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continued on the back inside cover

Cover: Watercolour illustrations—Striped Tiger *Danaus genutia*, Common Silverline *Cigaritis vulcanus*, Tamil Lacewing *Cethosia mahratta*. © Mayur Nandikar.

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ARTICLE

Declining trends of over-summering shorebird populations along the southeastern coasts of Tamil Nadu, India

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Abstract: Over-summering of shorebirds refers to the phenomenon where certain species of shorebirds, primarily migratory, remain on their non-breeding grounds during the summer months for one or more years instead of migrating to their breeding grounds. The present study investigates the presence and abundance of over-summering shorebird species at four distinct sites covering 24 scanning points along the southeastern coasts of Tamil Nadu for 2017–2023. A total of 13 species were observed over-summering, with Lesser Sand Plover being the most dominant species, followed by Greater Sand Plover. Notably, 10 species were found across all four sites, while three species—Black-tailed Godwit, Bar-tailed Godwit, and Common Sandpiper—were exclusive to Dhanushkodi Lagoon, observed only during 2023. The study examined the year-wise abundance of these species, revealing a decline in over-summering shorebirds across all study sites. The Eurasian Curlew, Curlew Sandpiper, Bar-tailed & Black-tailed Godwits are the 'Near Threatened' species observed during the study. Furthermore, the research highlighted variations in Shannon species diversity index (H) location-wise and year-wise – Manoli Island (H = 2.25) in 2023; Dhanushkodi Lagoon (H = 1.8) in 2023; Valinokkam Lagoon (H = 1.63), and Pillaimadam Lagoon (H = 2.08) in 2017. Key findings are that among the study sites, in Pillaimadam Lagoon all 10 species' abundance declined; in Valinokkam Lagoon, Greater Sand Plover and Little Stint marginally increased, and eight species declined; Common Redshank and Ruddy Turnstone marginally increased in Manoli Island, while other eight species declined; Grey Plover population increased in Dhanushkodi Lagoon along with a marginal decrease in Common Redshank and Ruddy Turnstone as other species declined, over the years of study.

Keywords: Abundance, avian ecology, breeding patterns, coastal wetlands, conservation strategies, habitat degradation, monitoring, population dynamics, shorebird migration, species diversity.

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Competing interests: The authors declare no competing interests.

Author details: Byju H., has worked on the shorebirds and waterbirds in the Gulf of Mannar region for a decade and at present a member of the biodiversity panel of five bird sanctuaries including two Ramsar sites and the Gulf of Mannar Biosphere Reserve. Maitreyi H. is a research assistant working on seabirds in the region. Raveendran N. is a naturalist with a decade of experience in birds and awareness education and serves as a biodiversity member in the bird sanctuaries and Gulf of Mannar Biosphere Reserve. Ravichandran S. is a professor with three decades of experience in marine ecology.

Author contributions: BH—conceptualization, design of work, writing, and editing; MH—data curation, analysis, mapping, and writing; RN—data compilation, writing; SR—writing.

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INTRODUCTION

Few species of long-distance migratory shorebirds tend to remain on the non-breeding grounds during the summer months, forgoing migration during the breeding season. This phenomenon is called over-summering (Cramp et al. 1985; Soto-Montoya et al. 2009) mostly influenced by environmental, physiological, and ecological factors. One of the major reasons that is attributed to these over-summering individuals is that they are either sexually immature birds (McNeil et al. 1994; Soto-Montoya et al. 2009) or avoid the risks of migration (McNeil et al. 1994; Vieira 2016). Compared to various shorebird ecological studies done across the globe, this strategy is an aspect least studied (Gutierrez 2017; Martínez-Curci et.al. 2020). The over-summering phenomenon is common in the families of Charadriidae and Scolopacidae (McNeil et al. 1994) and is documented in 15 other bird groups.

