

Macroinvertebrate Diversity and Abundance as Key Determinants of Waterbird Foraging Habitats in Bagan Percut Mudflats, North Sumatra

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Abstract Coastal mudflats play a critical role in supporting biodiversity, particularly for migratory waterbirds, by providing essential foraging habitats. Understanding the dynamics of macroinvertebrate communities in these areas is crucial, as they serve as the primary food source for many waterbird species. This study aims to assess the diversity, abundance, and vertical distribution of macroinvertebrates across sediment depths in the mudflats of Bagan Percut, North Sumatra, and evaluate their relationship with waterbird populations. Macroinvertebrate samples were collected from sediment layers (0–40 cm) using PVC core sampling. A total of 16 species from three phyla (Annelida, Arthropoda, and Mollusca) were identified, with Bivalvia being the dominant group, particularly in deeper sediments. Species richness and total abundance were highest at the surface layer (0–10 cm) and decreased with depth. Key indices, including Shannon's diversity index and Pielou's evenness, showed greater diversity and species evenness near the surface, which declined in deeper layers. A bird survey recorded 32 species of waterbirds, primarily from the Charadriiformes, Pelecaniformes, and Ciconiiformes orders. A significant and positive correlation ($R^2 = 0.456$, $P = 0.0321$) was found between the abundance of benthic

macroinvertebrates and waterbird presence, highlighting the ecological importance of prey availability for waterbird foraging. This study contributes valuable insights into the conservation and management of coastal ecosystems, particularly for species that rely on mudflats for their survival.

Keywords Foraging Site, Mudflat, Macroinvertebrate, North Sumatra, Prey Availability, Waterbirds

1. Introduction

Waterbirds are essential contributors to the biodiversity of wetland ecosystems. Nearly 10% of the world's bird species are dependent on wetlands, either entirely or during key stages of their life cycle [1]. Intertidal mudflats, a critical component of wetland ecosystems, serve as vital feeding grounds for coastal waterbirds [2]. These areas are often rich in benthic communities, with infauna and epifauna in the mudflat sediment providing primary food sources for many waterbird species [3]. Migratory

waterbirds, especially shorebirds, rely on these habitats as crucial stopover sites during their migratory journeys.

Sumatra, with its extensive mangrove forests and intertidal mudflats, is particularly important for migratory shorebirds within the East Asian-Australasian Flyway Partnership (EAAFP) lists of internationally important wetlands [4,5]. Along with the west coast of Peninsular Malaysia, these regions form one of the most expansive areas of intertidal flats, mangroves, and associated wetlands in Southeast Asia [6]. These ecosystems support large congregations of migratory waterbirds, which are indicative of the rich availability of food resources, particularly macroinvertebrates.

Recent studies have recorded a total of 51 bird species in these coastal regions, including 35 migratory species and 8 breeding species at the Tanjung Rejo rookery [4]. Specific surveys in Bagan Serdang Beach and Percut Sei Tuan District documented 17 and 16 species of shorebirds, respectively [7,8]. However, like many coastal areas in Southeast Asia, large expanses of estuarine mangroves in Sumatra are being rapidly converted for human use, leading to a decline in shorebird and waterbird populations [9]. None of the mudflat or mangrove habitats in this region are currently under formal protection, leaving them vulnerable to conversion into oil palm plantations and fish ponds. The mangroves around the Sei Tuan study site, for example, are being rapidly transformed, which poses a significant threat to prey availability for waterbirds [4]. Evidence from natural sites has shown that such habitat changes can lead to reduced diversity and abundance of macroinvertebrates in adjacent areas, which may impact the food resources critical for sustaining local and migratory bird populations [10].

The aim of this study is to evaluate the diversity of macroinvertebrate communities in the coastal mudflat ecosystems and investigate the relationship between waterbird populations and their prey availability. By understanding these ecological interactions, this research seeks to provide valuable insights into the initiation of management and conservation strategies to preserve these coastal habitats and their avian populations.

