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Avian Diversity in the Ulavaipu and Kandakadavu Mangrove Ecosystems of Central Kerala

Neena Narayanan, Latha C

PG and Research Dept. of Zoology, Fatima Mata National College, Kollam-691001. neenanarayanan84@gmail.com

PG Dept. of Zoology, Milad-E-Sherief Memorial College, Kayamkulam, Alappuzha-690502, lathacmsm@gmail.com

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KEYWORDS

Avian diversity, Ulavaipu (Inland mangroves), Kandakadavu (Saline mangroves), Biodiversity indices

ABSTRACT:

Introduction: Mangrove ecosystems, both inland and saline, play a crucial role in maintaining ecological balance and providing essential habitats for a wide variety of avifauna. These ecosystems act as breeding, feeding, and roosting grounds for both resident and migratory bird species, making them important biodiversity hotspots. Understanding the diversity and community composition of birds in these habitats helps in monitoring ecosystem health and guiding conservation efforts. The present study was conducted in two contrasting mangrove ecosystems of Central Kerala — Ulavaipu (inland mangroves) and Kandakadavu (saline mangroves) — to compare avian diversity and assess how habitat type influences species composition and community structure.

Objectives: To document the avian species richness and community composition in Ulavaipu (inland mangroves) and Kandakadavu (saline mangroves), To compare diversity indices, including Margalef Richness (DMg), Berger-Parker Dominance (d), Shannon-Wiener Index (H'), and Pielou's Evenness (J'), between the two sites and to identify the dominant avian orders and families in both ecosystems and assess seasonal variations in their occurrence.

Methods: Ulavaipu represents inland mangrove habitat, with relatively lower salinity and more freshwater influence. Kandakadavu: Represents saline mangrove habitat, influenced by tidal influx and higher salinity. The study was carried out for one year, from January to December 2023. Survey Method: Point count method was employed to record bird species and their abundance. Identification: Birds were identified using standard field guides and online databases. Diversity Analysis: The following indices were calculated to compare diversity between sites: Margalef Richness (DMg) – species richness, Berger-Parker Dominance (d) – dominance of most abundant species, Shannon-Wiener Index (H') – overall diversity and Pielou's Evenness (J') – distribution of individuals among species

Results: A total of 99 bird species were documented, belonging to 16 orders and 44 families. Passeriformes was the most dominant order, represented by 19 families and 28 species, followed by Charadriiformes, which comprised 5 families and 19 species. Diversity indices: Kandakadavu (Saline mangroves), highest Margalef Richness (9.66). Ulavaipu (Inland mangroves), highest Berger-Parker Dominance (0.13), Shannon-Wiener Index (3.50), and Pielou's Evenness (0.81). These results indicate that while Kandakadavu had a higher species richness, Ulavaipu had a more evenly distributed and diverse bird community.

Conclusions: The comparative assessment highlights the ecological significance of both inland and saline mangrove ecosystems as vital habitats for avifauna in Central Kerala. Kandakadavu supported a higher number of species, reflecting its importance for species richness, whereas Ulavaipu exhibited higher diversity and evenness, suggesting a more balanced bird community. These findings underscore

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the need for site-specific conservation and habitat management strategies to protect both inland and saline mangrove ecosystems for sustaining avian biodiversity.

1. Introduction

Mangrove forests serve as critical habitats for a diverse array of organisms, including numerous species of waterbirds (Andrimida *et al*., 2024). These unique ecosystems are crucial for sustaining coastal biodiversity by offering essential resources such as nesting grounds, shelter, and plentiful food (Christy N. *et al*., 2025). Birds such as both terrestrial and waterbirds are among the most commonly observed fauna in mangrove ecosystems and serve as reliable bioindicators of ecological change (Novita *et al.*, 2025). Given their role as indicators of wetland health, the conservation of bird communities has gained critical importance (Rahman *et al*., 2025). In this context, protected mangrove areas have become vital for biodiversity conservation, ensuring the survival of diverse bird species despite increasing human pressures (Qiu *et al.*, 2024). Given the ongoing threats such as deforestation, urban expansion, intensified horticulture, and the development of monoculture plantations (Mohd-Taib *et al*., 2020), along with continued land-use changes and sea-level rise, conserving and restoring mangrove habitats has become more critical than ever (Rahim *et al.*, 2024). The aim of the study was to assess the avian diversity in the Ulavaipu (inland mangroves) and Kandakadavu (saline mangroves) regions of Central Kerala during the period January to December 2023. The objective was to document the avian diversity in inland (Ulavaipu) and saline (Kandakadavu) mangrove ecosystems and to evaluate the ecological significance of these mangrove habitats for resident and migratory bird communities.