Of the 70 species of shorebirds recorded in India, 49 are migrants (Howes & Bakewell 1989). A few studies have been undertaken on the western Indian coast (Aarif et al. 2020; Anand et al. 2023; Shifa 2023) and the eastern coast (Balachandran 2006; Sandilyan et al. 2010; Byju et al. 2023a,b). Twenty shorebird species are found to over-summer in the eastern coast of India. The details are as follows: from Chilika Lake, Odisha, a few individuals of Grey Plover *Pluvialis squatarola*, Lesser Sand Plover *Charadrius mongolus*, Black-tailed Godwit *Limosa limosa*, Eurasian Curlew *Numenius arquata*, and Curlew Sandpiper *Calidris ferruginea*, in partial breeding, and some first-year birds are in nonbreeding plumage over-summering (Balachandran et al. 2009). Furthermore, from Point Calimere, Tamil Nadu, Grey Plover, Lesser Sand Plover, Whimbrel *Numenius phaeopus*, Eurasian Curlew, Common Greenshank *Tringa nebularia*, Terek Sandpiper *Xenus cinereus*, Little Stint *Calidris minuta*, Curlew Sandpiper (few adults in breeding plumage), Broad-billed Sandpiper *Limicola falcinellus*, and Ruff *Calidris pugnax* were reported to over-summer (Balachandran & Thirunavukarasu 2009). Balachandran (2006) listed the over-summering shorebirds from Pulicat Lake, Andhra Pradesh that included Pacific Golden Plover *Pluvialis fulva*, Black-tailed Godwit, Marsh Sandpiper *Tringa stagnatilis*, Common Sandpiper *Actitis hypoleucos*, Little Stint, and Ruff. In Gulf of Mannar, Tamil Nadu, Daniel et al. (2007) recorded that Bar-tailed Godwit *Limosa lapponica*, Grey Plover, Lesser Sand Plover, Greater Sand Plover *Charadrius leschenaultii*, Crab Plover *Dromas ardeola*, Whimbrel, Eurasian Curlew, Common Greenshank *Tringa nebularia*, Common Redshank *Tringa totanus*, Curlew Sandpiper, Little Stint, and Ruddy Turnstone *Arenaria interpres* were the shorebirds that were over-summering.

The survival of migratory birds is increasingly threatened by the over-exploitation of natural resources and associated development pressures. Factors such as habitat loss, degradation, pollution, illegal hunting and trade, poisoning, electrocution, and collisions with energy infrastructure pose significant risks to these birds. Global assessments highlighted the loss of habitats and the growing impacts of climate change on the economies and biodiversity of the Central Asian Flyway (CAF) (Mundkur et al. 2023). Shorebird abundance along the Indian coast is experiencing a tremendous decline due to several environmental and anthropogenic issues (Sandiliyan et al. 2010; Byju et al. 2023c). Understanding shorebird presence and richness is valuable information for conservation efforts (Newton 2010; Zöckler et al. 2010). The present study was conducted at four locations with good shorebird diversity: Valinokkam Lagoon with 35 shorebird species (Byju et al. 2023a), Dhanushkodi Lagoon with 32 shorebird species (Balachandran 1990), Manoli Island with 26 species (Byju et al. 2023c), and Pillaimadam Lagoon with 21 species (Balachandran 1990). The objective of the study was to document over-summering shorebird species from the mentioned different sites in the Ramanathapuram district on the southeastern coast of India and analyse the abundance pattern over the last six years.

MATERIALS AND METHODS

Study Areas

Ramanathapuram district in Tamil Nadu has five bird sanctuaries, which include two Ramsar sites and the Gulf of Mannar Biosphere Reserve (GoM), India's first Marine Biosphere Reserve. GoM is located off the southernmost tip of the country and consists of 21 islands ranging 0.2–8 km off the shore. Among the islands, most shorebird congregations are seen on Manoli Island (Byju et al. 2023c). The four study sites were selected based on the shorebird diversity in the region (Image 1). This includes: (i) Manoli Island (9.215N & 79.128E) is about 2 km long and 50 m broad, spanning an area of 25.90 ha, and contains tiny water ponds & open mudflats. The small water channels that run through the islands are surrounded by mangrove vegetation and coarse grass. The beach is sandy, and there is a lot of coral formation in the intertidal zone. The intertidal zone during the low tide served as the foraging area for the birds (Image 2);