2. Materials and Methods

This study was conducted in September 2022 on mudflats that serve as key feeding and resting grounds for waterbirds. The primary study site was located at coordinates 03°43'23.4"N, 98°47'52.5"E, where the mudflat substrate depth ranged from 20 to 40 cm. The surrounding wetlands include a mosaic of paddy fields, the Percut River, oil palm plantations, and aquaculture ponds (Figure 1). Dominant vegetation in the area consists of

mangrove species such as *Avicennia alba*, *A. marina*, *Bruguiera gymnorrhiza*, and *Rhizophora apiculata*. Many of the aquaculture ponds in the region have been abandoned, with some converted into oil palm plantations or repurposed for recreational use.

The potential food resources available for waterbirds were assessed by purposively selecting a total of 10 sampling plots. Sampling was conducted once at each plot under the assumption that environmental conditions remained stable throughout the study period. The plots selected for macroinvertebrate sampling were determined based on the presence of waterbirds observed on the same day and at the same hours across the sampling sites. Waterbird surveys were conducted using a direct observation method, aided by spotting scopes and a DSLR camera. Waterbird species encountered in the field were identified at the species level by an experienced bird observer. The number of individual waterbirds within the mudflats of each study plot was recorded using the direct count method. Substrate depth ranges were measured across different habitats, including mudflats (during low tide), paddy fields, and ponds, which are documented with waterbirds.

Macroinvertebrate sampling was performed using PVC pipes. Soil samples were collected from the waterbirds' feeding areas by inserting a PVC pipe per location to a depth of 40 cm. This depth was chosen to capture both fast-moving vertical prey and species accessible to long-billed birds. Sediment from each PVC pipe was combined with water in a bucket and sieved through a 1-mm mesh to isolate larger particles and macrozoobenthic organisms. The sediment samples were carefully washed with distilled water to separate fine sediment particles from the benthic organisms. The retained organisms were extracted from the sieve, sorted on a white tray for clarity, preserved in glass jars containing 70% (v/v) ethanol, and labeled for further analysis [11].

In the laboratory, the macrozoobenthic samples were counted and were identified at the species level in the laboratory using standard taxonomic keys and online resources such as WoRMS (World Register of Marine Species) and MyBIS (Malaysian Biodiversity Information System). These repositories were selected because they are frequently updated and reliable for species identification. The collected data were organized using Microsoft Excel, and statistical analyses were performed using Paleontological Statistics (PAST) version 4.14 and GraphPad Prism version 8.0. The relationship between waterbird abundance and the abundance of benthic macroinvertebrates was assessed using simple linear regression. The regression model's R^2 value was used to determine the strength of the relationship, with a higher R^2 value indicating a better fit.

