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Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Cover: The nine vultures of India, digital art made on Krita by Dupati Poojitha.

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ARTICLE

Diversity and status of shorebirds in the estuaries of Algiers, northern Algeria

Imad Eddine Rezouani [1], Belkacem Aimene Boulaouad [2], Selmane Chabani [3], Khalil Draidi [4] & Badis Bakhouche [5]

[1] Laboratory of Eco-Biology Animals (L.E.B.A.), École Normale Supérieure de Kouba Bachir El Ibrahimi, BP 92, Algiers 16050, Algeria.
[2] Department of Agronomy, SNV-TU Faculty, Mohamed El Bachir El Ibrahimi Bordj Bou Arreridj University, Algeria.
[3,5] Laboratory of Biological Oceanography and the Marine Environment (LOBEM), Faculty of Biological Sciences, University of Science and Technology of Houari Boumediene (USTHB), BP 32, Algiers 16111, Algeria.
[4] Environmental Research Center, Alzon Castle, Boughazi Said Street, PB 2024, Annaba 23000, Algeria.
[1] rezouani.imadeddine@outlook.fr, [2] aimenebelb@gmail.com, [3] chabani.selman@gmail.com, [4] khalildraidi@yahoo.fr,
[5] badis_bakhouche@yahoo.fr (corresponding author)

Abstract: Shorebird habitats have great importance in maintaining biodiversity and estuaries are among the most important habitats in this regard. The estuaries of Algeria are key habitats for migratory coastal birds along the Eurasian-African Flyway. The present study, conducted from February 2022 to December 2023, surveyed shorebirds in three estuaries located in Algiers: Réghaïa Estuary, Sablette, and Zéralda. Observations were made twice a month during early morning and late afternoon. A total of 27 shorebird species were recorded across the three estuaries, with each site showing distinct patterns of distribution, phenology, and conservation status. Réghaïa supported the highest bird diversity with 21 species recorded, reflecting its ecological richness, and suitability as a stopover, and wintering site for birds. Sablette exhibited the lowest diversity with eight species, attributable to significant human activity, and a lack of suitable habitats in the area. Zéralda recorded 13 species, indicating moderate diversity, and potential urban impacts on habitats. By assessing the status of birds and characterizing estuaries as habitats for shorebirds in Algeria, our observations provide support for shorebird conservation, and habitat management.

Keywords: Avian diversity, bird migration, breeding grounds, coastal biodiversity, conservation, flyway, habitat, nesting sites, Ramsar, stopover, threats, wetland degradation.

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Author details: Imad Eddine Rezouani—PhD candidate at the École Normale Supérieure of Kouba, conducting doctoral research in biomonitoring focused on the structure and phenology of shorebirds in Algeria. Belkacem Aimene Boulaouad—assistant professor at the University of Bordj Bou Arréridj, a naturalist researcher known for having recorded several new findings on Algerian biodiversity. Selmane Chabani—PhD candidate at the University of Science and Technology Houari Boumediene (USTHB), conducting doctoral research on shorebird populations along the Algerian coastline. Khalil Draidi—assistant professor specializing in wetlands and bird ecology, a field in which he has been actively working since 2010. Badis Bakhouche—assistant professor at the University of Science and Technology Houari Boumediene (USTHB), where he has been conducting in-depth research on wetlands since 2010, with a particular focus on their biodiversity and ecological dynamics

Author contributions: All authors participated in the design of this article and the fieldwork in a similar manner.

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INTRODUCTION

Shorebirds predominantly inhabit wetland areas, coastal zones, mudflats, marshes, and other shallow aquatic ecosystems (Byju et al. 2024). Wetlands include marshes, peatlands, and aquatic habitats with depths not exceeding six meters that can be natural or artificial, and have permanent or temporary water ranging from fresh to saline. They are among the most productive ecosystems (Ramsar Convention Secretariat 2013) and provide habitats that contribute significantly to biodiversity, and play vital role in sustaining natural systems, and ensuring ecological stability globally (Ten et al. 2012; Draidi et al. 2019).