2. Objectives

The present study was designed with the following specific objectives:

1. To document avian species composition: Prepare a comprehensive checklist of bird species occurring in Ulavaipu (inland mangroves) and Kandakadavu (saline mangroves). Classify the recorded birds into orders, families, and guilds (resident/migratory, waders/waterbirds/terrestrial species).

2. To assess species richness and diversity patterns: Calculate species richness and compare it between the two sites using Margalef Richness Index (DMg). Estimate species dominance and community heterogeneity using Berger-Parker Dominance Index (d) and Shannon-Wiener Index (H').

3. To evaluate community evenness: Determine how evenly individuals are distributed among the recorded species using Pielou's Evenness Index (J'). Identify whether either site is dominated by a few abundant species or supports a balanced community.

4. To compare inland and saline mangrove ecosystems: Statistically compare diversity indices between Ulavaipu and Kandakadavu to identify significant differences.

5. To highlight dominant avian groups: Identify the most dominant avian orders and families contributing to species diversity..

3. Materials and Methods

Study Area

Study area selected are, Ulavaipu (Inland mangroves; Alappuzha District) and Kandakadavu (Saline mangroves; Ernakulam District), located in Central Kerala, India.

Ulavaipu (Inland mangroves):

Ulavaipu (Lat: 9°48'3.37" N; Long: 76°19'51.62" E) is a small village situated in the northern part of Thaikattussery Panchayath, Cherthala Taluk, Alappuzha District, Kerala.

Kandakadavu (Saline mangroves):

Kandakadavu (Lat: 9°51'35.96" N; Long: 76°16'40.93" E) is a village located within the Palluruthy Block of Ernakulam District, Kerala. It falls under the jurisdiction of Palluruthy Panchayath and belongs to the Central Kerala Division.

Methodology

Sampling and Observation of Birds

A systematic sampling of bird species was carried out from January to December 2023, primarily during the morning hours between 6:00 AM and 10:00 AM as per Verner and Ritter (1986). Bird sampling was conducted using the point count method as described by Ralph *et al.*

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(1995) to perform monthly surveys of bird species across the selected ecosystems. This method was employed to document bird species richness and abundance, and to assess bird diversity, including both resident and migratory species (Hamel *et al*., 1996). Each sampling, Inland and Saline Mangrove ecosystems included six sampling points, with each point having a 50m-meter radius were recorded over a 15-minute observation period (Pendleton, 1995). Observations at each point were carried out on only clear days as per Verner and Ritter (1986) . To avoid double counting, a 50m-meter interval between point count stations was maintained (Fuller and Langslow, 1984). Birds flying or interacting within 25 meters above the tallest vegetation or structure within the 50-meter radius were included, while high-flying birds (above this threshold) were excluded as they were considered flyovers and not directly associated with the habitat (Huff, 2000). Observations were carried out using Nikon binoculars (10x50 magnification) and all birds were morphologically documented using a Nikon Coolpix p1000 camera. Bird identification and classification were based on "**The Book of Indian Birds**" by Dr. Salim Ali (2002) and "**Birds of the Indian Subcontinent**" by Richard Grimmett (2000).

Statistical Analysis

Avian diversity across the two mangrove sites were assessed using several biodiversity indices, including the Margalef Richness Index (Margalef, 1958), Berger-Parker Dominance Index (Berger & Parker, 1970), Shannon-Wiener Diversity Index (Shannon & Weaver, 1949), and Pielou's Evenness Index (Pielou, 1969). Each of these indices provided insights into different aspects of the avian community structure, including species richness, dominance, diversity, and evenness.