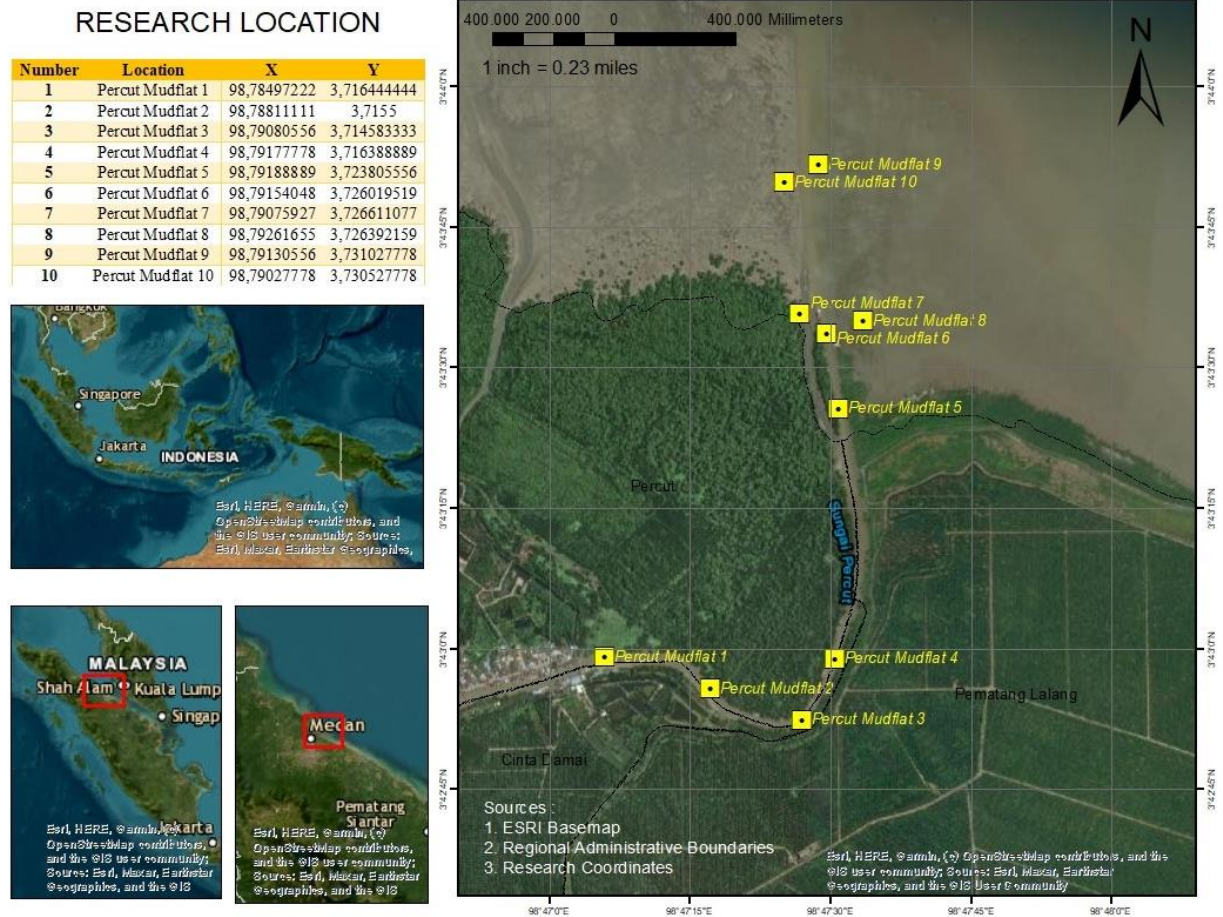


Figure 1. Maps showing the ten sampling points in the Bagan Percut mudflats, North Sumatra, designated for macrozoobenthos sampling. Each point represents a specific location where sediment samples were collected across varying depths (0–10 cm, 20 cm, 30 cm, and 40 cm) to assess the abundance and diversity of macroinvertebrate communities

3. Results and Discussion

The survey of macroinvertebrate community in the foraging site for waterbirds in Bagan Percut mudflats was examined for their abundances and species composition (community) across different sediment depths. The boxplot (Figure 2) summarizes the total abundance and distribution of macroinvertebrates ($\log N$ of ind/m²). At the surface layer (0–10 cm), the data show a relatively narrow interquartile range (IQR) and higher consistency in abundance, indicating a stable presence of macroinvertebrates near the surface. As depth increases, particularly at 10–20 cm and 20–30 cm, there is greater variability in abundance (wider IQR), reflecting more heterogeneous distributions of macroinvertebrates at these depths.

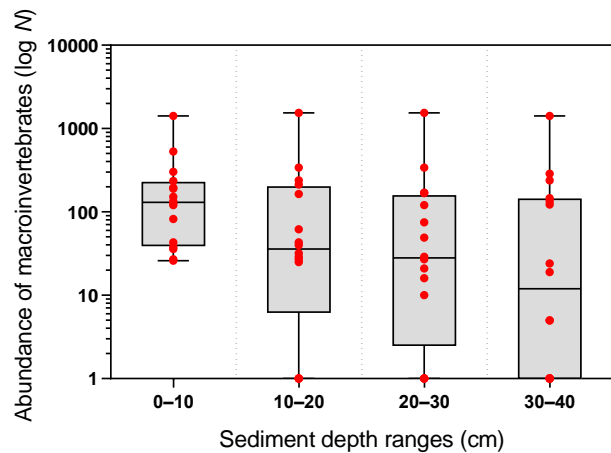


Figure 2. Total abundance ($\log N$ of ind.) of benthic macroinvertebrates across sediment layers (depth) in Bagan Percut mudflat

The bottom layer (30–40 cm) exhibits the lowest median abundance, showing that fewer species or individuals are present at deeper sediment levels. The presence of outliers across all depths suggests occasional fluctuations in macroinvertebrate populations, potentially influenced by sediment physicochemical properties (organic and sand content) [12]. The surface layer of mudflats plays a critical role in supporting complex ecological interactions, such as algal growth and grazing by macro-heterotrophs [13]. The findings indicate a trend of decreasing abundance with increasing depth, with macroinvertebrates concentrated primarily in the upper sediment layers, which serve as critical foraging resources for waterbird species relying on these habitats through trophic resource partitioning [14].