Estuaries and coastal zones, known for their high productivity due to nutrient-rich shallow waters (Nixon et al. 1986; Reshmi et al. 2024), are essential for shorebirds, and seabirds (Byju & Raveendran 2022), which often occupy apex predator roles in ecosystems. When these areas become recreational and socio-economic hubs, there can be significant negative impacts on plant, and animal communities (Draidi et al. 2023; Kutir et al. 2024). Human activities around estuaries, such as urbanization, pollution, and habitat alteration, have profoundly affected shorebirds (Jackson et al. 2024), which are particularly sensitive to changes in ecosystem health since their distribution, and abundance are closely tied to the availability of food resources.

Globally, coastal birds face growing threats from anthropogenic pressures, including habitat degradation, pollution, overharvesting of prey, and the loss of essential foraging, roosting, and breeding sites (Otieno 2011; Byju et al. 2025). In Algeria, wetlands and estuaries serve as critical staging posts, and wintering grounds for migratory birds (Gill et al. 2001). Despite this, urbanization's direct impact on avian diversity in the estuaries of Algiers remains understudied.

While studies have documented shorebird diversity in various parts of Algeria, limited information exists on the distribution and diversity of waders in urban estuaries, particularly in the Algiers region. To address this knowledge gap, the present study aimed to investigate the temporal distribution and diversity of wader bird species in the estuaries of Réghaïa, Sablette, and Zéralda, and to establish a checklist of migratory, and non-migratory shorebird species, and identify factors influencing their distribution.

MATERIALS AND METHODS

Study site

Algiers, the capital of Algeria, is located in the north-central part of the country along the Mediterranean coast, between 36.0000° N & 3.0000° E and 36.7667° N & 5.0000° E (Image 1). The city is bordered by a coastal strip approximately 80 km long, which is part of Algeria's 1,622-km coastline. Algiers features three main estuaries:

Réghaïa Estuary: Located within the Mitidja plain at coordinates 36.800° N & 3.316° E–36.800° N & 3.350° E (Image 1). This estuary is recognized internationally as a Ramsar site of wetlands of global importance. It is bordered to the east by the Makin region, to the west by agricultural lands, and to the north by a strip of sand dunes.

Sablette Estuary: Located at coordinates 35.895° N and 0.047° E (Image 1). This area stretches for 4.5 km in the middle of the Gulf of Algiers, between the estuaries of the Oued El Harrach, and the desalination plant. Sablette is an urban public space facing the Mediterranean Sea.

Zéralda Estuary: Located at coordinates 36.711° N and 2.842° E (Image 1), this estuary is an important part of the coastal system of Algiers, and is situated near the town of Zéralda.

Bird survey

This study was conducted from February 2022–December 2023, with observations made twice a month during early morning (0730–1000 h) and late afternoon (1530–1800 h), as bird activity is highest during these periods. Observations were made using binoculars (Zenith 10 × 50) and a Nikon P900 camera. Digital photographs were taken to aid in species identification when direct observation in the field was insufficient or inconclusive. Birds flying over the survey points without a clear association with the site were excluded to avoid overestimation, following the methodology of (Buckland & Elston 1993). At each estuary, five fixed survey points were established, spaced at least 200 apart to avoid double counting. Observations were conducted for 15 minutes at each point during each visit.

Surveys were not conducted during heavy rainfall, or when wind speeds exceeded normal levels, to ensure data reliability. The methodology followed the standard protocols for bird monitoring (Howes & Bakewell 1989; Bibby et al. 1998).

The scientific names and classification of the species in this study adhere to the most recent version of the IOC