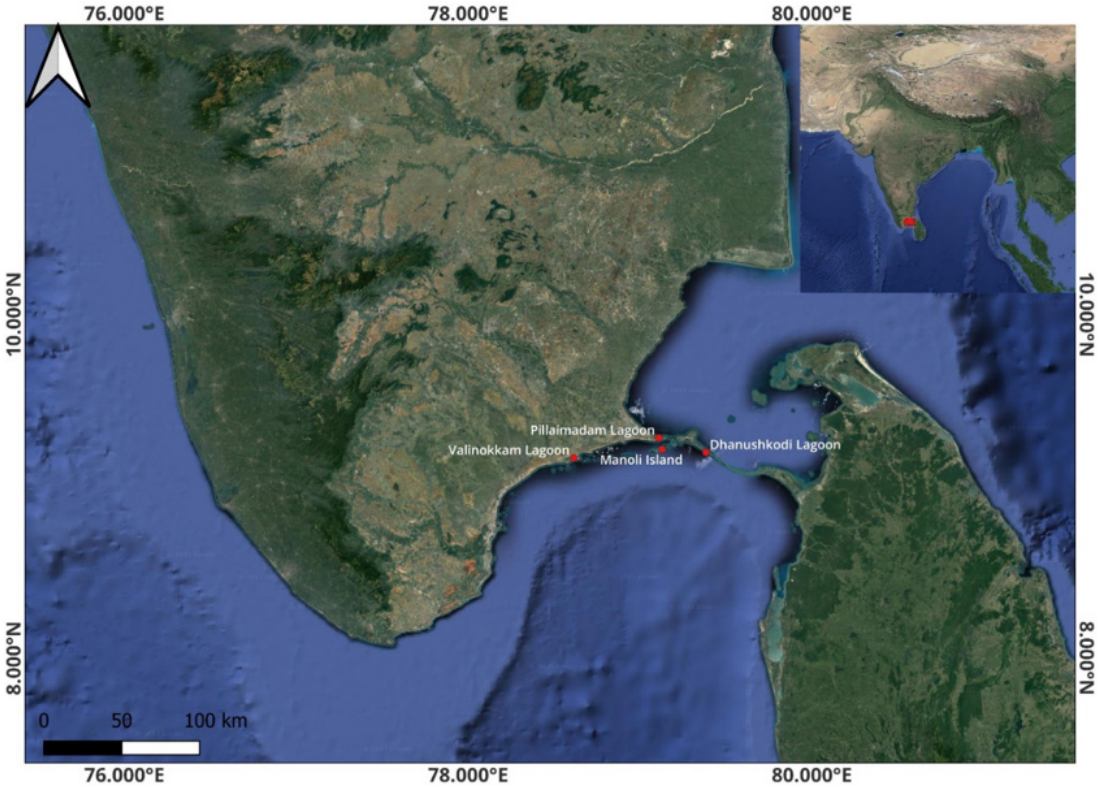

Image 1. Study areas—Pillaimadam Lagoon, Valinokkam Lagoon, Dhanushkodi Lagoon, and Manoli Island—on the southeastern coast of India.

(ii) Dhanushkodi Lagoon (9.198N & 79.383E) situated on Rameswaram Island, extends from Rameswaram Road to Arichalmunai. The total length of the lagoon is 15 km. The lagoon has mudflats and sandy areas. The width varies 0.7–1 km. The western side is mostly mudflats. The lagoon, tapering towards the eastern side, becomes an exclusive marine habitat. Most of the birds are seen mainly on the mudflats exposed after the high tides in the mid region of the lagoon (Image 3); (iii) Valinokkam Lagoon (9.166N & 78.614E) is an area with state, and private-run salt pans and prawn cultures. The excess water pumped from the sea is stored in bunds for salt extraction and pumped to form a man-made lagoon. This, over time, had developed into a mudflat. The salt pans extract salt, and seawater is pumped to the lagoon that maintains water in the artificial lagoon throughout the year. The mudflats available in the lagoon throughout the year due to the continuous pumping of water for salt extraction from the sea served as a foraging area for the birds (Image 4); and (iv) The Palk Bay bounds Pillaimadam Saltwater Lagoon (9.282N & 79.108E) near Mandapam on the north and the Rameswaram-Ramnad railroad on the south. It covers an area of about 450 ha. The lagoon is connected to Palk Bay by a bar mouth, through which it receives the tidal water. The lagoon is bordered by grassy areas on the landward side and sand dunes on the seaward site. Birds are mostly restricted to mudflat areas (Image 5).

Methods

The arrival of migratory shorebirds on the wintering grounds of southern India generally starts in August and the departure by May (Balachandran 1990; Aarif et al. 2021; Shifa 2023). The Gulf of Mannar (GoM) is a major wintering site (Balachandran 1990) on the southeastern coast, and all the locations chosen for study are either part of or near GoM. We surveyed the shorebirds once a week during the over-summering period (15 June to 31 July), based on the early literature on the arrival and departure of birds in the region (Balachandran 1990) from 2017 to 2023 by using direct visual counts (Howes & Bakewell 1989).

Observations were made using binoculars (Nikon 10*50), a camera (Canon 100–400 mm lens), and a spotting scope (Vanguard 14*70) between 06.00 h and 11.00 h at previously fixed 24 scanning points covering all four study locations at low tides. We started our count five minutes after reaching each scanning point so that the birds got acclimated to our presence at a distance varying from 100–300 m. As the bird numbers were fewer,

except for a few species, double counts were ruled out with the help of other observers. Birds were identified using field guides (Grimmett et al. 2011; Hayman et al. 2011). We calculated the population abundance of each species as mean ± standard deviation between 2017 and 2023 and for each study site. Shannon diversity Index and Menhinick's species richness Index were calculated for each site from 2017 to 2023, using PAST software (version 4.17).

