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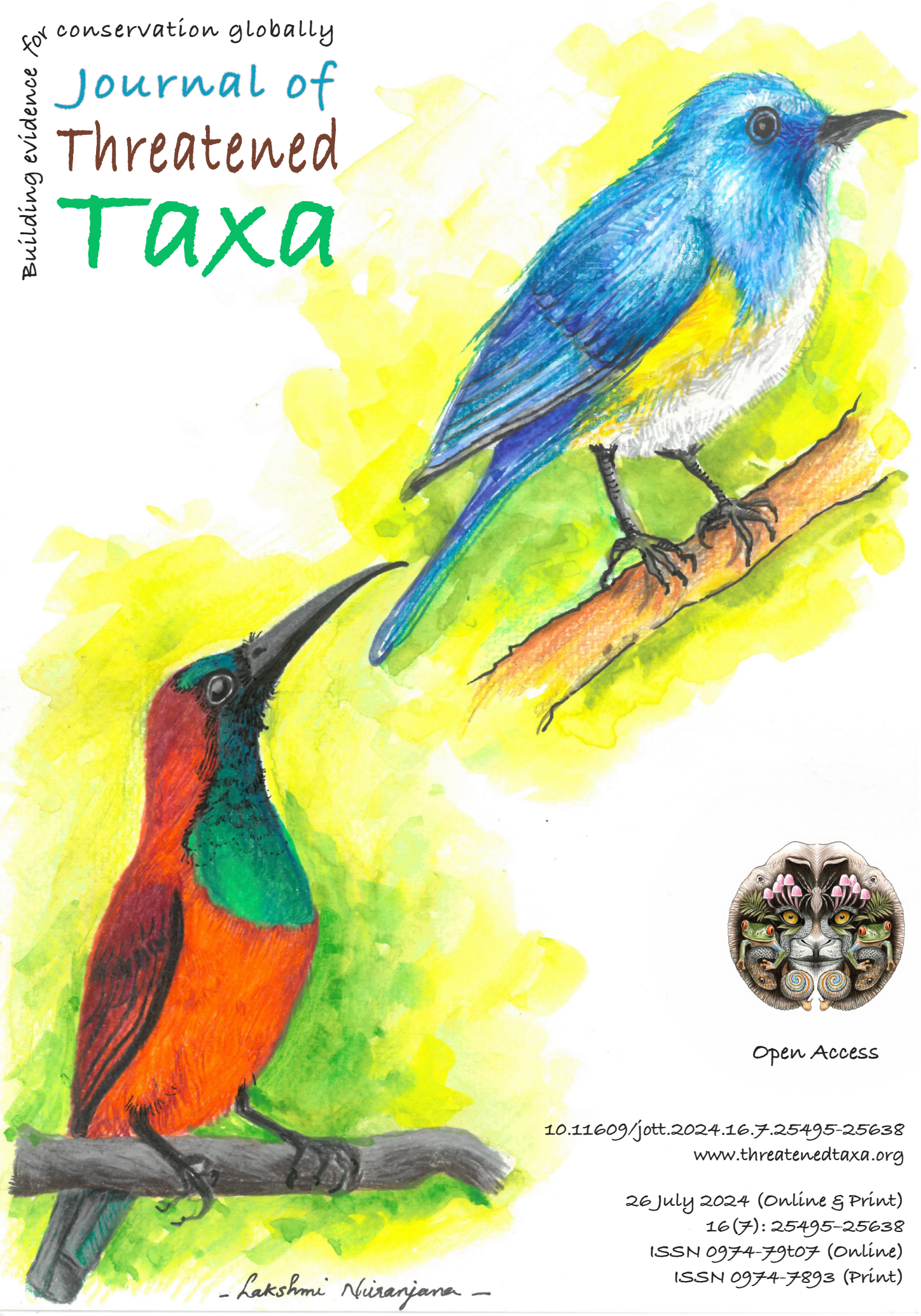

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10.11609/jott.2024.16.7.25495-25638
www.threatenedtaxa.org

26 July 2024 (Online & Print)
16(7): 25495-25638
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2024 | 16(7): 25495–25506

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.9003.16.7.25495-25506

#9003 | Received 29 February 2024 | Final received 09 June 2024 | Finally accepted 18 July 2024

OPEN ACCESS

ARTICLE

Spatial assemblage of shorebirds (Aves: Charadriiformes) in an altered wetland of the southern coast of Sri Lanka

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Abstract: The coastal wetlands along the southern coast of Sri Lanka are home to a diverse array of shorebirds thriving in their natural habitats, classified under the order Charadriiformes. This study examines the impact of land cover changes within the Kalametiya Sanctuary, situated on the southern coast, on the diversity, distribution, and habitat utilization of migrant and breeding resident shorebirds. Three distinct habitat types were selected within the study area: grassland, lagoon, and mixed mangroves. Employing Geographic Information System (GIS) data the land cover changes of these habitats from 2002 to 2023 were analyzed using satellite imagery. Results indicated a substantial decrease in lagoon habitat area by 70% and grassland habitat by 30%, while mixed mangrove habitat saw an increase of >90%. These changes were attributed to anthropogenic interventions and natural events such as the 2004 Tsunami. To determine the shorebird assemblages within the study area thriving in these changing habitats, surveys were conducted from May 2022 to April 2023 at 30 fixed point-count stations along transects in the selected habitat types. A total of 25 shorebird species belonging to six families were recorded. Notable among these were the globally 'Near Threatened' species such as the Black-tailed Godwit *Limosa limosa* and the Great Thick-knee *Esacus recurvirostris*, alongside nationally threatened species including Kentish Plover *Charadrius alexandrinus*, Gull-billed Tern *Gelochelidon nilotica*, and Common Tern *Sterna hirundo* species. The mixed-mangrove habitat exhibited the highest shorebird abundance, with 19 species recorded, surpassing the 13 and 11 species recorded in the grassland and lagoon habitats, respectively. Additionally, both grassland and mixed-mangrove habitats demonstrated similar diversity indices and shared more species in common (Shannon's diversity index [H] = 2.17; Jaccard Similarity Index = 0.45) compared to the lagoon habitat (H = 2.09). Despite the notable decline in lagoon habitat cover, during the present study, it was observed that the overall shorebird populations have been sustained within grassland and mixed-mangrove habitats utilized for their feeding and nesting. Additionally, over-summering migratory shorebirds were observed utilizing these habitats. Hence, the Kalametiya sanctuary serves as a unique setting to study the ecological resilience of migratory and breeding resident shorebirds amidst human interventions. This research provides valuable insights for biodiversity conservation and habitat management in the face of human-induced alterations within ecosystems located especially along migratory pathways of shorebird species. Both grassland and mixed-mangrove habitats exhibited similar diversity indices and shared more species (Shannon's diversity index [H] = 2.17; Jaccard Similarity Index = 0.45) compared to the lagoon habitat (H = 2.09). Despite the significant decline in lagoon habitat cover, this study observed that overall shorebird populations have been sustained within the grassland and mixed-mangrove habitats, which they use for feeding and nesting. Additionally, over-summering migratory shorebirds were observed utilizing these habitats. Thus, the Kalametiya sanctuary serves as a unique setting for studying the ecological resilience of migratory and breeding resident shorebirds amidst human interventions. This research offers valuable insights for biodiversity conservation and habitat management, particularly in ecosystems along migratory pathways of shorebird species, in the face of human-induced alterations.

Keywords: Bird migration, Central Asian Flyway, coastal wetland, habitat alteration, habitat utilization, land cover changes, protected areas, wetland conservation.