4. Results

Bird species composition

This study documented 99 avian species across 16 orders and 44 families at different sites. Passeriformes was the most dominant order, comprising 19 families and 28 bird species, followed by Charadriiformes, which included 5 families and 19 species. The orders Apodiformes, Podicipediformes, Strigiformes, Psittaciformes, and Columbiformes were the least represented, each with only one species. At the Inland mangroves, 75 species belonging to 14 orders and 39 families were observed. Passeriformes was again the dominant order, with 19 families and 27 species, followed by Charadriiformes, with 5 families and 11 species. Ciconiiformes, Strigiformes, Psittaciformes,
and Columbiformes were the least represented. At the saline mangroves, 77 species belonging to 15 orders and 35 families were recorded. Passeriformes remained dominant, comprising 12 families and 19 species, followed by Pelecaniformes, with 3 families and 14 species. The least represented orders were Apodiformes, Podicipediformes, Psittaciformes, and Columbiformes, each represented by a single species. Table 1 presents the bird species observed in the Ulavaipu and Kandakadavu mangrove ecosystems from January to December 2023.

Biodiversity Indices of Ulavaipu (Inland mangroves) and Kandakadavu (Saline mangroves)

The comparative assessment of avian diversity between Ulavaipu and Kandakadavu was carried out using biodiversity indices, including Margalef Richness Index (DMg), Berger-Parker Dominance (d), Shannon-Wiener Diversity Index (H'), and Pielou's Evenness (J'). Kandakadavu (Saline mangroves) exhibited the highest Margalef richness (9.66), indicating greater species richness. In contrast, Ulavaipu (Inland mangroves) recorded the highest Berger- Parker dominance (0.13), suggesting a higher level of species dominance. Inland mangrove support diverse and evenly distributed bird assemblages. Table 2 presents the biodiversity indices across different mangrove sites.

5. Discussion

Mangrove forests offer vital ecosystem services and supporting wide range of biodiversity (Canales *et al*., 2019). Mangrove species such as *Rhizophora mangle, Bruguiera gymnorhiza,* and *Excoecaria agallocha* play a crucial ecological role in supporting avian biodiversity by offering a range of resources and habitat structures: Nesting and Roosting Sites: It provide ideal nesting and roosting platforms for birds such as herons, egrets, cormorants, and kingfishers. Nypa fruticans and low-lying shrubs also offer shelter for smaller birds like warblers and sunbirds (Baharuddin *et al*., 2024). Mangrove ecosystems support a rich food web, including fish, crabs, insects, and mollusks that attract piscivorous (fish-eating) birds like little cormorants, egrets, and darters. Flowering plants like *Thespesia populnea and Cocculus hirsutus* support insectivorous and nectar-feeding birds such as sunbirds and bulbuls. Diverse vegetation and mudflats in mangrove zones offer safe

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stopover sites for migratory waders and shorebirds such as sandpipers, redshanks, and plovers, which feed on invertebrates in tidal zones. *Acrostichum aureum* (a fern found in both sites) grows at the landward edge and offers cover for ground-nesting or insect-hunting birds. *Excoecaria agallocha* is often found along the water's edge and helps stabilize the soil, supporting wader birds that forage in shallow waters (Canales *et al*., 2019). The diverse mangrove flora in Ulavaipu and Kandakadavu creates a mosaic of microhabitats, each supporting different bird species based on their feeding habits, nesting requirements, and migration patterns. Thus, conserving these specific mangrove species is essential for maintaining healthy avian communities in these wetlands. In the present study, the mangrove species identified in Ulavaipu (Inland mangroves) included *Rhizophora mangle, Kandelia candel, Bruguiera gymnorhiza, Rhizophora apiculata,* with *Rhizophora mangle* being the most common. Other plant species observed in this area were A*crostichum aureum, Thespesia populnea, Calystegia sepium,* and *Cocculus hirsutus*. In the Kandakadavu (Saline mangroves), dominant mangrove species included *Rhizophora mangle, Bruguiera gymnorhiza, Bruguiera sexangula, Rhizophora mucronata,* and *Excoecaria agallocha* with *Bruguiera gymnorhiza* being the most prevalent. Additional plant species were *Cerebera odollam, Derris trifoliata, Acrostichum aureum,* and *Pittosporum undulatum.*