RESULTS

A total of 13 over-summering species were documented from four sites along the southeastern coasts of Tamil Nadu. We observed a few shorebird species—Ruddy Turnstone, Curlew Sandpiper, Grey Plover, Lesser Sand Plover, and Greater Sand Plover—with breeding plumage and mostly others in non-breeding plumage from all four study sites. Out of the 13 species, 10 (Lesser Sand Plover, Greater Sand Plover, Grey Plover, Whimbrel, Eurasian Curlew, Common Greenshank, Common Redshank, Little Stint, and Ruddy Turnstone) were documented from all four sites. Meanwhile, three species—Black-tailed Godwit, Bar-tailed Godwit, and Common Sandpiper—were recorded only from the Dhanushkodi Lagoon, in 2023. The year-wise abundance (2017–2023) expressed as mean ± standard deviation, of all over-summering species in each study site, is provided in Tables 1–4. The dominant over-summering species observed from all four sites was Lesser Sand Plover followed by Greater Sand Plover. Lesser Sand Plover was more abundant in Valinokkam and Dhanushkodi, whereas Greater Sand Plover was highest in Valinokkam and Pillaimadam.

The over-summering species richness and diversity across all the years at each of the four study sites are summarized in Table 5. A higher value of the Shannon Index (H) indicates greater diversity in the community. Among the four sites, the highest species diversity was observed in Manoli in 2023 (H = 2.25). In contrast, 2020 and 2021 were marked by low diversity values across all the sites. The highest diversity values were recorded in Dhanushkodi (H = 1.8) in 2023, and in Manoli in 2023 (H = 2.2), whereas in Valinokkam and Pillaimadam the highest diversity was recorded in 2017, with an H index of 1.63 and 2.08, respectively. Notably, the diversity index for Pillaimadam remained stable until 2022 but experienced a significant decline in 2023. Menhinick's index, which emphasizes species richness, also indicated that 2023 was a peak year for over-summering species richness across all sites. Manoli recorded the highest value (0.8), followed by Pillaimadam and Dhanushkodi (0.6), and Valinokkam recorded the lowest value (0.5).

Species trends also varied among sites and years of the study. In Valinokkam, eight over-summering species declined over the study period as shown in Figure 1. However, there was a marginal increase in the populations of Greater Sand Plover (Figure 6) and Little Stint (Figure 13). In Pillaimadam, all over-summering species experienced a drastic reduction throughout the study period (Figure 2). On Manoli Island, two species, Ruddy Turnstone (Figure 11) and Common Redshank (Figure 14) showed a marginal decline, while the decline in other over-summering species was more pronounced (Figure 3). In Dhanushkodi Lagoon (Figure 4), the Grey Plover population increased (Figure 5), while Common Redshank (Figure 11) and Ruddy Turnstone (Figure 14) showed marginal reductions. Notably, three new species—Bar-tailed Godwit (Figure 15), Black-tailed Godwit (Figure 16), and Common Sandpiper (Figure 17)—were recorded in 2023.

Table 1. Abundance of over-summering shorebirds documented in Valinokkam Lagoon (mean ± SD).

Common name	2017	2018	2019	2020	2021	2022	2023
Grey Plover	33 ± 5.66	29 ± 7.07	27.5 ± 9.19	24 ± 9.89	19 ± 9.89	15.5 ± 3.53	5 ± 1.41
Greater Sand Plover	40.5 ± 6.36	42 ± 12.73	34 ± 9.89	36 ± 16.97	18 ± 8.48	23.5 ± 2.12	45 ± 7.071
Lesser Sand Plover	269 ± 72.12	261 ± 70.71	260 ± 66.46	251 ± 70.71	250 ± 70.711	147 ± 35.35	65 ± 49.49
Whimbrel	29 ± 2.83	24.5 ± 0.71	22.5 ± 2.12	19 ± 2.82	15.5 ± 2.12	11 ± 0	1 ± 0
Eurasian Curlew	15 ± 1.41	14.5 ± 0.71	11.5 ± 0.70	10.5 ± 0.7	8.5 ± 2.12	5 ± 0	1 ± 0
Common Greenshank	12.5 ± 0.71	11.5 ± 0.71	10.5 ± 0.70	10 ± 0	5.5 ± 0.7	4.5 ± 0.7	2 ± 0
Common Redshank	17.5 ± 7.78	19.5 ± 12.02	17 ± 9.89	14.5 ± 9.19	13 ± 9.89	8 ± 5.65	11 ± 1.41
Curlew Sandpiper	15.5 ± 4.95	12 ± 1.41	10.5 ± 0.70	10 ± 2.82	9 ± 1.41	5.5 ± 0.7	1 ± 0
Little Stint	16 ± 4.24	14.5 ± 3.54	13.5 ± 3.53	12 ± 2.82	9 ± 5.65	7.5 ± 4.94	25 ± 9.89
Ruddy Turnstone	38.5 ± 9.19	36 ± 8.49	30.5 ± 7.77	24 ± 4.24	18.5 ± 4.94	17 ± 1.41	2 ± 0