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

Date of publication: 26 July 2024 (online & print)

Citation: Mendis, V.N., E.J.A.P.B. Priyankara, E.G.D.P. Jayasekara & W.A.D. Mahaulpatha (2024). Spatial assemblage of shorebirds (Aves: Charadriiformes) in an altered wetland of the southern coast of Sri Lanka. *Journal of Threatened Taxa* 16(7): 25495–25506. https://doi.org/10.11609/jott.9003.16.7.25495-25506

Funding: This research was funded by the University of Sri Jayewardenepura postgraduate grant (ASP/01/RE/SCI/2022/18).

Competing interests: The authors declare no competing interests.

Author details, Author contributions & Acknowledgements: See end of this article.

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INTRODUCTION

Sri Lanka serves as a major landmass for migratory birds traversing the Central Asian Flyway (CAF). The coastal wetlands on the island support a rich biodiversity and provide essential ecosystem services such as maintaining ecological balance and nutrient cycling (Basset et al. 2013; Gunatilleke et al. 2017; Newton et al. 2018). They also play a pivotal role in connecting global habitats by serving as a vital stopover, feeding and nesting grounds for migrating and breeding resident avifauna, especially shorebirds of the Order Charadriiformes (Kotagama et al. 2006). Notably, coastal wetlands particularly in southern Asia are known to offer critical habitat for threatened migratory shorebirds with decreasing populations due to the depletion of the coastal environment (Ferreira et al. 2005; Delany et al. 2009). They are indispensable for long-distance migrant shorebirds to replenish energy stores, feed, and rest, and for resident shorebirds to sustain their populations through nesting sites (Pérez-Ruzafa et al. 2011; Aycock & Sims 2015; Duan et al. 2022).

Despite their importance, human exploitation has led to threats and modifications to Sri Lanka's coastal wetlands over the years (Jayathilake & Chandrasekara 2015; Madarasinghe et al. 2020b; Kodikara et al. 2023). However, studies identify that understanding interactions with the ecology and biodiversity of coastal wetlands in developing countries including Sri Lanka show a lack of improvement in comparison to the well-developed regions of the world. Hence, it is important to determine the influence of such interventions on the biodiversity that depends on these habitats, especially for sensitive species like shorebirds, and what measures could be taken to manage and minimize any detrimental effects on the shorebird community.

The Kalametiya Sanctuary, located on the southern coast of Sri Lanka, is renowned for its biodiversity and ecological significance, serving as an avifaunal region (Ekanayake et al. 2005; Bernard et al. 2023). Encompassing over 700 hectares, the sanctuary comprises various habitats including mangrove swamps, lagoons, sandy shores, and grasslands, all of which support shorebird communities (Ekanayake et al. 2005; Bernard et al. 2023). Designated as a sanctuary since 1984, it is governed by the Fauna and Flora Protection Ordinance and the southern Province Hambantota Integrated Coastal Zone Management Project (Jayatissa et al. 2002; Ekanayake et al. 2005; Perera et al. 2013; Madarasinghe et al. 2020a). Scientific research within Kalametiya sanctuary can therefore provide valuable insights into not only avian ecology but also on coastal wetland dynamics and ecosystem resilience of sustaining faunal communities. Previous studies have documented the sanctuary's floral and fauna diversity and how various interventions, such as the Udawalawe Irrigation and Resettlement Project and the 2004 Tsunami tragedy, have altered the habitat composition within the sanctuary, over the course of the period from 2005 to 2020 (Bambaradeniya et al. 2005; Ekanayake et al. 2005; Madarasinghe et al. 2020a,b).

Based on the literature, one of the main factors for good shorebird habitat is the presence of adequate foraging sites. Effective conservation of shorebird habitats requires a thorough understanding of the patterns of shorebirds' spatial and temporal utilization of habitats. This knowledge can be difficult to attain and may be time-consuming, especially in coastal settings, since shorebirds can show complex local movements, being very specific in their habitat requirements and their capability of traversing long distances between preferred sites (Warnock & Bishop 1998; Pearce-Higgins et al. 2017). Hence, to better understand species-habitat relationships within coastal wetlands, it is imperative to adopt a multispectral and multi-temporal data analysis approach using modern remote sensing and GIS technologies (Albanese et al. 2012; Kaliraj et al. 2017; Vivekananda et al. 2021). Studies such as the present research that incorporates both on-ground field records and remote sensing analysis could serve the purpose of achieving the intended objectives of effective shorebird species conservation and habitat management.

Moreover, since shorebirds serve as biological indicators of ecosystem health (Colwell 2010), conservation efforts must focus on preserving their habitats, including wintering, feeding, and nesting grounds (Thomas et al. 2004; Jumilawaty et al. 2022). Yet none of the research conducted thus far has assessed shorebird diversity, distribution, and habitat utilization in the Kalametiya Sanctuary. This study aims to address this gap by determining shorebird diversity, distribution, and habitat utilization in Kalametiya Sanctuary, considering the effects of recent land cover changes, and proposing management options, including the possibility the Sanctuary be declared as a Ramsar-protected wetland based on identified human and natural threats.

MATERIALS AND METHODS

Study area

This study was conducted within Kalametiya Sanctuary (6.086 N, 80.936 E) situated in the southern province of Sri Lanka. This region falls within the island's dry zone, receiving an average annual rainfall ranging 1,000–1,250 mm. Spanning an area of 700 ha, the sanctuary is designated under the Fauna and Flora Protection Ordinance (FFPO) and governed by the Department of Wildlife Conservation (DWC) (Ekanayake et al. 2005; Perera et al. 2013). It comprises the larger Kalametiya lagoon and a smaller Lunama lagoon, connected by a man-made narrow channel. For the study, three primary habitat types were identified: grassland (G), lagoon (L), and mixed mangrove (MM), and selected (Image 1) based on accessibility and extensive land cover availability (Ekanayake et al. 2005).

Field survey and avifaunal sampling

Sampling was conducted from May 2022 to April 2023, employing 30-point count stations fixed along transects (Figure 1; GPS points of point count stations given in Table 4) (Bibby et al. 1998; Ntongani & Andrew 2013) in the three selected habitats. The point counts were fixed such that each station was separated by the other by 50 m or greater to minimize double counting (Bibby et al. 1998; Sutherland et al. 2012; Bernard et al. 2023) and the accessibility to each site was available throughout the study period. ArcGIS version 10.8 (Esri, Redlands, USA) was used to overlay the fixed-point count stations on a satellite map of the selected study area.

Two days of sampling were allocated for each of the three months during both the bird migratory season (October–April) and non-migratory season (May–September). Morning and evening point counts lasting 10 minutes each were conducted within a 2–3 h window of predicted low tide - conducted during daylight, although some shorebird foraging occurs at night (Bibby et al. 1998), on each sampling day at each station by pairs of observers with similar training levels. Surveys were conducted either on foot in the grassland and