This study revealed that the order Passeriformes was the most dominant, followed by Charadriiformes. The dominance of the order Passeriformes in mangrove areas can be attributed to their high species richness, ecological adaptability, and diverse feeding habits. Passerines include a wide variety of birds such as bulbuls, sunbirds, flycatchers, and warblers, many of which are resident or migratory and well-adapted to the shrubby and forested vegetation of mangrove ecosystems. Their ability to utilize different layers of vegetation—ranging from undergrowth to canopy—along with their omnivorous and insectivorous diets, allows them to exploit a variety of food sources found in mangroves, such as insects, nectar, and fruits. The order Charadriiformes was the second most dominant, largely due to its association with intertidal and open mudflat habitats, particularly in saline mangrove areas like Kandakadavu. This order includes shorebirds such as sandpipers, plovers, and redshanks, many of which are long-distance migrants that visit these wetlands seasonally to feed on invertebrates during low tide. Since the surveys were conducted during morning low tides. when these birds are actively foraging their detectability and count were naturally higher. The least represented orders included Apodiformes, Podicipediformes, Strigiformes, Psittaciformes, and Columbiformes. Previous studies had reported varied patterns in avian community composition. For example, Charadriiformes, particularly the family Laridae were identified as the most common waterbirds in several studies. However, their abundance was comparatively lower in the Liaohe Estuary (Li *et al*., 2021). In another study, 15 bird species belonging to four orders and six families were recorded, with Charadriiformes once again emerging as the dominant order (Andrimida *et al*., 2024). In inland mangroves, a Shannon Index value of 2.08 was reported (Narayanan *et al*., 2023), while coastal mangrove forests in Situbondo Regency showed a slightly higher index of 2.19 for waterbirds (Dewi *et al*., 2022). Additionally, Miotto *et al.*, (2023) documented 41 species of Charadriiformes in the dry season and 39 in the rainy season, confirming their dominance in mangrove regions. Anthropogenic disturbances such as land-use change, deforestation, urban development, habitat loss, overfishing, pollution (including plastic and domestic waste), invasive species, and climate changes were significantly altering mangrove ecosystems (Mancini *et al*., 2023; Mohd-Taib *et al.*, 2020). Species richness, as shown in Figure 1, was higher in Kandakadavu, indicating that saline mangroves provide more favorable conditions for a broader range of bird species. This is likely due to the availability of waterlogged environments, mudflats, and open spaces, which are essential for many waterbird species. In contrast, Ulavaipu, while poor in species richness, but with higher diversity and evenness indices, suggesting a more uniform distribution of individuals across species. Figure 2 further reveals differences in avian community composition: in Ulavaipu, 56% of observed birds were terrestrial and 44% were waterbirds, whereas in Kandakadavu, waterbirds constituted 58.44% and terrestrial birds 41.56%. The higher proportion of waterbirds in Kandakadavu may be attributed to its predominantly water-covered landscape, offering favourable conditions for aquatic avifauna.

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Table 1: Observed birds from Ulavaipu (Inland mangroves) and Kandakadavu (Saline mangroves)

Sl. No.	Order & Family	Common Name	Scientific Name	IUCN Status	Presence of research location	
					Inland mangroves	Saline mangroves
1.	**Anseriformes** Anatidae	Lesser whistling duck	*Dendrocygna javanica*	LC	✓	✓
		Cotton pygmy goose	*Nettapus coromandelianus*	LC		✓
		Northern pintail	*Anas acuta*	LC	✓	✓
		Garganey	*Spatula querquedula*	LC		✓
		Indian spot-billed duck	*Anas poecilorhyncha*	LC		✓
2	**Apodiformes** Apodidae	Little swift	*Apus affinis*	LC		✓
3	**Gruiformes** Rallidae	Common moorhen	*Gallinula chloropus*	LC		✓
		Watercock	*Gallicrex cinerea*	LC	✓	
		White-breasted waterhen	*Amaurornis phoenicurus*	LC	✓	✓
		Grey-headed swamphen	*Porphyrio poliocephalus*	LC	✓	✓
		Eurasian coot	*Fulica atra*	LC		✓
4	**Podicipediformes** Podicipedidae	Little grebe	*Tachybaptus ruficollis*	LC		✓
5	**Charadriiformes** Recurvirostridae	Black-winged stilt	*Himantopus himantopus*	LC	✓	✓
	Charadriidae	Pacific golden plover	*Pluvialis fulva*	LC	✓	
		Red-wattled lapwing	*Vanellus indicus*	LC	✓	✓
	Jacanidae	Pheasant-tailed jacana	*Hydrophasianus chirurgus*	LC	✓	