Table 2. Abundance of over-summering shorebirds documented in Pillaimadam Lagoon (mean ± SD).

Common name	2017	2018	2019	2020	2021	2022	2023
Grey Plover	20 ± 1.41	19.5 ± 7.78	15 ± 1.41	12 ± 0	11.5±0.71	10.5 ± 0.71	1.5 ± 0.71
Greater Sand Plover	49 ± 9.9	38.5 ± 2.12	31 ± 0	26.5±0.71	22.5 ± 2.12	15.5 ± 0.71	0
Lesser Sand Plover	97 ± 0	90 ± 1.41	89 ± 11.31	79.5 ± 2.12	77 ± 1.41	56 ± 22.63	7.5 ± 10.61
Whimbrel	40 ± 2.83	36.5 ± 6.36	31.5 ± 6.36	24.5 ± 4.95	21.5 ± 0.71	15.5 ± 0.71	0
Eurasian Curlew	20 ± 2.83	15 ± 1.41	13 ± 1.41	13.5 ± 4.95	9.5 ± 2.12	11 ± 1.41	1.5 ± 0.71
Common Greenshank	13 ± 1.41	12 ± 1.41	11 ± 0	10 ± 0	9 ± 2.83	5 ± 0	2.5 ± 3.54
Common Redshank	14.5 ± 2.12	12.5 ± 2.12	11 ± 1.41	9 ± 2.83	9 ± 1.41	8 ± 0	2 ± 0
Curlew Sandpiper	19.5 ± 3.54	17.5 ± 4.95	9 ± 5.66	14 ± 2.83	11.5 ± 0.71	10.5 ± 0.71	0
Little Stint	9.5 ± 0.71	9.5 ± 2.12	11.5 ± 0.71	9 ± 5.66	8.5 ± 3.54	13 ± 8.49	0
Ruddy Turnstone	24.5 ± 3.54	21.5 ± 2.12	18.5 ± 3.54	15 ± 2.83	12.5 ± 2.12	11.5 ± 0.71	0.5 ± 0.71

Table 3. Abundance of over-summering shorebirds documented in Manoli Island (mean ± SD).

Common name	2017	2018	2019	2020	2021	2022	2023
Grey Plover	28.5 ± 6.36	23.5 ± 3.54	15 ± 1.41	11.5 ± 0.71	10 ± 0	9.5 ± 2.12	9 ± 1.41
Greater Sand Plover	23 ± 4.24	18 ± 5.66	17 ± 5.66	13 ± 2.83	10.5 ± 0.71	10 ± 2.83	10 ± 0
Lesser Sand Plover	83 ± 4.24	83 ± 4.24	74 ± 2.83	70 ± 2.83	61 ± 0	57.5 ± 0.71	40 ± 0
Whimbrel	30 ± 4.24	22.5 ± 2.12	15.5 ± 0.71	11.5 ± 0.71	10.5 ± 0.71	11.5 ± 2.12	6 ± 0
Eurasian Curlew	20 ± 4.24	15 ± 4.24	12 ± 1.41	12.5 ± 2.12	13.5 ± 2.12	10 ± 4.24	4.5 ± 0.71
Common Greenshank	21 ± 4.24	18.5 ± 3.54	15 ± 1.41	13.5 ± 0.71	11 ± 0	8.5 ± 2.12	5.5 ± 0.71
Common Redshank	17 ± 1.41	14.5 ± 0.71	11.5 ± 0.71	12 ± 1.41	10.5 ± 0.71	9 ± 2.83	11 ± 1.41
Curlew Sandpiper	20 ± 8.49	19.5 ± 2.12	14 ± 2.83	12 ± 1.41	10.5 ± 0.71	7 ± 1.41	4 ± 0
Little Stint	14 ± 2.83	11 ± 1.41	12 ± 1.41	10.5 ± 0.71	10 ± 0	8 ± 1.41	5.5 ± 0.71
Ruddy Turnstone	20 ± 0	20 ± 0	15 ± 1.41	13.5 ± 2.12	12 ± 1.41	11 ± 0	13.5 ± 2.12

Table 4. Abundance of over-summering shorebirds documented in Dhanushkodi Lagoon (mean ± SD).