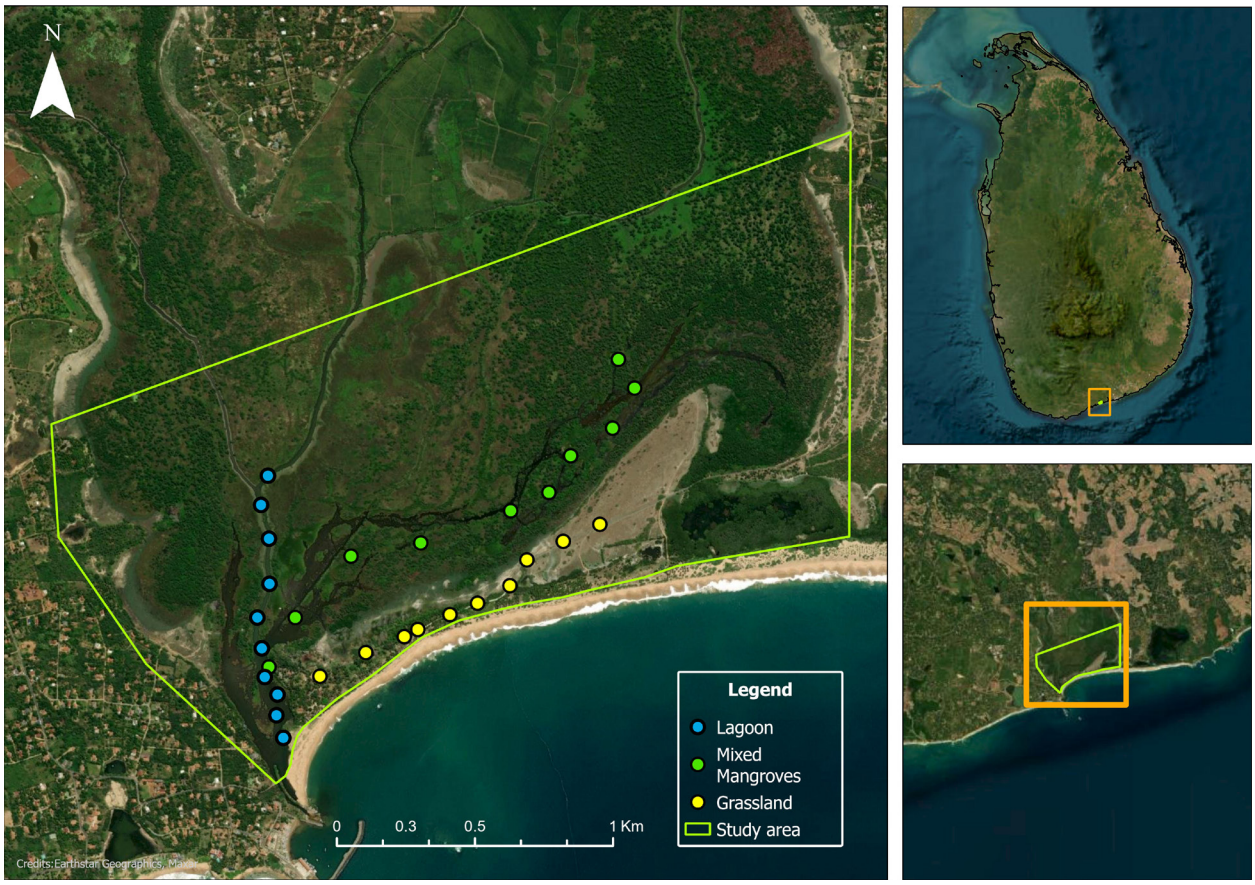

Figure 1. Point count stations along transects within the grassland, lagoon, and mixed-mangrove habitats in the Kalametiya Sanctuary, southern coast of Sri Lanka. Prepared by: E.G.D.P. Jayasekara.

mixed mangrove habitats or using slow paddle boats in the lagoon habitat, taking measures to minimize any disturbances to the species during the survey. Shorebirds that flew over a point were disregarded unless they landed or took off within the point count radius within the observation period. Standard birding equipment such as Nikon 8 × 40 Action Extreme and Nikon Monarch 10 × 42 binoculars, Vanguard Endeavor XF 60A 15–45 x 60 spotting scope, and standard field guides (Harrison & Worfolk 2011; Hayman et al. 2011) were utilized for species identification and recording. The observed shorebird species' common English names were documented, and their conservation status was later determined using the IUCN Red List of Threatened Species and the National Red List of Birds of Sri Lanka (Secretariat 2022).

Species richness, diversity, and similarity

Species richness was recorded as the number of shorebird species present in a particular habitat and season. PAST 4.15 open-source software was used to estimate Shannon's diversity index (H) based on the following equation:

$$H = \Sigma pi \log(ln)\ pi$$

where, *pi* is the proportion (n/N) of individuals of a particular species observed (n) divided by the total number of individuals recorded (N), while *ln* is the natural log, and Σ is the sum of the calculations. Significant differences between the seasonal diversity indices were calculated using the diversity t-test.

The Relative abundance was computed using [(number of individuals per species/total number of individuals) × 100%] and the Jaccard similarity index [SJ] was calculated between the habitats by using the equation,

$$SJ = S_a / (S_a + S_b + S_c)$$

where S_a is the number of species unique to the first habitat, S_b is the number of species unique to the second habitat, and S_c is the number of species common in both habitats.

Determination of habitat alteration

Multi-spectral satellite images from Landsat 7 (ETM+/path_141/row_56) and Landsat 8 (OLI_TIRS sensor/path_141/row_56) missions were obtained from the United States Geological Survey online database (https://earthexplorer.usgs.gov/). The search aimed to find Landsat datasets with minimal cloud cover during the months of June to August, consistent with previous studies (Jayatissa et al. 2002; Madarasinghe et al. 2020b; Bernard et al. 2023) to avoid months with extreme rainfall or drought conditions. The selected images for analysis were from 07 July 2002 (Landsat 7), July 18, 2012 (Landsat 7), and 09 July 2023 (Landsat 8). This approach minimized the seasonal impact on habitat spatial variation and allowed an unbiased evaluation of the lagoon's saltwater and freshwater balance, considering historical precipitation levels in July. To address differences in resolution and image quality among the Landsat datasets, Red and NIR (near-infrared) bands were utilized to generate normalized difference vegetation index (NDVI) rasters as the basis for image classification. NDVI values were calculated using the formula: NDVI = (NIR - Red)/(NIR + Red) (Grebner et al. 2013; Pantazi et al. 2020). Habitats were classified based on NDVI pixel values: lagoon <0.15, grassland 0.15–0.2, other vegetation 0.2–0.25, mixed mangrove >0.25 (Drisya & Roshni 2018). An accuracy assessment was performed on the classified images corresponding to the selected years and kappa coefficients were calculated using a confusion matrix (Vivekananda et al. 2021). Ground observations as well as Google Earth images were used for ground truthing the 2023 classified image. Google Earth images alone were used for the ground truthing accuracy assessment of 2002 and 2012 classified images. Therefore, the limited availability of corresponding Google Earth historical data was considered during the Landsat image selection.

RESULTS

Species Richness and Diversity

During the survey, 602 individuals of 25 shorebird species belonging to six families were recorded. A similar shorebird species diversity was recorded in the grassland and mixed-mangrove habitats (H = 2.17) and the least diversity was recorded in the lagoon habitat (H = 2.09) (Figures 2 & 3).

The Black-winged Stilt *Himantopus himantopus*, a breeding resident shorebird with a migrant population was the most abundant species recorded in all three habitats during the study period. The least abundant species recorded were the Gull-billed Tern *Gelochelidon nilotica* and the Whimbrel *Numenius phaeopus* species (Table 1). A notable observation was the record of over-summering populations of Common Redshank *Tringa totanus* and Ruddy Turnstone *Arenaria interpres* species utilizing the grassland and mixed mangrove habitats during the non-migratory season. The record of the globally 'Near Threatened' species Black-tailed Godwit *Limosa limosa* and Great Thick-knee *Esacus recurvirostris*,

Table 1. Shorebird species of Order Charadriiformes that were recorded during the study period in the selected three habitats.