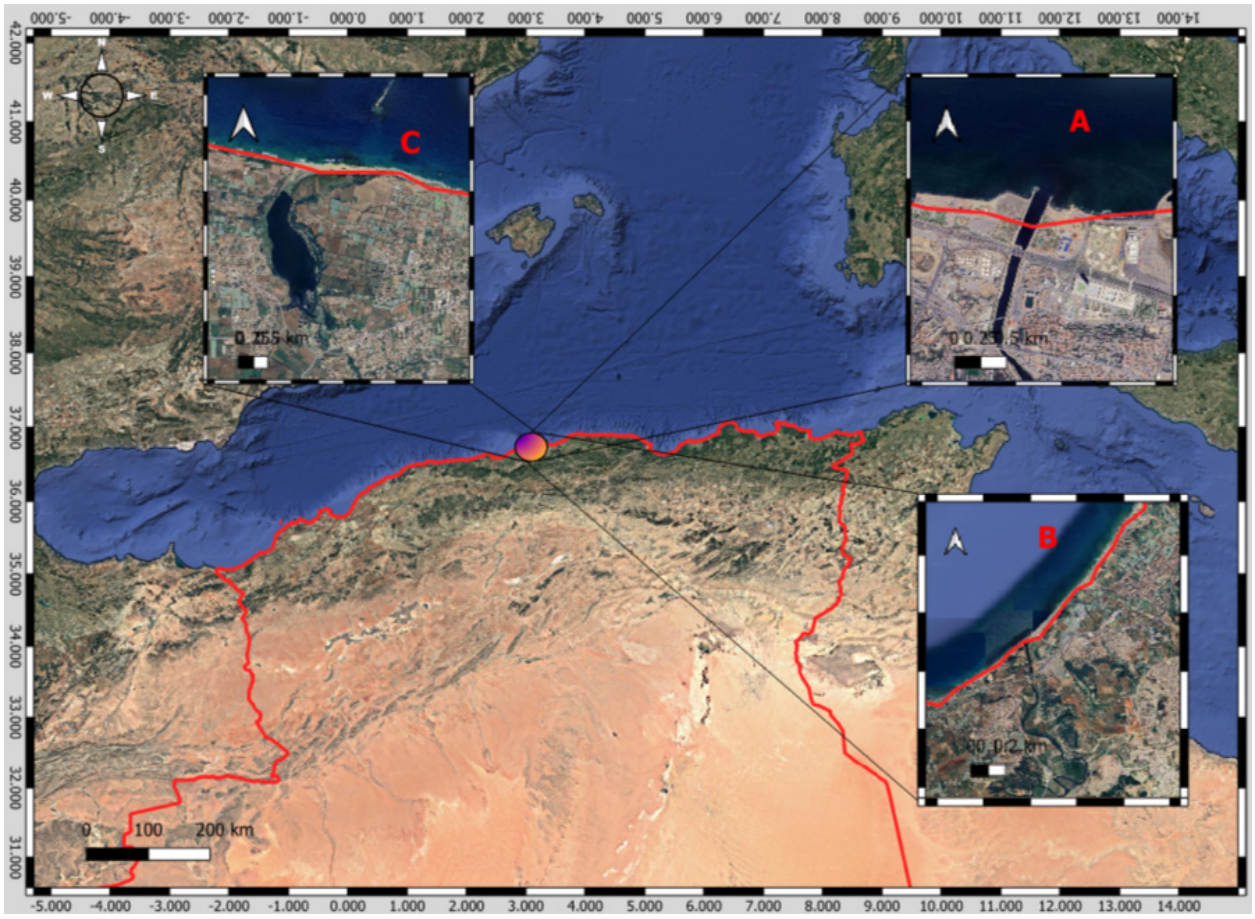

Image 1. Location of study areas in Algiers Province: A—Réghaïa Estuary | B—Sablette Estuary | C—Zéralda Estuary.

World Bird List (Gill et al. 2023). Regarding conservation status, Algeria follows Executive Fiat 12–235 of 24 May 2012, which lists protected nondomestic animal species, and Ordinance n° 06–05 of 15 July 2006, which governs the protection of endangered species. For international conservation status, we referred to the IUCN Red List (IUCN 2024).

Data analysis

Whittaker's Beta Diversity Index was used to measure species turnover between sites, highlighting variations in species composition across habitats. Jaccard's index of similarity was calculated to evaluate the degree of similarity in species assemblages between sites, providing a comparative perspective on community composition. the following formula:

J = c/ (A+B-c)*100

where: "A" is the Total number of species in the first site., "B" is the Total number of species in the second site, "c" Number of species common to both sites (Castilheiro et al. 2017).

Additionally, correspondence analysis (CA) was performed to explore relationships between species and sites, identifying ecological groupings, and habitat-specific preferences. R software version 4.0.2 was used to create the data visualizations, with the ggplot2, viridis, and Facto Miner packages.

RESULTS

Species Diversity

A total of 27 shorebird species were recorded across the three estuaries during the study period, with each site showing distinct patterns of distribution, phenology, and conservation status. Réghaïa supported the highest bird diversity, with 21 species recorded, reflecting its ecological richness, and suitability as a stopover, and wintering site for birds (Bakhouche et al. 2019). In contrast, Sablette exhibited the lowest diversity, with eight species, likely due to significant human activity and a lack of suitable habitats. Zéralda recorded 13 species,

indicating a moderate diversity, and potential urban impact on the habitat.