Common name	2017	2018	2019	2020	2021	2022	2023
Grey Plover	16 ± 1.41	13.5 ± 4.95	11.5 ± 0.71	10.5 ± 0.71	10 ± 8.49	8.5 ± 7.78	30 ± 14.14
Greater Sand Plover	27.5 ± 7.78	18.5 ± 3.54	20 ± 7.07	14.5 ± 0.71	14.5 ± 4.95	11.5 ± 2.12	8 ± 4.24
Lesser Sand Plover	270 ± 282.84	251 ± 284.26	225.5 ± 246.78	241.5 ± 282.14	243 ± 134.35	131.5 ± 72.83	83 ± 80.61
Whimbrel	29 ± 5.66	26.5 ± 7.78	15 ± 0	13 ± 1.41	11 ± 0	9 ± 1.41	8 ± 0
Eurasian Curlew	14.5 ± 0.71	11 ± 1.41	11.5 ± 0.71	10 ± 0	9.5 ± 2.12	8.5 ± 0.71	2.5 ± 0.71
Common Greenshank	13.5 ± 0.71	13 ± 1.41	11 ± 0	10 ± 0	7.5 ± 0.71	5 ± 0	5.5 ± 7.78
Common Redshank	45.5 ± 43.13	17 ± 4.24	13 ± 2.83	14 ± 2.83	25 ± 9.9	10 ± 5.66	33 ± 12.73
Curlew Sandpiper	55.5 ± 13.44	50 ± 14.14	44 ± 14.14	38 ± 9.9	29 ± 4.24	18 ± 2.83	11.5 ± 4.95
Little Stint	28 ± 11.31	26 ± 1.41	21 ± 0	16.5 ± 0.71	13 ± 0	11 ± 0	0
Ruddy Turnstone	22 ± 9.9	20 ± 9.9	13 ± 0	11.5 ± 0.71	17 ± 12.73	25.5 ± 23.33	10 ± 5.66
Bar-tailed Godwit	0	0	0	0	0	0	1.5 ± 0.71
Black-tailed Godwit	0	0	0	0	0	0	2 ± 0
Common Sandpiper	0	0	0	0	0	0	0.5 ± 0.71

Table 5. Over-summering shorebird species diversity and richness in all four sites from 2017 to 2023.

Study sites	Year	2017	2018	2019	2020	2021	2022	2023
Valinokkam	Shannon index	1.634	1.608	1.533	1.489	1.304	1.497	1.531
	Menhinick index	0.321	0.328	0.338	0.349	0.370	0.452	0.563
Pillaimadam	Shannon index	2.088	2.065	2.048	2.046	2.049	2.04	0.7285
	Menhinick index	0.4131	0.434	0.4709	0.4957	0.5322	0.5625	0.6124
Manoli	Shannon index	2.092	2.06	1.975	1.966	1.929	2.004	2.259
	Menhinick index	0.4149	0.445	0.4811	0.5137	0.5338	0.5965	0.8085
Dhanushkodi	Shannon index	1.704	1.603	1.545	1.419	1.415	1.635	1.802
	Menhinick index	0.3096	0.3346	0.3601	0.363	0.363	0.4579	0.6069