Family	Scientific name	Common name	GCS (2021)	NCS (2021)	Phenological status	Relative abundance (%)	Habitat
Burhinidae	*Esacus recurvirostris* (Cuvier, 1829)	Great Thick-knee	NT	LC	R	3.99	G/ L/ MM
	Burhinus indicus (Salvadori, 1865)	Indian Thick-knee	LC	LC	R	1.66	G
Charadriidae	*Charadrius mongolus* (Pallas, 1776)	Lesser Sand Plover	LC	-	M	8.80	G/ MM
	Charadrius leschenaultia (Lesson, 1826)	Greater Sand Plover	LC	-	M	0.83	G/ MM
	Pluvialis fulva (Gmelin, 1789)	Pacific Golden Plover	LC	-	M	2.82	G/ MM
	Charadrius alexandrinus (Linnaeus, 1758)	Kentish Plover	LC	EN	R / M	1.16	G
	Pluvialis squatarola (Linnaeus, 1758)	Grey Plover	LC	-	M	0.83	G/ MM
	Vanellus indicus (Boddaert, 1783)	Red-wattled Lapwing	LC	LC	R	12.62	G/ L/ MM
	Vanellus malabaricus (Boddaert, 1783)	Yellow-wattled Lapwing	LC	LC	R	3.16	G
Jacanidae	*Hydrophasianus chirurgus* (Scopoli, 1786)	Pheasant-tailed Jacana	LC	LC	R	2.33	L
Laridae	*Chlidonias hybrida* (Pallas, 1811)	Whiskered-Tern	LC	-	M	3.49	L/ MM
	Gelochelidon nilotica (Gmelin, 1789)	Gull-billed Tern	LC	CR	R / M	0.49	L
	Sterna hirundo (Linnaeus, 1758)	Common Tern	LC	CR	R / M	1.16	L
	Sternula albifrons (Pallas, 1764)	Little Tern	LC	VU	R / M	1.83	L/ MM
Recurvirostridae	*Himantopus himantopus* (Linnaeus, 1758)	Black Winged Stilt	LC	LC	R / M	24.25	G/ L/ MM
Scolopacidae	*Tringa totanus* (Linnaeus, 1758)	Common Redshank	LC	-	M	16.45	G/ L/ MM
	Tringa nebularia (Gunnerus, 1767)	Common Greenshank	LC	-	M	0.33	MM
	Tringa stagnatilis (Bechstein, 1803)	Marsh Sandpiper	LC	-	M	0.49	L/ MM
	Tringa glareola (Linnaeus, 1758)	Wood Sandpiper	LC	-	M	0.83	MM
	Actitis hypoleucos (Linnaeus, 1758)	Common Sandpiper	LC	-	M	1.33	L/ MM
	Arenaria interpres (Linnaeus, 1758)	Ruddy Turnstone	LC	-	M	4.98	G/ MM
	Calidris minuta (Leisler, 1812)	Little Stint	LC	-	M	1.66	MM
	Numenius phaeopus (Linnaeus, 1758)	Whimbrel	LC	-	M	0.49	MM
	Limosa limosa (Linnaeus, 1758)	Black-tailed Godwit	NT	-	M	0.83	MM
	Gallinago stenura (Bonaparte, 1830)	Pintail Snipe	LC	-	M	1.16	G/ MM

M—Migrant | R—Resident | GCS—Global Conservation Status | NCS— National Conservation Status.

and nationally critically endangered species Gull-billed Tern *Gelochelidon nilotica* and Common Tern *Sterna hirundo* and the nationally endangered Kentish Plover *Charadrius alexandrinus* within the study area highlights the overall standpoint of Kalametiya Sanctuary to support thriving shorebird communities.

Changes in shorebird species diversity and richness during the migratory and non-migratory seasons depicted that most shorebirds were observed utilizing mixed mangrove habitats than the grassland and lagoon habitats during the migratory season, while in the non-migratory season, the highest occurrence was recorded in the grassland habitat (Table 2). A t-test comparison of the diversity indices of the migratory season indicates

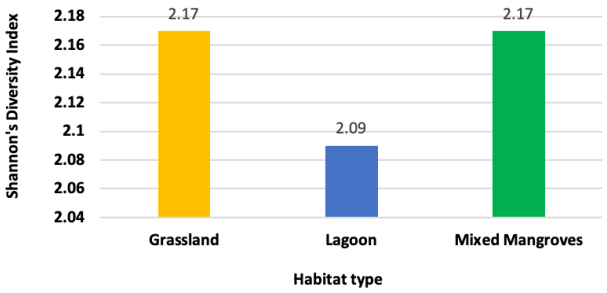

Figure 2. Shannon's diversity (H) indices which were recorded in the three habitats.

that there is a significant difference in the diversity recorded in the mixed mangrove habitat with that of the diversity recorded in the lagoon (t = 2.682, df = 85.52, p = 0.008) and grassland habitats (t = 2.034, df = 287.07, p = 0.0429). During the non-migratory season however, only the diversity of shorebird species recorded in the mixed mangrove and lagoon habitat (t = 3.132, df = 168.94, p = 0.002) significantly differed.

Changes in land cover within the study area

The spatio-temporal change in land cover within the study area for the past two decades is depicted in the maps (Figure 4) generated from satellite data. Overall, the lagoon area has decreased by 69.94% and the grassland area has decreased by 30.75%. However, the area of mixed mangroves within the study site has increased by 93% from 2002 to 2023 (Table 3). The accuracy assessment was performed for 2002, 2013, and 2023 land cover maps and an overall kappa statistic of 0.741, 0.754, and 0.736 were computed for each respectively.

DISCUSSION

The global decline in shorebird populations is of growing concern, highlighting the need for dedicated efforts towards their conservation and sustainable management (Clemens et al. 2010; Aarif et al. 2014). Coastal wetlands, particularly in Asia which support such migratory and breeding resident shorebird species, even though considered the most productive of the many types of wetlands categorized by the Ramsar Convention (https://rsis.ramsar.org/), are affected by exponential population growth and imbalances in demand-supply interactions arising mostly due to urban developments. Shorebirds are considered to play a significant role in maintaining the health of the environment they utilize (Colwell 2010) and therefore, the protection of their stopover resources within coastal wetlands could pave the way for the sustaining of both shorebird communities and the wetland habitats (Myers et al. 1987; Skagen & Knopf 1994). Considering the above concerns, it is evident that Sri Lanka's coastal wetlands present an understudied yet ecologically significant arena for investigating the dynamics of shorebird communities amidst continuing alterations in the southern Asian region. Hence, the present study conducted in the Kalametiya Sanctuary, located in southern Sri Lanka, which assesses the shorebird diversity, distribution, and habitat utilization considering habitat cover changes that have occurred over past decades, provides a reference framework for implementing timely species conservation and habitat management strategies.

During the present research, a total of 25 shorebird

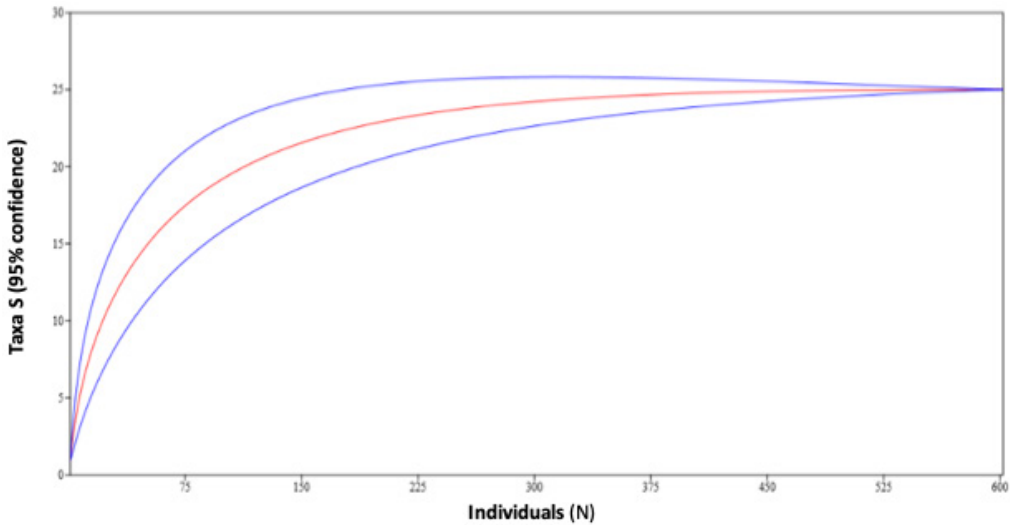

Figure 3. The rarefaction curve for species accumulation with the number of individuals recorded within the study area.