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		Bronze-winged jacana	*Metopidius indicus*	LC	✓	
	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	LC	✓	✓
		Green Sandpiper	*Tringa ochropus*	LC	✓	
		Marsh Sandpiper	*Tringa stagnatilis*	LC	✓	
		Wood Sandpiper	*Tringa glareola*	LC	✓	✓
		Common greenshank	*Tringa nebularia*	LC	✓	
	Laridae	Whiskered tern	*Chlidonias hybrida*	LC	✓	✓
		Little tern	*Sternula albifrons*	LC		✓
		Common tern	*Sterna hirundo*	LC		✓
		Gull-billed tern	*Gelochelidon nilotica*	LC		✓
		Brown-headed gull	*Chroicocephalus brunnicephalus*	LC		✓
		Black-headed gull	*Chroicocephalus ridibundus*	LC		✓
		Caspian tern	*Hydroprogne caspia*	LC		✓
		Greater crested tern	*Thalasseus bergii*	LC		✓
		Lesser crested tern	*Thalasseus bengalensis*	LC		✓
6	**Ciconiiformes** Ciconiidae	Asian openbill Stork	*Anastomus oscitans*	LC	✓	✓
		Painted stork	*Mycteria leucocephala*	LC		✓
7	**Suliformes** Anhingidae	Oriental darter	*Anhinga melanogaster*	LC	✓	✓
	Phalacrocoracidae	Little cormorant	*Microcarbo*	LC	✓	✓

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			niger			
		Indian cormorant	*Phalacrocorax fuscicollis*	LC	✓	✓
8	**Pelecaniformes** Threskiornithidae	Black-headed ibis	*Threskiornis melanocephalus*	LC	✓	✓
		Glossy ibis	*Plegadis falcinellus*	LC	✓	✓
		Eurasian spoonbill	*Platalea leucorodia*	LC		✓
	Ardeidae	Little egret	*Egretta garzetta*	LC	✓	✓
		Indian pond heron	*Ardeola grayii*	LC	✓	✓
		Eastern cattle egret	*Ardea coromanda*	LC	✓	✓
		Great egret	*Ardea alba*	LC	✓	✓
		Medium egret	*Ardea intermedia*	LC	✓	✓
		Grey heron	*Ardea cinerea*	LC	✓	✓
		Purple heron	*Ardea purpurea*	LC	✓	✓
		Black bittern	*Botaurus flavicollis*	LC	✓	
		Cinnamon bittern	*Botaurus cinnamomeus*	LC		✓
		Black- crowned night heron	*Nycticorax nycticorax*	LC		✓
		Striated heron	*Butorides striata*	LC		✓
	Pelecanidae	Spot-billed pelican	*Pelecanus philippensis*	LC		✓
9	**Accipitriformes** Accipitridae	Shikra	*Tachyspiza badia*	LC	✓	
		Brahminy kite	*Haliastur indus*	LC	✓	✓
		Black kite	*Milvus migrans*	LC	✓	✓
	Pandionidae	Osprey	*Pandion haliaetus*	LC		✓
10	**Strigiformes**	Jungle owlet	*Glaucidium*	LC	✓	

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	Strigidae		*radiatum*			
11	**Coraciiformes** Meropidae	Asian green bee- eater	*Merops orientalis*	LC	✓	✓
		Blue-tailed bee- eater	*Merops philippinus*	LC	✓	✓
	Alcedinidae	Common Kingfisher	*Alcedo atthis*	LC	✓	✓
		Stork-billed Kingfisher	*Pelargopsis capensis*	LC	✓	✓
		White-throated Kingfisher	*Halcyon smyrnensis*	LC	✓	✓
12	**Piciformes** Megalaimidae	White- cheeked barbet	*Psilopogon viridis*	LC	✓	✓
		Coppersmith barbet	*Psilopogon haemacephalus*	LC		✓
	Picidae	Black-rumped flameback	*Dinopium benghalense*	LC	✓	✓
		Rufous woodpecker	*Micropternus brachyurus*	LC	✓	
13	**Psittaciformes** Psittaculidae	Rose-ringed parakeet	*Psittacula krameri*	LC	✓	✓
14	**Passeriformes** Oriolidae	Indian golden oriole	*Oriolus kundoo*	LC	✓	✓
	Artamidae	Ashy woodswallow	*Artamus fuscus*	LC	✓	
	Dicruridae	Black drongo	*Dicrurus macrocercus*	LC	✓	✓
		Greater racket-tailed drongo	*Dicrurus paradiseus*	LC	✓	✓
	Monarchidae	Indian paradise flycatcher	*Terpsiphone paradisi*	LC	✓	
	Laniidae	Brown shrike	*Lanius cristatus*	LC	✓	
	Corvidae	Rufous treepie	*Dendrocitta vagabunda*	LC	✓	✓
		House crow	*Corvus splendens*	LC	✓	✓