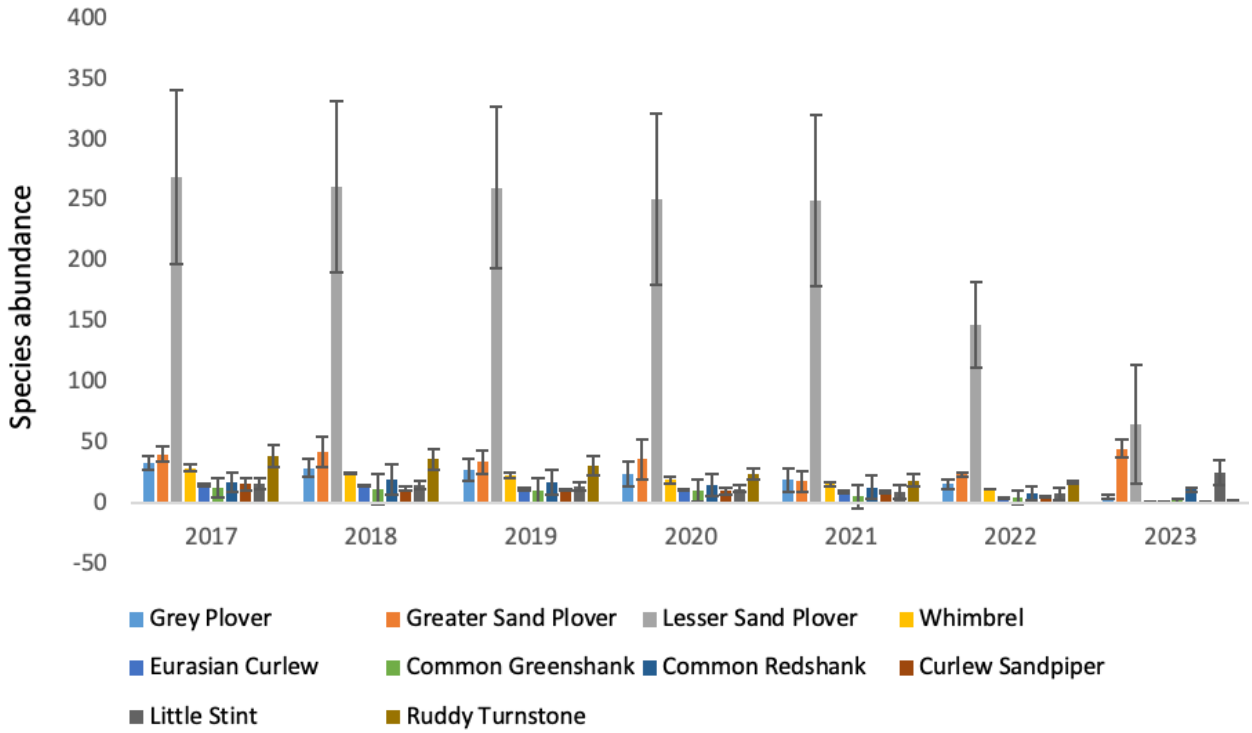

Figure 1. Abundance of over-summering shorebirds in Valinokkam Lagoon.

DISCUSSIONS

The occurrence and timely departure of shorebirds are intricately linked to the quality of stop-over and wintering sites (Smith et al. 2012). The understanding of the significance of over-summering as a life history strategy for migratory shorebirds remains limited (McNeil et al. 1994). The results of this study provide valuable insights into the species richness, diversity, and trends of over-summering shorebirds along the southeastern coasts of Tamil Nadu from 2017 to 2023. Some shorebird species, which winter in the southern hemisphere after breeding in the Arctic and northern temperate regions, exhibit delayed maturity. This delay is manifested as immatures staying on their wintering grounds in non-breeding plumage during their first breeding season, then migrating north to breed in their second or third years (Summers et al. 1995) to reduce migration risks (McNeil et al. 1994; Summers et al. 1995). We documented 13 species, with notable observations of shorebirds in breeding and non-breeding plumage. In the south-east of India, Lesser Sand Plover was the most abundant species followed by Greater Sand Plover in Point Calimere (Balachandran & Thirunavakarasu 2009), Chilika Lake (Balachandran et al. 2009), and Gulf of Mannar (Daniel et al. 2007). In our study too, these