Image 1. A—grassland | B—lagoon | C—mixed mangrove habitats during the study period. © V.N. Mendis.

Table 2. Shorebird species diversity comparison of the migratory and non-migratory seasons in the three habitats.

	Non-migratory season			Migratory season		
	Grassland	Lagoon	Mixed mangrove	Grassland	Lagoon	Mixed mangrove
Shannon's diversity index (H)	2.055	1.919	1.472	2.207	2.079	2.429
Evenness	0.7811	0.757	0.436	0.699	0.799	0.630
Richness	10	9	10	13	10	18
Total number of individuals (N)	89	68	101	126	48	170

species belonging to the order Charadriiformes were documented, of which 60% can be classified as migratory species, 20% as breeding residents, and the remainder as breeding resident species with a migrant population. In contrast, a recent study by Bernard et al. (2023) reported only 10 shorebird species, while a previous biodiversity profile by Ekanayake et al. (2005) documented 38 species. However, it is important to note that the 2005 survey considered the entire Kalametiya-Lunama sanctuary area, whereas the present research focused specifically on habitats adjoining the Kalametiya lagoon. Further, the species that were recorded in the 2005 survey that were not recorded in the present research are some of the rare and uncommon migrant shorebird species such as the Ruff *Calidris pugnax* and Long-toed Stint *Calidris subminuta* and some of the uncommon migrant tern species such as the Saunders's Tern *Sternula saundersi*, Great Crested Tern *Thalasseus bergii*, and Lesser Crested Tern *Thalasseus bengalensis*, which have been found utilizing mostly the brackish lagoon water habitat within the entire Kalametiya-Lunama sanctuary area. Consequently, direct comparisons of species richness values between studies are not feasible due to differences in study area delineation. The demarcated study area of the present study was chosen to assess how changes in land cover within the Kalametiya lagoon and surrounding habitats have impacted the diversity and habitat utilization of shorebirds, considering the proportional area of the sanctuary. Further studies in the Lunama lagoon area to supplement the present study could be suggested to follow a comparative approach in identifying the shorebird habitat utilization within the larger sanctuary area post two decades since the last published biodiversity profile (Ekanayake et al. 2005).

Sanctuaries play a crucial role in supporting biodiversity, albeit often subjected to regulated human interventions (Green 1990). Over the past decades, Kalametiya Sanctuary has undergone alterations, necessitating an understanding of the degree of habitat cover change and its impact on long-distance migrant

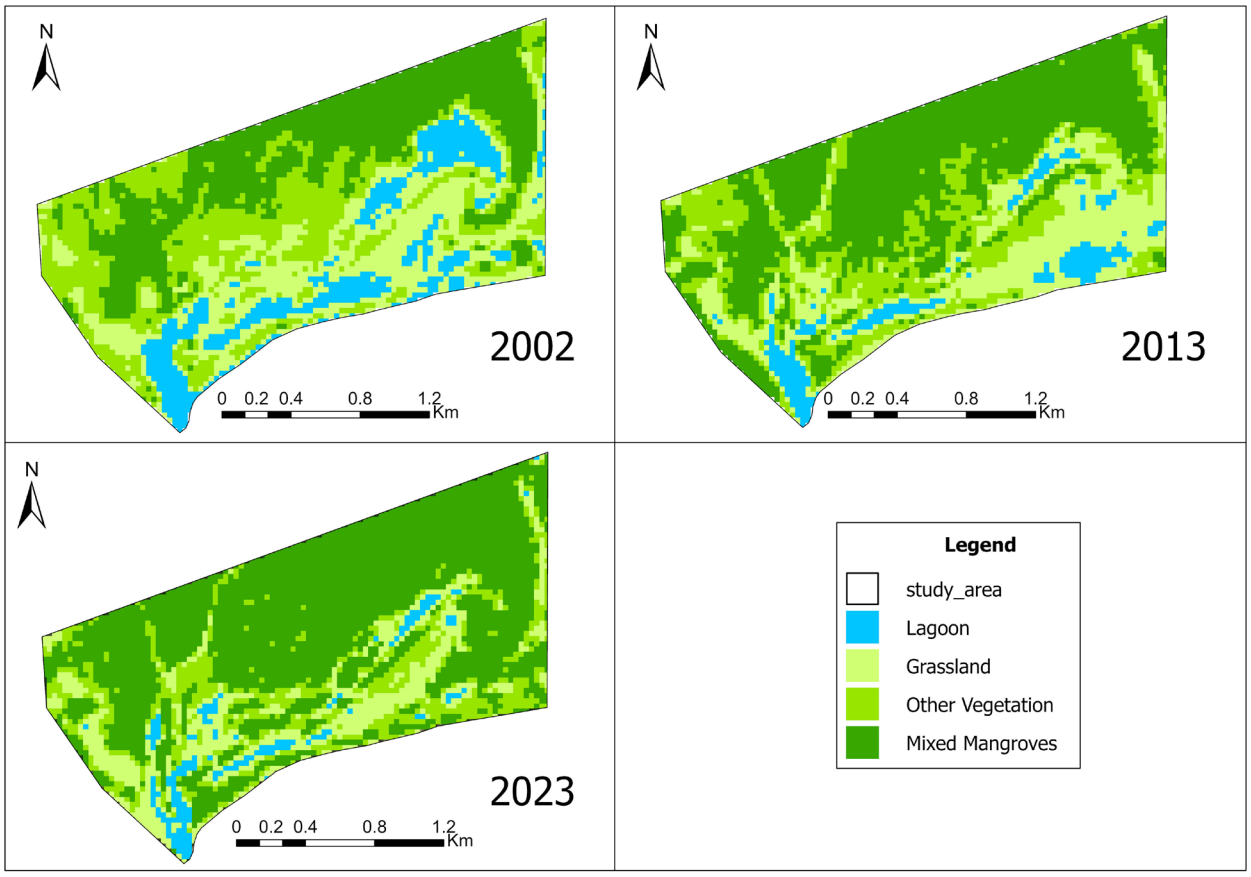

Figure 4. Spatio-temporal change of land cover within the study area depicted using satellite imagery. Prepared by E.G.D.P. Jayasekara.

and breeding resident shorebird species. Hence, the study analyzed satellite imagery data alongside spatial assemblage data of shorebirds utilizing the Kalametiya Lagoon and surrounding habitats with the intention of assessing the present conditions within the sanctuary. The findings revealed a significant decrease of over 69% in the lagoon area since 2002, a notable alteration that could potentially change the species composition within the sanctuary. Yet, this decrease in the lagoon area hasn't led to a drastic decline or a total displacement of shorebird communities. Based on the results of the present study, several reasons for this phenomenon can be proposed.

Studies identify that shorebirds feed and roost within the shallows of a wetland having water depths of less than 30cm, where prey availability and accessibility are mediated by their leg and bill lengths, or on the shores of wetland clusters during low tides, providing them chances with abundant prey (Zwarts & Wanink 1993; Bellio & Kingsford 2013). Hence, shorebirds continuing to sustain within the selected study area is reflected by the study results which show that their most utilized feeding grounds were the mixed mangrove and grassland habitats, recording shallower water depths (less than 30 cm) which match their bill length and leg heights, making these areas preferable over deeper lagoon waters.

Table 3. Land cover change (%) of the habitats in the study area over the period of 2002–2023.