Conservation Status

The conservation status of these species highlights critical insights. According to the IUCN Red List of Threatened Species (IUCN 2024), eight species, including Eurasian Oystercatcher *Haematopus ostralegus*, Northern Lapwing *Vanellus vanellus*, Eurasian Curlew *Numenius arquata*, Bar-tailed Godwit *Limosa lapponica*, Black-tailed Godwit *Limosa limosa*, Ruddy Turnstone *Arenaria interpres*, Red Knot *Calidris canutus*, and Dunlin *Calidris alpina* are classified as 'Near Threatened' (NT), while two species, Grey Plover *Pluvialis squatarola*, and Curlew Sandpiper *Calidris ferruginea* are classified as 'Vulnerable' (VU). At the national level, under Algerian legal frameworks, six species, such as Black-winged Stilt *Himantopus himantopus*, Eurasian Curlew *Numenius arquata*, Pied Avocet *Recurvirostra avosetta,* Common Ringed Plover *Charadrius hiaticula,* Green Sandpiper *Tringa ochropus*, and Collared Pratincole *Glareola pratincole* are legally protected. These findings underscore the need for both national and international conservation efforts for these species (Figure 1).

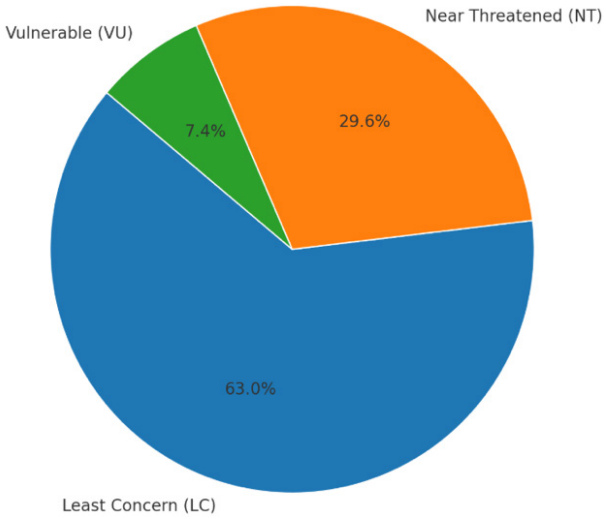

Figure 1. IUCN Red List status of shorebirds observed.

Phenological patterns

Phenological analyses indicate the importance of these estuaries for migratory birds. Most species were identified as winter visitors (WV), demonstrating the role of these sites as stopover points along migratory routes (Table 1; Figure 3). Only a few species, such as *Anarhynchus alexandrinus*, *Charadrius dubius*, and *Recurvirostra avosetta* were observed as residents and breeding birds (RB), highlighting their limited presence in the region (Table 1).

Site-Specific differences

Distinct patterns were observed at each estuary. Zéralda exclusively recorded species such as *Haematopus ostralegus* and *Pluvialis squatarola*, highlighting its role in hosting specific wintering birds. In contrast, Réghaïa sustained species restricted to this site, including *Limosa lapponica*, and *Gallinago gallinago*, emphasizing its ecological importance and diversity.

Our results show a diversity of species across the three study sites. This suggests that there is partial overlap in species across sites, as we observed differences in species composition between the Réghaïa and Sabalat regions, as well as Zéralda. The Whittaker's Beta Diversity Index (β = 1.97) (Table 2) reveals heterogeneity between sites with approximately 50.7% of shared species. Moreover, each site has its distinct species, and species turnover across sites accounts for 49.5% of diversity.

The Jaccard's Index of Similarity showed that Réghaïa and Zéralda had more similar bird species than the other sites (J = 0.45), while Réghaïa and Sablette (J = 0.21) as well as Zéralda and Sablette (J = 0.33) show less similarity in terms of distribution and species overlap. The correspondence analysis (CA) (Figure 2) effectively reflects variations in shorebird species distribution across the estuaries studied, with the Ruff *Calidris pugnax,* Sanderling *Calidris alba*, and Grey Plover showing their presence exclusively at Zéralda. Eurasian Curlew was present only in Sablette. The following species, including the Black-winged Stilt, Pied Avocet, Bar-tailed Godwit, Black-tailed Godwit, Common Snipe, Green Sandpiper, Wood Sandpiper, Common Redshank, Common Greenshank, Red Knot, and Collared Pratincole, were exclusively seen in Réghaïa Estuary.