A high variation appears in the vertical distribution of benthic organisms from three phyla namely Annelida, Arthropoda, and Mollusca with 16 species (Table 1). *Nereis* sp. was only found at the surface, while species like *Goneplax rhomboides* and *Balanus crenatus* were distributed across all depths, though their abundance decreased with depth. Bivalves, such as *Anadara gubernaculum*, *Corbula ovalina*, and *Latona faba*, showed a wider distribution, with *L. faba* and *Glaucanome virens* demonstrating high abundance across multiple depths. Other species, including *Gari crassula*, *Serratina perplexa*, and *Pirenella cingulata*, were present at varying depths but in lower numbers, while *Coralliophila clathrata* was

limited to the surface. The number of species identified in this study is similar to those reported from the adjacent region of Tanjung Rejo, located in the Percut area of North Sumatra, where 17 species were recorded [15]. This is higher than the findings from a study conducted in the mangrove forest of Percut, which documented only 7 species [10]. The dominance of *G. virens* (locally known as *ki-jing*) in the study area reflects a stable and sustainable population. In general, this supports the idea that bivalve-specialist waterbird species consume larger quantities of food, enabling them to effectively meet their energy and nutritional requirements [16].

Based on the findings, sediment depth plays a key role in shaping species distribution, with some taxa showing broad depth ranges and others restricted to shallower sediments. Intertidal mudflats host diverse macroinvertebrate communities, primarily composed of annelids, molluscs, and arthropods [17]. These ecosystems are characterized by high densities of deposit-feeding species, with oligochaetes and polychaetes often dominating in terms of abundance [18]. However, polychaetes were the least represented class in this study, with only one genus, *Nereis* sp., identified. Their low numbers may be due to limitations in the sampling methods. The soft and flexible bodies of polychaetes likely allowed some to escape the sampling cores while also prone to breakage during handling and examination [11].

Table 1. Taxonomical list of macroinvertebrates and their abundances in Bagan Percut mudflat

No.	Phylum (Sub-)	Class	Family	Species	Abundance (N) per sediment depth from surface (0 cm)				Total
					10	20	30	40	
1.	Annelida	Polychaeta	Nereididae	<i>Nereis</i> sp.	532	0	0	0	532
2.	Arthropoda (Crustacea)	Malacostraca	Goneplacidae	<i>Goneplax rhomboides</i>	27	27	16	5	75
3.			Palaemonidae	<i>Palaemon elegans</i>	190	0	0	0	190
4.			Penaeidae	<i>Penaeus</i> sp.	304	0	0	0	304
5.		Thecostraca	Balanidae	<i>Balanus crenatus</i>	36	25	10	5	76
6.	Mollusca	Bivalvia	Arcidae	<i>Anadara gubernaculum</i>	121	29	121	146	417
7.			Corbulidae	<i>Corbula ovalina</i>	152	239	168	239	798
8.				<i>Corbula tunicata</i>	26	40	29	19	114
9.			Donacidae	<i>Latona faba</i>	236	164	339	287	1026
10.			Glauconomidae	<i>Glaucanome virens</i>	1422	1541	1541	1422	5926
11.			Mactridae	<i>Mactra turgida</i>	134	213	170	134	651
12.				<i>Mactrellona alata</i>	82	62	75	123	342
13.			Psammobiidae	<i>Gari crassula</i>	127	32	21	0	180
14.			Tellinidae	<i>Serratina perplexa</i>	43	43	27	0	113
15.			Gastropoda	Muricidae	<i>Coralliophila clathrata</i>	38	0	0	0
16.	Potamididae	<i>Pirenella cingulata</i>		195	340	49	24	608	

The relative abundance of macroinvertebrate taxa confirms the former results revealing a marked dominance of Bivalvia throughout the vertical profile (Figure 3). The surface layer (0–10 cm) exhibits the highest taxonomic diversity, with Bivalvia being the most abundant group, followed by major contributions from Crustacea, Polychaeta, and Gastropoda. As depth increases to 20 cm, Bivalvia continues to dominate, comprising nearly the entire community, while Crustacea and Polychaeta show a sharp decline. At depths of 20–30 cm and 30–40 cm, the community assemblage is predominantly composed of Bivalvia, with minimal contributions from other taxa. This distribution demonstrates an increasing dominance of Bivalvia with depth, whereas other groups, such as Crustacea and Polychaeta, are primarily adapted to the shallower sediment layers.