	2002	2013	2023	Change (2002–2023)	% change
Lagoon	13.7	6.5	4.1	-9.6	-69.9373
Grasslands	24.6	22.7	17.0	-7.6	-30.7483
Other vegetation	30.0	24.0	17.7	-12.3	-40.9414
Mixed mangroves	31.6	46.8	61.1	29.5	93.19583

Additionally, breeding resident shorebirds such as the Black-winged Stilts (Ashoori 2011) and Red-wattled Lapwings (Hart et al. 2002; Arya et al. 2023) construct their nests in grassy areas or abandoned agricultural lands using dung, mud, and decayed plant materials, unlike waterbirds that prefer aquatic vegetation for nesting. Therefore, the decrease in the lagoon area doesn't significantly impact the nesting behaviors of these shorebirds. The nesting sites also contribute to

Table 4. Point count stations fixed along transects in the three selected habitats within the study area.

Grassland T1			Lagoon T2			Mixed mangrove T3		
Point count station	Longitude	Latitude	Point count station	Longitude	Latitude	Point count station	Longitude	Latitude
P1i	80.937	6.082	P1ii	80.936	6.080	P1iii	80.935	6.083
P2i	80.938	6.083	P2ii	80.935	6.081	P2iii	80.936	6.084
P3i	80.940	6.084	P3ii	80.935	6.081	P3iii	80.938	6.086
P4i	80.940	6.084	P4ii	80.935	6.082	P4iii	80.940	6.087
P5i	80.941	6.084	P5ii	80.935	6.083	P5iii	80.943	6.088
P6i	80.942	6.085	P6ii	80.935	6.084	P6iii	80.944	6.088
P7i	80.943	6.085	P7ii	80.935	6.085	P7iii	80.945	6.090
P8i	80.944	6.086	P8ii	80.935	6.087	P8iii	80.947	6.090
P9i	80.945	6.087	P9ii	80.935	6.088	P9iii	80.947	6.092
P10i	80.946	6.087	P10ii	80.935	6.089	P10iii	80.947	6.093

the notable species diversity observed in the grassland habitat during the non-migratory season. Furthermore, during the non-migratory season, coinciding with the dry spell in the study area, the drying up of mixed mangrove habitats reduces invertebrate food sources for shorebirds. In the grassland habitat where cattle grazing activities occur, the soil is disturbed, exposing land invertebrates such as snails and soft annelids, which serve as a vital food source for nesting parents and newly hatched shorebirds. However, such agricultural interventions contribute both positively and negatively to shorebird habitat utilization, and if not managed can lead to detrimental impacts.

Despite past recommendations for cattle grazing to be limited to demarcated buffer zones (Ekanayake et al. 2005), herds were observed in sensitive mixed mangrove and grassland habitats, risking nest trampling (Hart et al. 2002) and disturbing shorebird feeding grounds. A trampled nest of each of Red-wattled Lapwing and Black-winged Stilt were recorded during the present study. It is encouraged to conduct further research to actively monitor and quantify trampling rates of shorebird nests and highlight the need for the demarcation of grazing buffer zones within the Sanctuary.

The loss of wintering grounds in southern Asia for long distant migratory shorebirds due to coastal developments and habitat loss has posed a significant threat over the past years (Aarif et al. 2014; Byju et al 2023), especially to over-summering populations of shorebird species including the Common Redshank and Ruddy Turnstone (Aarif et al. 2020) which were recorded during the present study in the Kalametiya Sanctuary. Conservation of their over-summering habitats becomes crucial for successful population recruitment of these species into migratory counterparts in a consequent season or provides conditions supporting them to adapt and withstand changes beyond their home grounds. Moreover, habitat alterations following the 2004 Tsunami (Bambaradeniya et al. 2005; Perera et al. 2013; Madarasinghe et al. 2020a), the irrigation project bringing in more siltation into the lagoon (Madarasinghe et al. 2020b; Kodikara et al. 2023) and the recent breakwaters built in the Kalametiya fishing harbor, have impacted the ecosystem. Effective management actions are essential to regulate the environment for wildlife and humans. Despite past recommendations (Ekanayake et al. 2005) the present study notes continued habitat depletion due to inadequate intervention. This underscores the urgent need for enhanced conservation efforts to protect these vital habitats and their biodiversity.

Kalametiya Sanctuary sustains local livelihoods through fisheries and cattle farming (Ekanayake et al. 2005) and promotes eco-tourism with peaceful paddle boat rides dedicated to birdwatching. However, despite the numerous services the coastal wetland provides to maintain a healthy and productive ecosystem, it is evident that human interventions like habitat mismanagement, over-exploitation of resources, negligence, and uncontrolled waste disposal have disrupted the human-wildlife coexistence, especially in terms of the sustainability of thriving populations like shorebirds that bring not only ecological but also economical values using eco-tourism, habitat upliftment and food web balances within their utilized habitats. Therefore, advocating for heightened public awareness and community engagement in sustainable practices of living is recommended to safeguard the sanctuary for future generations. Awareness campaigns

among the local fisheries and farming communities on the effects of mismanaged waste disposal affecting both human health utilizing contaminants, and the health of the wetland mangroves that prevent coastal erosion, effective ways of reducing the risk of nest trampling and disturbances to the mixed mangroves by adhering to demarcated grazing buffer zones are some of the ground level initiatives that can be proposed to assist shorebird species conservation and sustainable coastal wetland habitat management implications. Further studies that identify the impacts of microplastic contamination similar to the study conducted by Luna et al. (2022) which found microplastics in nests of Black-winged Stilts in a Biosphere Reserve in Spain could comprehend to the present study in enhancing shorebird nesting habitat conservation. The year 2024 World Wetland Day theme, "Wetlands and Human Wellbeing," offers an opportune moment for initiating conservation efforts in the coastal wetland habitat of Kalametiya Sanctuary.

Since the shorebird ecology and causes and drivers for population decline in the CAF are less explored (Mundkur & Selvaraj 2023) research such as the present study supplements to identification of human interactions that affect the shorebird assemblage and their habitat utilization within coastal wetlands along the CAF and what are the timely conservation strategies that can be newly implemented and what existing strategies can be improved for better results in future. The present study, alongside previous research, suggests the potential declaration of the sanctuary as a Ramsar site due to its global conservation significance, providing crucial habitats for long- distant migrant shorebirds, threatened shorebirds, and over-summering shorebird species. Moreover, it sheds light on the impacts of land cover and land use changes on biodiversity in this altered coastal wetland, providing valuable insights for authorities and communities to recognize Kalametiya Sanctuary as a vital hub for biodiversity conservation and environmental sustainability in Sri Lanka.

CONCLUSION

The present study highlights the resilience of Kalametiya Sanctuary in supporting both migratory and breeding resident shorebird species despite ongoing habitat alterations over the past two decades. A survey conducted covering both migratory and non-migratory seasons recorded 25 shorebird species from six families, including globally and nationally threatened species. Land cover changes were assessed using satellite imagery, achieving acceptable accuracy rates exceeding 70% for each assessment year. Encouragingly, the study found that the present status of the habitats did not adversely affect migratory and breeding resident shorebirds, avoiding a wipe out of the species from the habitats. Over-summering species were also found utilizing the habitats. However, proactive management and conservation efforts are crucial to ensure the continued thriving of shorebird populations and to prevent further habitat depletion. Overall, this research underscores the significance of conserving altered coastal wetlands to maintain vital stopover and over-summering sites, especially in the southern Asian region along the CAF, while promoting sustainable livelihoods within and surrounding the sanctuary.