Additionally, Zeralda, and Sablette share one common species: the Eurasian Oystercatcher. Réghaïa and Sablette have Common Sandpiper as the common species. Réghaïa and Zeralda also share four species in common: European Golden Plover, Curlew Sandpiper, Dunlin, and Little Stint. All three sites of Réghaïa, Sablette, and Zéralda are characterized by the presence of four common species. namely, Common Ringed Plover, Little Ringed Plover, Kentish Plover, and Ruddy Turnstone, reflecting the similarity of ecological conditions that shape their bird assemblages.

Table 1. Presentation of recorded species.

Scientific name	Common name	Phenological status (Isenmann & Moali 2000)	Réghaïa	Sablette	Zéralda	Red List status (IUCN 2024)	Algerian law
Haematopus ostralegus	Eurasian Oystercatcher	WV	-	+	+	NT	-
Himantopus himantopus	Black-winged Stilt	MB	+	-	-	LC	+
Recurvirostra avosetta	Pied Avocet	RB	+	-	-	LC	+
Pluvialis squatarola	Grey Plover	WV	-	-	+	VU	-
Pluvialis apricaria	European Golden Plover	WV	+	-	+	LC	-
Charadrius hiaticula	Common Ringed Plover	WV	+	+	+	LC	+
Charadrius dubius	Little Ringed Plover	RB	+	+	+	LC	-
Vanellus vanellus	Northern Lapwing	WV	+	-	-	NT	-
Anarhynchus alexandrinus	Kentish Plover	RB	+	+	+	LC	-
Numenius phaeopus	Eurasian Whimbrel	WV	-	+	-	LC	-
Numenius Arquata	Eurasian Curlew	WV	-	+	-	NT	+
Limosa lapponica	Bar-tailed Godwit	WV	+	-	-	NT	-
Limosa limosa	Black-tailed Godwit	WV	+	-	-	NT	-
Gallinago gallinago	Common Snipe	WV	+	-	-	LC	-
Actitis hypoleucos	Common Sandpiper	WV	+	+	-	LC	-
Tringa ochropus	Green Sandpiper	WV	+	-	-	LC	+
Tringa glareola	Wood Sandpiper	WV	+	-	-	LC	-
Tringa tetanus	Common Redshank	WV	+	-	-	LC	-
Tringa nebularia	Common Greenshank	WV	+	-	-	LC	-
Arenaria interpres	Ruddy Turnstone	WV	+	+	+	NT	-
Calidris canutus	Red Knot	PV	+	-	-	NT	-
Calidris pugnax	Ruff	WV	-	-	+	LC	-
Calidris ferruginea	Curlew Sandpiper	WV	+	-	+	VU	-
Calidris alba	Sanderling	WV	-	-	+	LC	-
Calidris alpina	Dunlin	WV	+	-	+	NT	-
Calidris minuta	Little Stint	WV	+	-	+	LC	-
Glareola pratincole	Collared Pratincole	MB	+	-	-	LC	+

NT—No definite status | VB—Vanished breeder | AV—Accidental visitor | CB—Casual breeder | MB—Migrant breeder | RB—Resident breeder | PV—Passage visitor | WV—Winter visitor | VU—Vulnerable | NT—Near Threatened | LC—Least Concern (Isenmann & Moali 2000).

DISCUSSION

Birds serve as excellent bioindicators, since their populations are influenced by factors such as climate, vegetation, food availability, rainfall, prey presence, and other ecological conditions (Aarif et al. 2025). Our research underscores the significance of understanding habitat diversity and species distribution for effective conservation strategies in Algeria's estuarine ecosystems. We identified 27 shorebird species across various threatened categories, including winter visitors and breeding populations, which highlights the seasonal abundance of shorebirds, and the ecological importance of Algeria's estuarine habitats (Hong et al. 2024). Local habitat characteristics, such as distribution, vegetative structure, moisture levels, biomass availability, and cover patterns, strongly influence shorebird distribution, and abundance during wintering, and stopover periods (Cerda-Peña & Rau 2023).