Bivalves are key contributors to biomass and energy flow in mudflat ecosystems, playing an important role in supporting higher trophic levels through predation and decomposition [19,20]. Juvenile bivalves exhibit high mobility, dispersing over several meters, with their movement influenced by sediment transport and current velocities [21]. Bivalves move using siphon and mantle

muscle contractions to facilitate surface relocation, allowing them to navigate and adapt to shifting environmental conditions [22].

Multiple regression (Figure 4) reveals the relationships between sediment depth and the abundance of macroinvertebrate taxa, with varying R-squared (R^2) values indicating the strength of these relationships. Bivalvia maintains a relatively stable abundance across all depths, as reflected by a low R^2 value (0.07), suggesting minimal influence of depth on its distribution. In contrast, Crustacea and Gastropoda show a drastic decrease in abundance with increasing depth, indicated by higher R^2 values of 0.92 and 0.81, respectively, implying a strong correlation between sediment depth and their declining numbers. Polychaeta, which was only collected at the surface layer, could not be statistically analyzed due to the unreliable trend and lack of sufficient data across deeper sediment layers. The factors potentially contributing to the macroinvertebrate assemblage were not assessed from a habitat perspective (environmental factors), as the investigation was confined to a single site without distinct habitat patches that may become a limitation in this study.

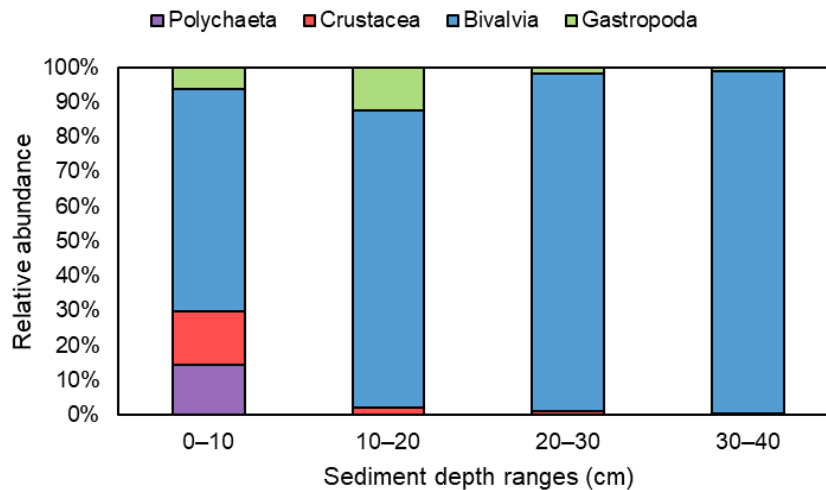


Figure 3. Relative abundance of macroinvertebrate groups across sediment depths in mudflat, Bagan Percut

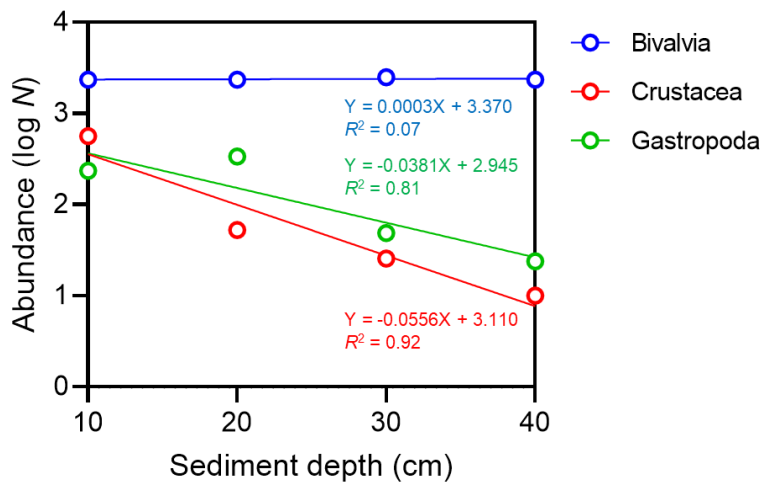


Figure 4. Multiple linear regression of macroinvertebrate abundance across sediment depths in mudflat, Bagan Percut