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		Large-billed crow	*Corvus macrorhynchos*	LC	✓	✓
	Cisticolidae	Common tailorbird	*Orthotomus sutorius*	LC	✓	✓
		Streaked fantail warbler	*Cisticola juncidis*	LC	✓	
		Ashy prinia	*Prinia socialis*	LC	✓	✓
		Plain prinia	*Prinia inornata*	LC	✓	✓
	Acrocephalidae	Blyth's reed warbler	*Acrocephalus dumetorum*	LC	✓	✓
		Clamorous reed warbleree	*Acrocephalus stentoreus*	LC	✓	✓
	Hirundinidae	Barn swallow	*Hirundo rustica*	LC	✓	✓
	Pycnonotidae	Red-whiskered bulbul	*Pycnonotus jocosus*	LC	✓	
		Red-vented bulbul	*Pycnonotus cafer*	LC	✓	✓
	Leiothrichidae	Jungle babbler	*Argya striata*	LC	✓	
	Sturnidae	Common myna	*Acridotheres tristis*	LC	✓	✓
	Muscicapidae	Oriental magpie-robin	*Copsychus saularis*	LC	✓	✓
	Dicaeidae	Pale-billed flowerpecker	*Dicaeum erythrorhynchos*	LC	✓	✓
	Nectariniidae	Purple rumped sunbird	*Leptocoma zeylonica*	LC	✓	✓
		Loten's sunbird	*Cinnyris lotenius*	LC	✓	✓
	Estrildidae	White-rumped munia	*Lonchura striata*	LC	✓	
	Motacillidae	Western yellow wagtail	*Motacilla flava*	LC	✓	
	Artamidae	Ashy woodswallow	*Artamus fuscus*	LC		✓
	Ploceidae	Baya weaver	*Ploceus philippinus*	LC	✓	

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15	**Cuculiformes** Cuculidae	Pied cuckoo	*Clamator jacobinus*	LC	✓	
		Greater coucal	*Centropus sinensis*	LC	✓	✓
		Asian koel	*Eudynamys scolopaceus*	LC	✓	✓
		Common hawk-cuckoo	*Hierococcyx varius*	LC	✓	
16	**Columbiformes** Columbidae	Rock pigeon	*Columba livia*	LC	✓	✓

Table 2 summarizes the biodiversity Indices recorded at the various mangrove sites.

Mangrove sites	Margalef Richness (DMg)	Berger-Parker Dominance (d)	Shannon- Wiener Index (H')	Pielou's Evenness (J')
Ulavaipu (Inland mangroves)	9.26	0.13	3.50	0.81
Kandakadavu (Saline mangroves)	9.66	0.12	3.45	0.79

Fig. 1. Species richness at Ulavaipu (Inland mangrove) and Kandakadavu (Saline mangrove)

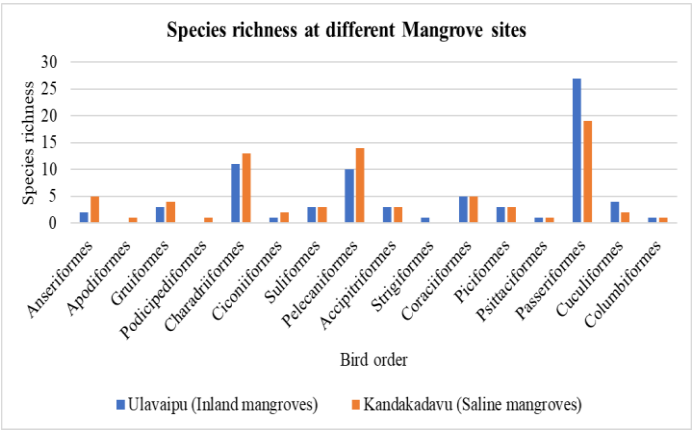

Fig. 2. Abundance of terrestrial and waterbird species at Ulavaipu (Inland mangrove) and Kandakadavu (Saline mangrove)