REFERENCES

Aarif, K.M., S.B. Muzaffar, S. Babu & P.K. Prasadan (2014). Shorebird assemblages respond to anthropogenic stress by altering habitat use in a wetland in India. *Biodiversity and Conservation* 23(3): 727–740. https://doi.org/10.1007/s10531-014-0630-9

Aarif, K.M., S.A. Kaiser, A. Nefla & S. Almaarofi (2020). Over-summering abundance, species composition, and habitat use patterns at a globally important site for migratory shorebirds. *The Wilson Journal of Ornithology* 132(1): 165–172. https://doi.org/10.1676/19-06

Albanese, G., C.A. Davis & B.W. Compton (2012). Spatiotemporal scaling of North American continental interior wetlands: Implications for shorebird conservation. *Landscape Ecology* 27(10): 1465–1479. https://doi.org/10.1007/s10980-012-9803-7

Arya, A.K., K.K. Joshi, D. Kumar & A. Bachheti (2023). A study on the breeding habits of Red-wattled Lapwing *Vanellus indicus* Boddaert, 1783 (Aves: Charadriformes: Charadridae) in the agricultural landscape of Muzaffarnagar District, Uttar Pradesh, India. *Journal of Threatened Taxa* 15(4): 23119–23122. https://doi.org/10.11609/jott.8066.15.4.23119-23122

Ashoori, A. (2011). Breeding Ecology of the Black-winged Stilt *Himantopus himantopus* in Boujagh National Park, Gilan Province, Northern Iran. *Podoces* 6(1): 87–91

Aycock, J.E. & C. Sims (2015). Shorebird Foraging Habitat in Southeast Arkansas. *Journal of the Arkansas Academy of Science* 69: 25–28. https://doi.org/10.54119/jaas.2015.6901

Bambaradeniya, C., S.P. Ekanayake, S.J. Perera & R.K. Rodrigo (2005). A report on the terrestrial assessment of Tsunami impacts on the coastal environment in Rekawa, Ussangoda and Kalametiya (RUK) area of southern Sri Lanka. IUCN – The World Conservation Union, Horton Place, Colombo, 33 pp.

Basset, A., M. Elliott, R.J. West & J.G. Wilson (2013). Estuarine and lagoon biodiversity and their natural goods and services. *Estuarine, Coastal and Shelf Science* 132: 1–4. https://doi.org/10.1016/j.ecss.2013.05.018

Bellio, M. & R.T. Kingsford (2013). Alteration of wetland hydrology in coastal lagoons: Implications for shorebird conservation and wetland restoration at a Ramsar site in Sri Lanka. *Biological Conservation* 167: 57–68. https://doi.org/10.1016/j.biocon.2013.07.013

Bernard, T., K.A.S. Kodikara, J. Sleutel, G.G.N.K. Wijeratne, J. Hugé, M.P. Kumara, M.A.Y.N. Weerasinghe, D.P.D. Ranakawa, W.A.K.G. Thakshila & F. Dahdouh-Guebas (2023). Assessing the Influence of Anthropogenic Land-Use Changes on Bird Diversity and Feeding Guilds—A Case Study of Kalametiya Lagoon (Southern Sri Lanka). *Diversity* 15(3): 383. https://doi.org/10.3390/d15030383

Bibby, C.J., M. Jones & S. Marsden (1998). *Bird surveys*. Expedition Advisory Centre, London, 137 pp.

Byju, H., N. Raveendran, S. Ravichandran & R. Kishore (2023). Importance of conserving a critical wintering ground for shorebirds in the Valinokkam Lagoon—a first study of the avifaunal distribution of the southeastern coast of India. *Journal of Threatened Taxa* 15(8): 23696–23709. https://doi.org/10.11609/jott.2023.15.8.23631-23836

Clemens, R.S., M.A. Weston, A. Haslem, A. Silcocks & J. Ferris (2010). Identification of significant shorebird areas: Thresholds and criteria. *Diversity and Distributions* 16(2): 229–242. https://doi.org/10.1111/j.1472-4642.2009.00635

Colwell, M.A. (2010). *Shorebird ecology, conservation, and management*. In: Delany, S., D. Scott, A.T.F. Helmink, T. Dodman, S. Flink, D. Stroud & L. Haanstra (2009). *An Atlas of Wader Populations in Africa and Western Eurasia*. Wetlands International, University of California Press.

Drisya, J. & T. Roshni (2018). Spatiotemporal Variability of Soil Moisture and Drought Estimation Using a Distributed Hydrological Model. *Integrating Disaster Science and Management* 2018: 451–460. https://doi.org/10.1016/B978-0-12-812056-9.00027-0

Duan, H., X. Yu, K. Shan, C. Zhang & H. Liu (2022). Effects of habitat loss on migratory shorebird community structure at stopover sites: A case study in the Yellow River Delta, China. *Frontiers in Marine Science* 9: 1049765. https://doi.org/10.3389/fmars.2022.1049765

Ekanayake, S.P., C.N.B. Bambaradeniya, W.P.N. Perera, M.S.J. Perera, R.K. Rodrigo, V.A.M.P.K. Samarawickrema & T.N. Peiris (2005). A Biodiversity Status Profile of Lunama - Kalametiya Wetland Sanctuary. *Occassional Paper*. 8. IUCN, Sri Lanka., iv–43.

Ferreira, W.L.S., L.C. da Rosa & C.E. Bemvenuti (2005). Effects of the shorebirds predation on the estuarine macrofauna of the Patos lagoon, south Brazil. *Thalassas. An International Journal of Marine Sciences* 21: 77–82.

Grebner, D.L., P. Bettinger & J.P. Siry (2013). Forest Measurements and Forestry-Related Data. *Introduction to Forestry and Natural Resources* 2013: 191–220. https://doi.org/10.1016/B978-0-12-386901-2.00008-7

Green, M.J.B. (1990). IUCN Directory of South Asian Protected Areas. IUCN – The World Conservation Union. http://www.archive.org/details/iucndirectoryofs90gree

Gunatilleke, N., R. Pethiyagoda & S. Gunatilleke (2017). Biodiversity of Sri Lanka. *Journal of the National Science Foundation of Sri Lanka* 36: 25. https://doi.org/10.4038/jnsfsr.v36i0.8047

Harrison, J. & T. Worfolk (2011). *A Field Guide to the Birds of Sri Lanka* (2). Oxford University Press, New York, 224 pp.

Hart, J.D., T.P. Milsom, A. Baxter, P.F. Kelly & W.K. Parkin (2002). The impact of livestock on Lapwing *Vanellus vanellus* breeding densities and performance on coastal grazing marsh. *Bird Study* 49(1): 67–78

Hayman, P.J., J.H. Marchant & A.J. Prater (2011). *Shorebirds: An identification guide to the waders of the world*. Christopher Helm Publishers, London, 17–202 pp.

Jayathilake, M.B. & W.U. Chandrasekara (2015). Variation of avifaunal diversity in relation to land-use modifications around a tropical estuary, the Negombo estuary in Sri Lanka. *Journal of Asia-Pacific Biodiversity* 8(1): 72–82. https://doi.org/10.1016/j.japb.2015.02.001

Jayatissa, L.P., M.C. Guero, S. Hettiarachchi & N. Koedam (2002). Changes in vegetation cover and socio-economic transitions in a coastal lagoon (Kalametiya, Sri Lanka), as observed by teledetection and ground truthing, can be attributed to an upstream irrigation scheme. *Environment, Development and Sustainability* 4(2): 167–183. https://doi.org/10.1023/A:1020831416827

Jumilawaty, E., A.L.A. Nasution & S. Siregar (2022). Shorebird community and diversity in Bagan Serdang Beach, North Sumatra. IOP Conference Series: *Earth and Environmental Science* 1115: 012001. https://doi.org/10.1088/1755-1315/1115/1/012001

Kaliraj, S., N. Chandrasekar, K.K. Ramachandran, Y. Srinivas & S. Saravanan (2017). Coastal landuse and land cover change and transformations of Kanyakumari coast, India using remote sensing and GIS. *Egyptian Journal of Remote Sensing and Space Science* 20(2): 169–185. https://doi.org/10.1016/j.ejrs.2017.04.003

Kodikara, K.A.S., T. Hoessein, P.M.C.S. De Silva, P. Ranasinghe, H.P.P.S. Somasiri, S.K. Madarasinghe, D.U.V. Gunathilaka, D. Ranawaka, M. Danaee, J. Andrieu & F. Dahdouh-Guebas (2023). Spatial distribution of heavy metals in surface sediments of the Kalametiya Lagoon in southern Sri Lanka: Insights into the pollution status and socio-economic interactions. *Journal of the National Science Foundation of Sri Lanka* 51(3): 387–397. https://doi.org/10.4038/jnsfsr.v51i3.11193

Kotagama, S., M. Bellio & K. Dayananda (2006). Pioneering shorebird research in Sri Lanka: launch of the National Bird Ringing Programme. *Bulletin Wader Study Group* 109: 106–110.