Table 2. Ecological index of macroinvertebrate community in Bagan Percut

Parameter(s)	Sediment depth ranges (cm)				Mudflat (Total)
	0–10	10–20	20–30	30–40	
Taxa (<i>S</i>)	16	12	12	10	16
Total abundance (<i>N</i> ind.)	3,665	2,755	2,566	2,404	11,390
Shannon's diversity index (<i>H'</i>)	2.125	1.563	1.448	1.389	1.841
Dominance index (<i>D</i>)	0.194	0.346	0.390	0.383	0.296
Pielou's evenness index (<i>J</i>)	0.767	0.629	0.583	0.603	0.664

Table 3. List of waterbirds in Bagan Percut and their current conservation status during the survey

No.	Order	Family	Species	Common name	Conservation status		
					PP ^{a)}	IUCN ^{b)}	CITES ^{c)}
1.	Charadriiformes	Charadriidae	<i>Anarhynchus leschenaultii</i>	<i>Cerek-pasir besar</i>	–	LC	–
2.			<i>Anarhynchus mongolus</i>	<i>Cerek-pasir siberia</i>	–	EN	–
3.			<i>Pluvialis fulva</i>	<i>Cerek kernyut</i>	–	LC	–
4.			<i>Pluvialis squatarola</i>	<i>Cerek besar</i>	–	LC	–
5.		Scolopaciidae	<i>Actitis hypoleucos</i>	<i>Trinil pantai</i>	–	LC	–
6.			<i>Arenaria interpres</i>	<i>Trinil pembalik-batu</i>	–	LC	–
7.			<i>Calidris falcinellus</i>	<i>Kedidi paruh-lebar</i>	–	LC	–
8.			<i>Calidris ferruginea</i>	<i>Kedidi golgol</i>	–	NT	–
9.			<i>Calidris tenuirostris</i>	<i>Kedidi besar</i>	–	EN	–
10.			<i>Limnodromus semipalmatus</i>	<i>Trinil-lumpur asia</i>	P	NT	–
11.			<i>Limosa lapponica</i>	<i>Biru-laut ekor-blorok</i>	–	NT	–
12.			<i>Limosa limosa</i>	<i>Biru-laut ekor-hitam</i>	–	NT	–
13.			<i>Numenius arquata</i>	<i>Gajahan erasia</i>	P	NT	–
14.			<i>Numenius madagascariensis</i>	<i>Gajahan timur</i>	P	EN	–
15.			<i>Tringa nebularia</i>	<i>Trinil kaki-hijau</i>	–	LC	–
16.			<i>Tringa totanus</i>	<i>Trinil kaki-merah</i>	–	LC	–
17.			<i>Xenus cinereus</i>	<i>Trinil bedaran</i>	–	LC	–
18.			Laridae	<i>Chlidonias leucopterus</i>	<i>Dara-laut sayap-putih</i>	P	LC
19.		<i>Gelochelidon nilotica</i>		<i>Dara-laut tiram</i>	P	LC	–
20.		<i>Sterna acuticauda</i>		<i>Black-bellied Tern</i>	–	EN	–
21.		<i>Sterna hirundo</i>		<i>Dara-laut biasa</i>	P	LC	–
22.		<i>Sternula albifrons</i>		<i>Dara-laut kecil</i>	–	LC	–
23.		<i>Thalasseus bengalensis</i>		<i>Dara-laut benggala</i>	P	LC	–
24.	Pelecaniformes	Ardeidae	<i>Ardea alba</i>	<i>Cangak besar</i>	P	LC	–
25.			<i>Ardea cinerea</i>	<i>Cangak abu</i>	–	LC	–
26.			<i>Ardea intermedia</i>	<i>Kuntul-perak asia</i>	–	LC	–
27.			<i>Ardea purpurea</i>	<i>Cangak merah</i>	–	LC	–
28.			<i>Bubulcus ibis</i>	<i>Kuntul kerbau</i>	–	LC	–
29.			<i>Butorides striata</i>	<i>Kokokan laut</i>	–	LC	–
30.			<i>Egretta garzetta</i>	<i>Kuntul kecil</i>	–	LC	–
31.	Ciconiiformes	Ciconiidae	<i>Mycteria cinerea</i>	<i>Bangau bluwok</i>	P	EN	I
32.			<i>Leptoptilos javanicus</i>	<i>Bangau tongtong</i>	P	NT	–

