, Cemara, and Dubibir. This species was frequently found in the coastal area, including the mangrove area [1, 32]. Besides, the Meropidae family consists of slender birds, predominantly covered by green color feathers, and mainly feed insects [1, 33]. Furthermore, the Scolopacidae family is a small to medium-sized bird, measuring 12 to 66 cm in length, having dull feathers, cryptic brown, grey, or streaked patterns, and long and narrow sensitive bills. These birds eat small invertebrates living in the mud or sand around mangrove or coastal open areas [34].

This study recorded a spatial variation of the waterbird community and diversity in the research stations. Table 3 shows the highest diversity index of waterbirds recorded in the Baluran as a reference site (H'= 2.26), species evenness (E) 0.75, and species richness 13. Therefore, this station was categorized as having moderate diversity and a stable ecosystem for waterbirds. The ecosystem would be balanced if the density of species was even [35]. The diversity and structure of waterbirds in Kampung Blekok were closer to those in Baluran, especially in terms of species richness 14. However, Kampung Blekok waterbirds showed a lower diversity index (H') of 1.39 and low species evenness (E) of 0.29. It revealed a high variation of species density, while *B. ibis* was the most abundant species.

The Neu index analysis showed that Kampung Blekok, Tanjung Pecinan, and Cemara were the preferred habitat for waterbirds with the value of $wi > 1$. Kampung Blekok was dominantly cov-

ered by agricultural areas and enough mangrove as waterbird habitat. During the early rice growing season, especially in the seeding and germination period, the rice field was a temporary wetland and provided more grains for waterbirds [36]. On the other hand, Banyuglugur was a less favorable habitat for waterbirds, as shown by its zero neu index and low density. The high industrial and settlement area in this station reduced mangrove area as a waterbird habitat. Only one species was recorded, *Nycticorax nycticorax*. It was reported as the most widespread heron in the world and showed behavioral flexibility that might have facilitated the successful colonization of a human-modified landscape. Its natural habitats were marshes, swamps, ponds, lakes, and sewage lagoons, but the birds were also recorded in residential areas or urban city parks [37].

In order to determine the variation of community composition among stations, Whittaker's beta diversity analysis was carried out. The results showed that the highest Whittaker's beta diversity value was found in Baluran and Banyuglugur (1.0), followed by other stations, as shown in Table 4. This result confirmed the survey, indicating that Baluran showed the highest waterbird species composition, while Banyuglugur had the lowest.

The different waterbird community structures found in Situbondo Regency might be related to the different land used and its ecological service. The extensive mangrove forests for waterbird breeding, sheltering, and feeding, surrounded by agricultural areas for provisioning prey, while minimal settlements and industry areas were the preferred habitats for waterbirds [39–41]. The high evenness value of waterbirds in this area indicated that the area was favorable for a more diverse and lesser density of waterbirds population, including the near-threatened *C. javanicus* and vulnerable *L. javanicus*.

The correlation analysis between waterbirds profile and land use quality (Table 5) revealed that variations in land use disturbance had significantly affected the waterbird diversity index, richness, and density. Land use affected

Table 3. The spatial variation of waterbirds diversity and community structure

Stations	Diversity (H')	Evenness (E)	Species richness (SR)	Density (ind.m^{-2})	Neu index (*wi*)
Baluran	2.26	0.75	13	0.02	0.25
Tanjung Pecinan	0.94	0.26	10	0.42	1.16
Cemara	0.81	0.22	10	0.28	1.21
Kampung Blekok	1.39	0.29	14	0.69	3.25
Dubibir	0.85	0.26	8	0.15	0.63
Banyuglugur	0	0	1	0	0

Table 4. Whittaker's beta diversity of waterbirds among six stations of Situbondo Regency

Stations	Baluran	Tanjung Pecinan	Cemara	Kampung Blekok	Dubibir	Banyuglugur
Baluran	0	0.391	0.391	0.407	0.524	1.000
Tanjung Pecinan	0.391	0	0.100	0.167	0.111	0.818
Cemara	0.391	0.100	0	0.167	0.222	0.818
Kampung Blekok	0.407	0.167	0.167	0	0.273	0.867
Dubibir	0.524	0.111	0.222	0.273	0	0.778
Banyuglugur	1.000	0.818	0.818	0.867	0.778	0

Table 5. The correlation between waterbirds diversity, community structure and land use

Variables	Diversity	Species richness	Density	Mangrove	Agriculture	Industry	Hemeroby
Diversity		0.030	0.833	0.095	0.197	0.329	0.004
Species richness	0.855**		0.249	0.567	0.639	0.082	0.026
Density	0.112	0.559		0.295	0.252	0.119	0.579
Mangrove	0.737*	0.297	-0.516		0.012	0.920	0.168
Agriculture	0.611*	0.245	-0.556	0.907***		0.994	0.298
Industry	-0.485	-0.757*	-0.703*	0.053	0.004		0.152
Hemeroby	-0.951***	-0.864**	-0.289	-0.643*	-0.513	0.662*	