A recent study, Palacios et al. (2022), illustrated the impact of human disturbance on the distributions of shorebirds during migratory, and non-migratory periods. This study showed negative correlations between human disturbance and the abundance of this group of birds, suggesting that Sablette has high human activity due to the low abundance in this area compared to

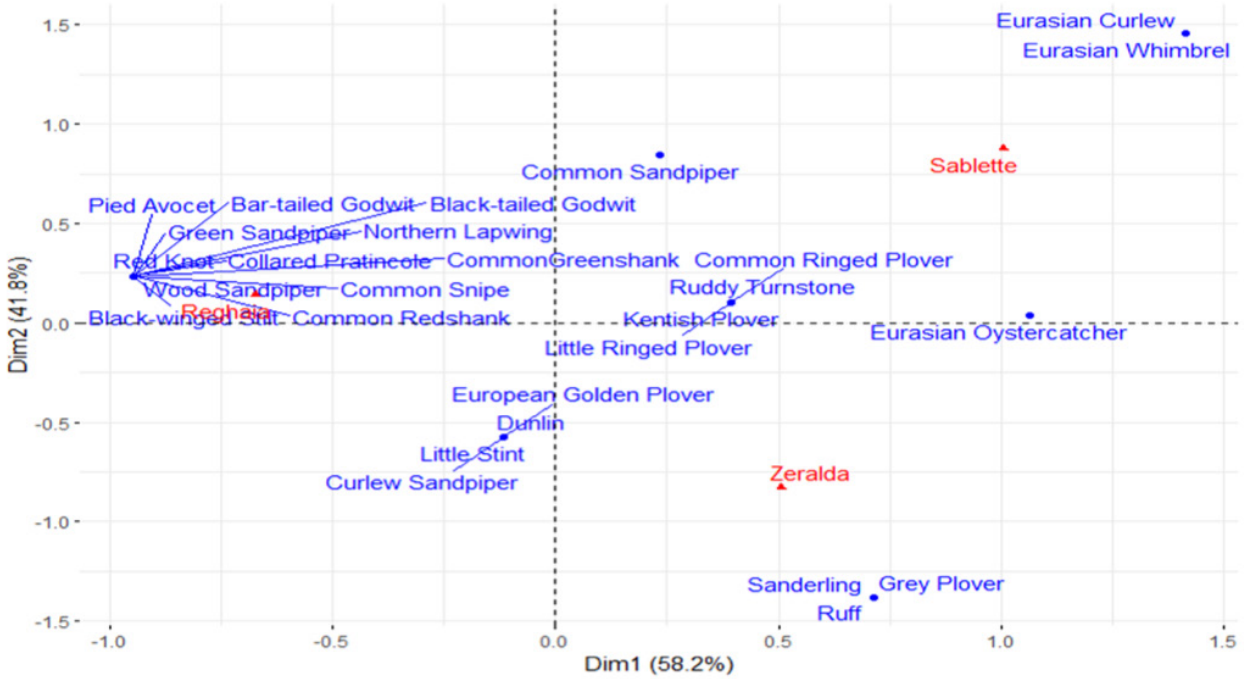

Figure 2. Correspondence analysis map (CA) of shorebird distribution in sites from February 2022 to December 2023.

Raghiya. The effects of foraging, vigilance, and aggressive behaviour of shorebirds, and seagulls in the presence of human disturbance were also compared (Burger et al. 2007). It was observed in this study that within a few minutes, seagulls returned to pre-disturbance levels; however, shorebirds did not return to pre-disturbance levels within the same time frame. These observations suggest that shorebirds respond more strongly to human disturbance despite the presence of food competition. This explains the difference in bird distribution in this study, as the Sablette is a tourist area, and the rate of human activity is very high compared to other areas. Human disturbances, such as habitat alteration, foraging disruption, and reproductive interference, significantly affect shorebird populations (Gibson et al. 2018; Setsaas et al. 2018; Rao et al. 2022). The decline in species abundance in Sablette and Zéralda could be further accentuated if disturbance levels increase, as they decreased by 50% between 1972 and 1989 at the Atlantic coast of the United States between Florida and Cape Cod Bay (Pfister et al. 1992). In general, the diversity of shorebirds in the Réghaïa estuary was much higher than in the Sablette area, potentially due to the fact the latter is at risk due to human intervention through the construction of canyons & platforms, and the installation of sea walls on the inlet beaches (Reed et al. 2012; VanDusen et al. 2012), unlike in the Réghaïa area, which is still a natural area.