^{a)} PP refers to *Peraturan Pemerintah* or Indonesian Government Regulation as stated in *Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia* No.: P.106/MENLHK/SETJEN/KUM.1/12/2018. 'P' = Protected; ^{b)} IUCN refers to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. 'EN' = Endangered, 'LC' = Least concern, 'NT' = Near threatened; ^{c)} CITES refers to the Convention on International Trade in Endangered Species of Wild Fauna and Flora. 'I' = Appendix-1, '–' = no information.

The mudflat ecosystem supports a diverse and abundant macroinvertebrate as evidenced by the analysis of key ecological indices such as species richness, total abundance, Shannon's diversity index, dominance index, and Pielou's evenness index to assess the distribution patterns of macroinvertebrates (Table 2). The species richness (S) at the surface sediment layer (0–10 cm) harbors the highest number of taxa, with 16 species, while species richness gradually decreases with depth, reaching only 10 species at 30–40 cm. This finding suggests that the surface layer of the mudflat provides more favorable conditions for a diverse range of species, likely due to factors such as higher oxygen levels, more organic matter, and greater food availability [23–25]. Similarly, total macroinvertebrate abundance (N ind.) shows a declining trend with increasing sediment depth. The highest abundance was observed at 0–10 cm with 3,665 individuals, whereas the lowest abundance was recorded at 30–40 cm with 2,404 individuals.

Shannon's diversity index (H'), which reflects both species richness and evenness, also decreased with depth (Table 3). The highest diversity was recorded at 10 cm ($H' = 2.125$), with progressively lower values at greater depths, indicating that deeper sediments support less diverse macroinvertebrate communities. The total diversity for the mudflat was moderate ($H' = 1.841$), reflecting a balance between species richness and evenness across the entire habitat. On the contrary, the dominance index (D) increased with sediment depth, with the lowest value at 10 cm ($D = 0.194$) and the highest at 30 cm ($D = 0.390$), indicating that deeper layers are more likely to be dominated by a few species, while the surface layer shows more balanced species composition. Pielou's evenness index (J), which measures the relative distribution of individuals among species, also decreased with sediment depth. The evenness was highest at 10 cm ($J = 0.767$), indicating that species were more evenly distributed in the surface layer, and the lowest at 30 cm ($J = 0.583$). In intertidal sand flats, the majority of infaunal species are concentrated within the upper 15 cm of sediment, with an average median depth of approximately 8 cm [26]. Abundance decreases with increasing depth, driven by factors such as reduced food availability and the presence of anoxic conditions in deeper sediment layers, which limit the habitat suitability for many species [27].

The bird survey recorded a total of 32 species across three avian orders: Charadriiformes, Pelecaniformes, and Ciconiiformes in Bagan Percut (Table 3). Within the Charadriiformes, species from the families Charadriidae, Scolopacidae, and Laridae were predominant, including the Lesser Sand Plover (*Anarhynchus mongolus*) and Great Knot (*Calidris tenuirostris*), both classified as *Endangered* (EN) on the IUCN Red List. Members of Scolopacidae are the most speciose taxa with 13 species. Scolopacidae, one of the largest and most diverse avian groups, consists predominantly of migratory species [7]. These birds play a crucial role in waterbird populations along coastal areas,

using these habitats as stopover points during their migrations to restore energy reserves [28]. The mudflat areas in Bagan Percut provide rich food resources, which also attract numerous waterbirds, particularly from the Ardeidae family, (egrets, herons). These species were frequently observed during the sampling period, likely due to their partially migratory behavior in the region. Wetland habitats are essential for Ardeidae species, supporting key activities like feeding, roosting, and nesting [29].