Note: * (significant correlation level p; *** 0-0.01, ** 0.01-0.05, * 0.05-0.1)

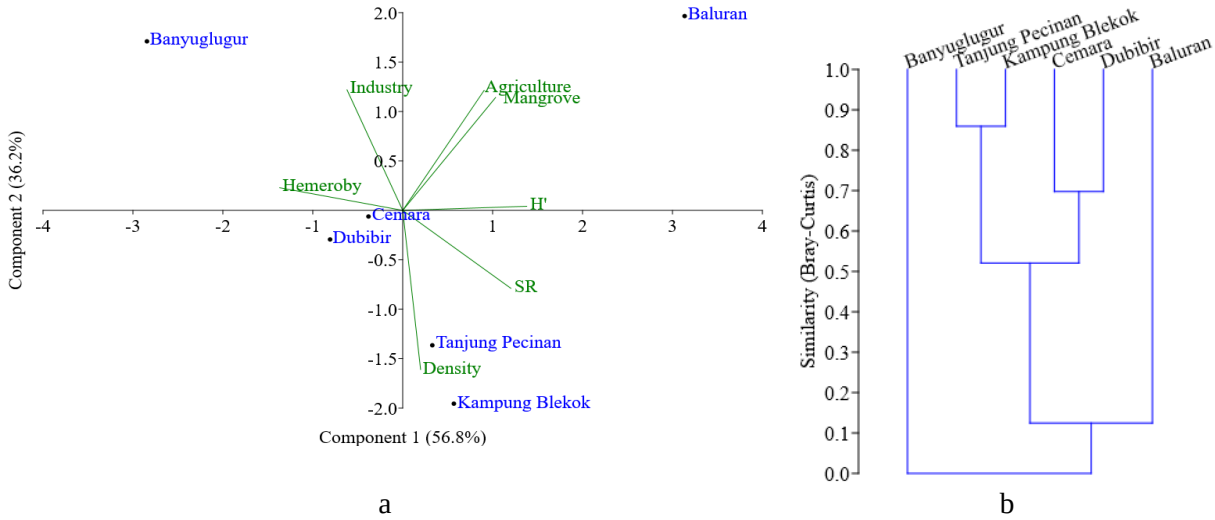

Figure 3. Profile of spatial variation of waterbird diversity, structure and its relations with land use changes. (a) The biplot analysis for integrative variables: land use, diversity (H') and species richness (SR) community structure of waterbirds in study sites; (b) The Bray-Curtis similarity index of waterbirds density.

the waterbird diversity in research stations. Mangrove and agriculture areas in the coastal areas significantly increased diversity index (H') and species richness (SR), but neither significantly increased the waterbird density.

The hemeroby index and industrial area were significantly correlated, and the diversity index and species richness of waterbirds decreased. However, industrial areas significantly reduced species richness and density. On the other hand, land use in the Baluran National Park was different from that of other parks. It is covered by complex agriculture and high naturalness mangroves that were natural waterbird habitats. The birds were facilitated for foraging, breeding, and building nests [31, 38].

The results of the PCA analysis (Figure 3a) of component 1 (56.8%) and component 2 (36.2%), where the total component parameters contribute > 75%, showed Baluran station as a unique reference site. Its Bray-Curtis similarity was only 15% with others. This protected area was characterized by the high mangroves and agriculture areas, as well as the most preferable habitat for the highest waterbird diversity. Mangrove and agriculture areas were preferred muddy wetlands for waterbirds as they provide abundant and diverse prey [28, 40]. The profiles of Tanjung Pecinan and Kampung Blekok stations showed a high similarity (almost 87%), characterized by moderate coverage of mangrove or agriculture area, Hemeroby index, and the lowest industrial area. These characters influenced waterbirds' high density and species richness, whereas the H' and E values were moderate.

The next cluster comprised Cemara and Dubibir stations (with 70% similarity) that were characterized by moderate areas of mangroves, agriculture and industry, Hemeroby index and also the moderate value of H', SR, and density of waterbird. On the other hand, the last station, Banyuglugur station, showed a high distinctness from others (almost 100% dissimilarity). It was covered by the moderate area of mangrove and agriculture but showed a high industrial area and Hemeroby index. These areas showed a low diversity, richness, and density of water birds. Anthropogenic activities in industrial area produced noise and diverse wastes that disturbed the ecosystem and biodiversity integrities [6]. The largest industrial area in Banyuglugur reduced the mangrove area and disturbed the waterbird's habitat.

Conclusion

The changes in coastal land use on the northern coast of Situbondo Regency strongly influenced the waterbird diversity and community structure. The expansion of industrial areas in Banyuglugur station decreased the density of waterbirds. However, Tanjung Pecinan and Kampung Blekok stations were still more favorable habitats for waterbirds due to higher agriculture and mangrove areas and low industrial areas.

These stations supported waterbird life and closed habitat properties to Baluran National Park. Therefore it is crucial to preserve mangrove vegetation as the best habitat for waterbird life.

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