Luna, Á., J. Gil-Delgado & E. Bernat-Ponce (2022). Plastic Debris in Nests of Two Water Bird Species Breeding on Inland Saline Lakes in a Mediterranean Biosphere Reserve. *Animals* 12(22): 3222. https://doi.org/10.3390/ani12223222

Madarasinghe, S.K., K.K.A.S. Yapa, B. Satyanarayana, P.M.P. Udayakantha, S. Kodikara & L.P. Jayatissa (2020a). Inland Irrigation Project Causes Disappearance of Coastal Lagoon: The Trajectory of Kalametiya Lagoon, Sri Lanka from 1956 to 2016. *Coastal Management* 48(3): 188–209. https://doi.org/10.1080/08920753.2020.1747914

Madarasinghe, S.K., Y.W.P. Amarasinghe, C.H. Liyanage, H.M.S.A.T. Gunathilake, J.A.I.K. Jayasingha, M. Jayasingha, W.K.L. Priyankara, K.A.S. Kodikara, N. Koedam, F. Dahdouh-Guebas & L.P. Jayatissa (2020b). Retrospective study on changes in Dondra lagoon (2006–2017) resulting from tsunami impact and post-tsunami development. *Journal of Coastal Conservation* 24: 58. https://doi.org/10.1007/s11852-020-00777-1

Mundkur, T. & R. Selvaraj (2023). Central Asian Flyway – Situation Analysis: The status of migratory birds and their habitats and recommendations for their conservation, 67 pp. https://doi.org/10.13140/RG.2.2.32281.80480

Myers, J., R. Morrison, P. Antas, B. Harrington, T.E. Lovejoy, M. Sallaberry, S. Senner & A. Tarak (1987). Conservation strategy for migratory species. *American Scientist* 75: 19–26

Newton, A., A.C. Brito, J.D. Icely, V. Derolez, I. Clara, S. Angus, G. Schernewski, M. Inácio, A.I. Lillebø, A.I. Sousa, B. Béjaoui, C. Solidoro, M. Tosic, M. Cañedo-Argüelles, M. Yamamuro, S. Reizopoulou, H. Tseng, D. Canu, L. Roselli & V. Khokhlov (2018). Assessing, quantifying and valuing the ecosystem services of coastal lagoons. *Journal for Nature Conservation* 44: 50–65. https://doi.org/10.1016/j.jnc.2018.02.009

Ntongani, W.A. & S.M. Andrew (2013). Bird species composition and diversity in habitats with different disturbance histories at Kilombero Wetland, Tanzania. *Open Journal of Ecology* 03(07): 482–488. https://doi.org/10.4236/oje.2013.37056

Pantazi, X.E., D. Moshou & D. Bochtis (2020). Utilization of multisensors and data fusion in precision agriculture. *Intelligent Data Mining and Fusion Systems in Agriculture* 2020: 103–173. https://doi.org/10.1016/B978-0-12-814391-9.00003-0

Pearce-Higgins, J.W., D.J. Brown, D.J.T. Douglas, J.A. Alves, M. Bellio, P. Bocher, G.M. Buchanan, R.P. Clay, J. Conklin, N. Crockford, P. Dann, J. Elts, C. Friis, R.A. Fuller, J.A. Gill, K. Gosbell, J.A. Johnson, R. Marquez-Ferrando, J.A. Masero & Y.I. Verkuil (2017). A global threats overview for Numeniini populations: Synthesising expert knowledge for a group of declining migratory birds. *Bird Conservation International* 27(1): 6–34. https://doi.org/10.1017/S0959270916000678

Perera, W.P.N., M.S.J. Perera, R. Rodrigo, N. Peiris, V.A.M.P.K. Samarawickrema, S.P. Ekanayake & C.N.B. Bambaradeniya (2013). An assessment of biodiversity in the Rekawa, Ussangoda and Kalametiya inland coastal ecosystems in southern Sri Lanka. Proceedings of International Forestry and Environment Symposium, 41 pp. https://doi.org/10.31357/fesympo.v0i0.1519

Pérez-Ruzafa, A., C. Marcos, I.M. Pérez-Ruzafa & M. Pérez-Marcos (2011). Coastal lagoons: "transitional ecosystems" between transitional and coastal waters. *Journal of Coastal Conservation*

15(3): 369–392. https://doi.org/10.1007/s11852-010-0095-2

Secretariat, B., S. Dayananda, S. Fernando, T. Herath, N. Perera, S. Perera, S. Seneviratne, A. Sumanapala, S. Wickramasinghe & D. Weerakoon (2022). *The National Red List: Conservation Status of Birds of Sri Lanka*. Biodiversity Secretariat Ministry of Environment, Sri Lanka, viii + 476 pp.

Skagen, S.K. & F.L. Knopf (1994). Wilson Ornithological Society Migrating Shorebirds and Habitat Dynamics at a Prairie Wetland Complex. *The Wilson Bulletin* 106(1): 91–105.

Sutherland, W.J., J.A. Alves, T. Amano, C.H. Chang, N.C. Davidson, C.M. Finlayson, J.A. Gill, R.E. Gill, P.M González, T.G. Gunnarsson, D. Kleijn, C.J. Spray, T. Székely & D.B.A. Thompson (2012). A horizon scanning assessment of current and potential future threats to migratory shorebirds. *Ibis* 154(4): 663–679. https://doi.org/10.1111/j.1474-919X.2012.01261

Thomas, G.H., M.A. Wills & T. Székely (2004). A supertree approach to shorebird phylogeny. *BMC Evolutionary Biology* 4: 28. https://doi.org/10.1186/1471-2148-4-28

Vivekananda, G.N., R. Swathi & A.V.L.N. Sujith (2021). Multi-temporal image analysis for LULC classification and change detection. *European Journal of Remote Sensing* 54(2): 189–199. https://doi.org/10.1080/22797254.2020.1771215

Warnock, N. & M. Bishop (1998). Spring stopover ecology of migrant Western Sandpipers. *The Condor* 100: 456–467. https://doi.org/10.2307/1369711

Zwarts, L. & J. Wanink (1993). How the food supply harvestable by waders in the Wadden Sea depends on the variation in energy density, body weight, biomass, burying depth and behaviour of tidal-flat invertebrates. *Netherlands Journal of Sea Research* 31: 441–476. https://doi.org/10.1016/0077-7579(93)90059-2

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Author contributions: All authors contributed equally to data collection, sampling and analysis, and preparing the manuscript. The maps were prepared by E G D P Jayasekara, and the photographs were taken by V N Mendis.

Acknowledgements: We acknowledge the immense support and guidance given by the Department of Wildlife Conservation Sri Lanka (Permit No: WL/3/2/42/22), Department of Zoology and Faculty of Graduate Studies of the University of Sri Jayewardenepura, and the members of the Wildlife Circle of the University of Sri Jayewardenepura to conduct this research successfully.

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.64

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Journal of Threatened Taxa

www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

July 2024 | Vol. 16 | No. 7 | Pages: 25495–25638
Date of Publication: 26 July 2024 (Online & Print)
DOI: 10.11609/jott.2024.16.7.25495-25638

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