Several species of Scolopacidae, such as the Eurasian Curlew (*Numenius arquata*) and the Bar-tailed Godwit (*Limosa lapponica*), were found to be near-threatened (NT), reflecting the pressures on global migratory bird populations. In the Ciconiiformes order, the Milky Stork (*Mycteria cinerea*) was identified as endangered (EN) and their trades are regulated under CITES Appendix I due to its declining population across Southeast Asia. The relationship between macroinvertebrate abundance and waterbird presence was analyzed using simple linear regression, revealing a significant ($F_{1,8} = 6.705$, $P = 0.0321$) and moderate correlation with an R^2 value of 0.456 (Figure 5).

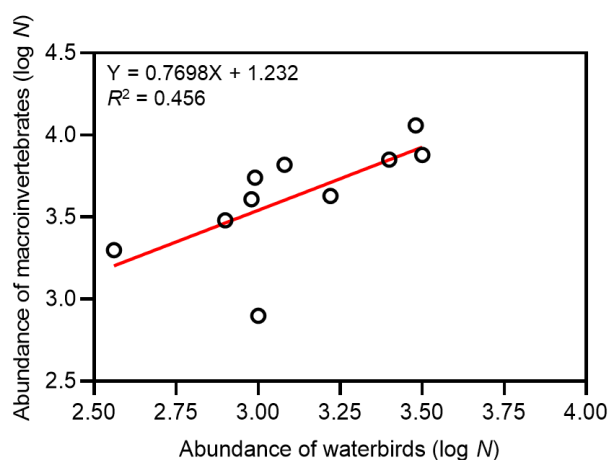


Figure 5. Significant linear regression between the abundance of macroinvertebrates and waterbirds

This limitation could be attributed to the relatively small sample size used in the study, which may not fully capture the diversity of macroinvertebrate communities. Additionally, the reliance on a sampling method that exclusively targets macroinvertebrates might inadvertently overlook other potential prey items, such as fish or smaller aquatic organisms, which could also play a significant role in supporting the local food web. Furthermore, the sampling and handling techniques employed may not have been optimal for capturing the full range of prey species. For instance, the high mobility of certain species, along with the fragility of others, which may easily break or be damaged during examination, could have led to an underrepresentation of some key prey species in the collected samples. These factors suggest that a more comprehensive sampling strategy, encompassing a broader range of potential prey types and considering species-

specific handling methods, would provide a more accurate assessment of the prey availability for waterbird populations.

Based on the moderate relationship, it can be indicated that as the abundance of benthic macroinvertebrates increases, the number of waterbirds also tends to rise similar to a previous study in South West Johor Coast, Malaysia [11]. The connection between waterbirds and macroinvertebrates in wetland ecosystems is complex yet produces mixed results in different studies [30,31]. It should be noteworthy that the data were collected during the same period, which may not fully account for temporal variations (e.g., seasonal shifts) and species-specific dynamics. However, the observed trend still suggests a general link between macroinvertebrate availability as a prey resource and the occurrence of waterbirds in Bagan Percut as an important foraging site in the northern Sumatra coastline.

4. Conclusions

In conclusion, this study highlights the critical role of surface sediment layers in supporting macroinvertebrate communities and, by extension, sustaining waterbird populations in coastal mudflat ecosystems, specifically in Bagan Percut, North Sumatra. Macroinvertebrate diversity and abundance were highest at the surface layer (0–10 cm), with *Bivalvia* being the dominant group, and a significant positive correlation ($R^2 = 0.456$, $P = 0.0321$) was found between their abundance and the presence of 32 waterbird species. The importance of sediment layers in providing essential foraging habitats for migratory waterbirds, may potentially be influenced by the preserved healthy mangrove ecosystems in proximity to the mudflat areas. Additionally, the presence of minor habitats, such as rice fields, has also become a foraging spot for waterbirds. However, limitations such as the study's restricted spatial scale and potential seasonal variations call for further research to better understand these ecosystems. Despite these challenges, the study offers valuable insights into the conservation and management of coastal ecosystems, particularly in conducting environmental impact assessments to evaluate potential risks to waterbird populations and their habitats in the Bagan Percut area.

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