Table 2. Summary statistics of Whittaker beta diversity index, gamma diversity, and turnover (%).

Whittaker beta diversity index	**1.97561**
Alpha diversity	13.6667
Gamma diversity Turnover (%)	27 49.4%

Additionally, the presence of invertebrate prey plays a crucial role in shorebird abundance (Cerda-Peña & Rau 2023). Factors influencing the distribution of shorebirds in search of food among the mudflats were studied (VanDusen et al. 2012), and it was found that the spatial structure of the benthic invertebrate prey community is correlated with the density and composition of the community of shorebirds. In our study, it was in a similar line that none of the three studied locations is ideal for the entire shorebird community, which explains the low species similarity between Réghaïa, and Sablette in terms of distribution. Comparative analyses of species richness across study areas reveal that Réghaïa and Zéralda share higher species similarity, whereas Sablette shows lower similarity in species composition compared to both Réghaïa and Zéralda. This highlights the necessity for localized conservation efforts, habitat protection, and community engagement (Gibson et al. 2018; Setsaas et al. 2018).

Despite the scarcity of comprehensive regional or

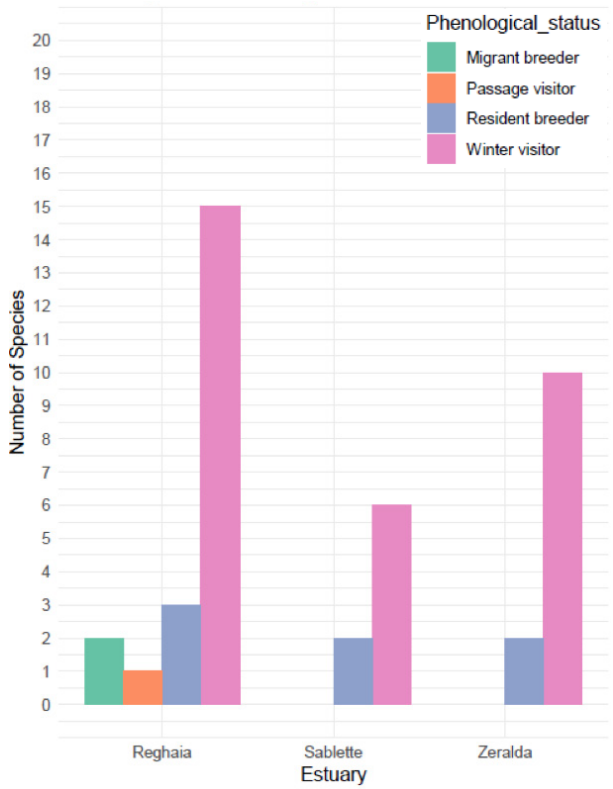

Figure 3. Phenological status of bird species across estuaries.

national assessments for shorebird species under the IUCN Red List criteria in Algeria, species like the Curlew Sandpiper and Grey Plover are now listed as Vulnerable (IUCN 2024). Furthermore, eight shorebird species, including the Eurasian Oystercatcher, Northern Lapwing, Bar-tailed Godwit, and Eurasian Curlew, Bar-tailed Godwit, Black-tailed Godwit, Ruddy Turnstone, Red Knot and Dunlin, are categorized as Near Threatened (NT) (IUCN 2024). Conservation strategies should be adapted to the specific ecological conditions of each site. At Sablette, where human disturbance is high, efforts should focus on regulating tourist activities, restricting access during sensitive periods, and restoring degraded habitats to improve their suitability for shorebirds. In contrast, at Réghaïa, which still maintains a relatively natural state, the priority should be to preserve its ecological integrity by preventing urban expansion, infrastructure development, or any modifications that could alter the estuarine ecosystem.

CONCLUSION

The variation in species presence among study sites can reasonably be linked to habitat differences such as the availability of suitable foraging areas, nesting areas, and less disturbed areas. To ensure effective and sustainable conservation of these estuarine habitats, it is essential to implement long-term population monitoring, habitat restoration programmes, community education initiatives, and robust local protection policies. These measures are particularly important to safeguard key zones used by migratory shorebirds for foraging, breeding, and wintering. In addition, it is necessary to conduct specific research on natural and anthropogenic disturbances to gain a greater understanding of their effects on estuarine habitats. By implementing these efforts, we can help reduce negative impacts and maintain the environmental integrity and long-term conservation of these vital coastal areas.

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