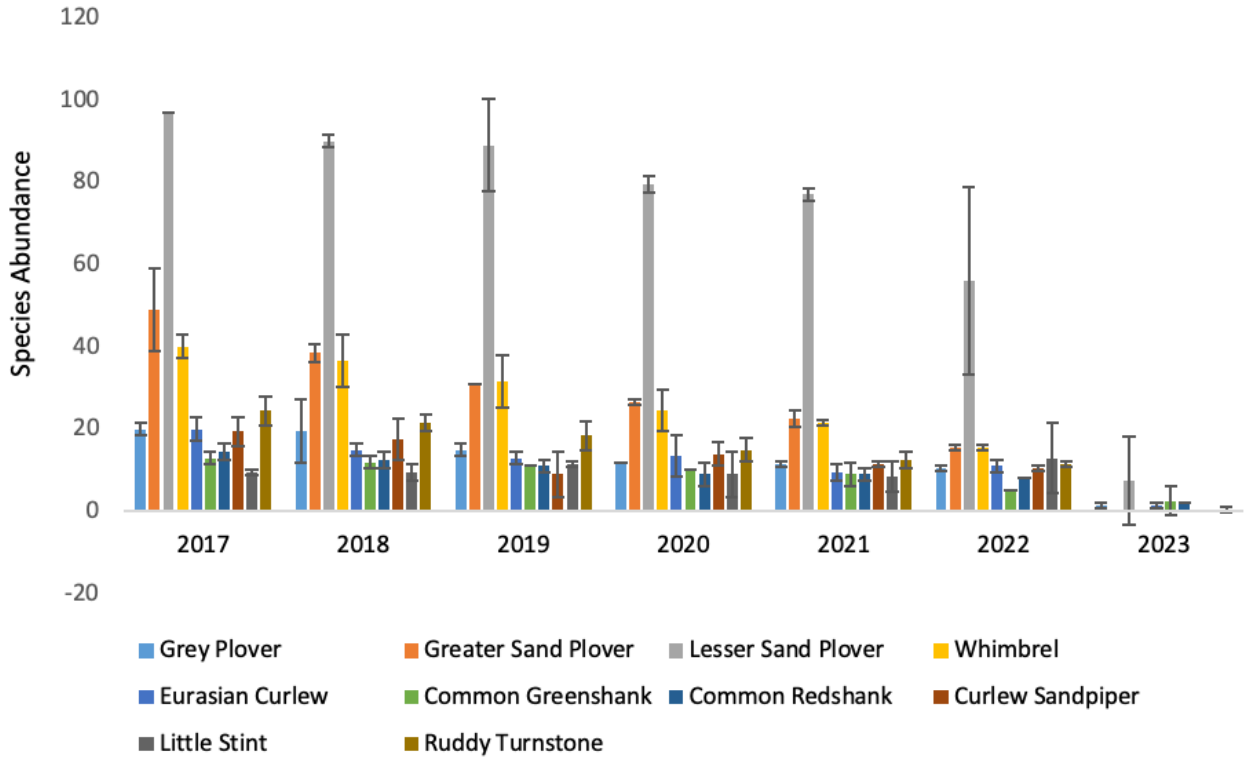

Figure 2. Abundance of over-summering shorebirds in Pillaimadam Lagoon.

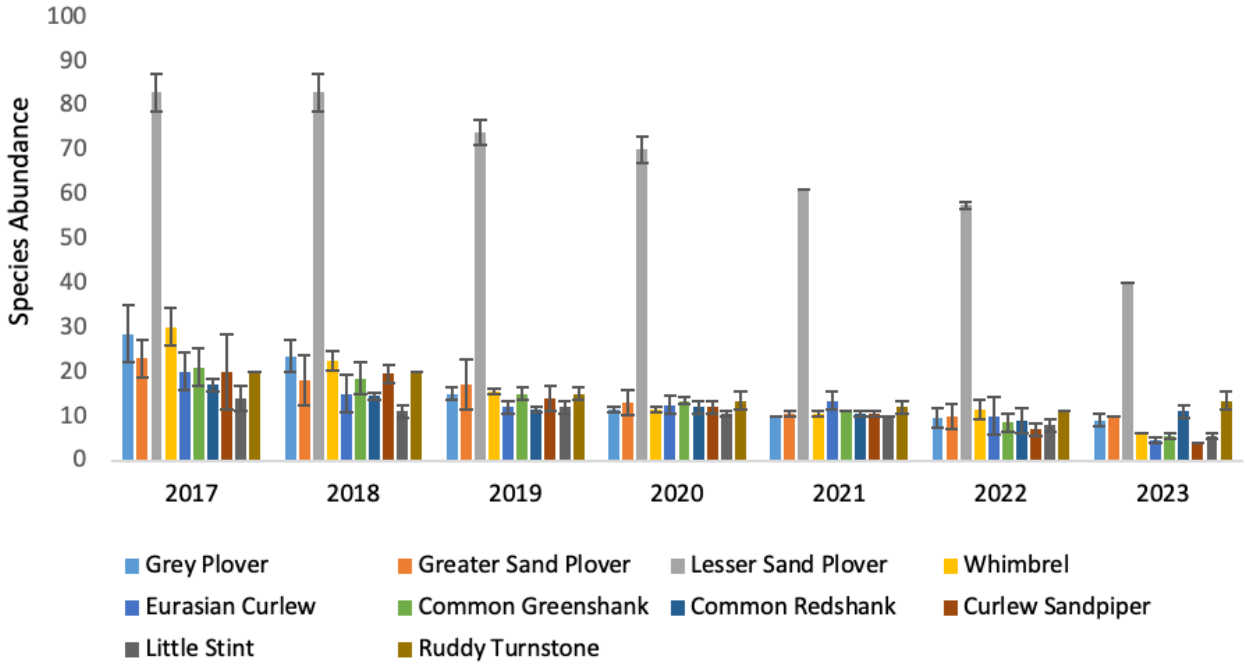

Figure 3. Abundance of over-summering shorebirds on Manoli Island.

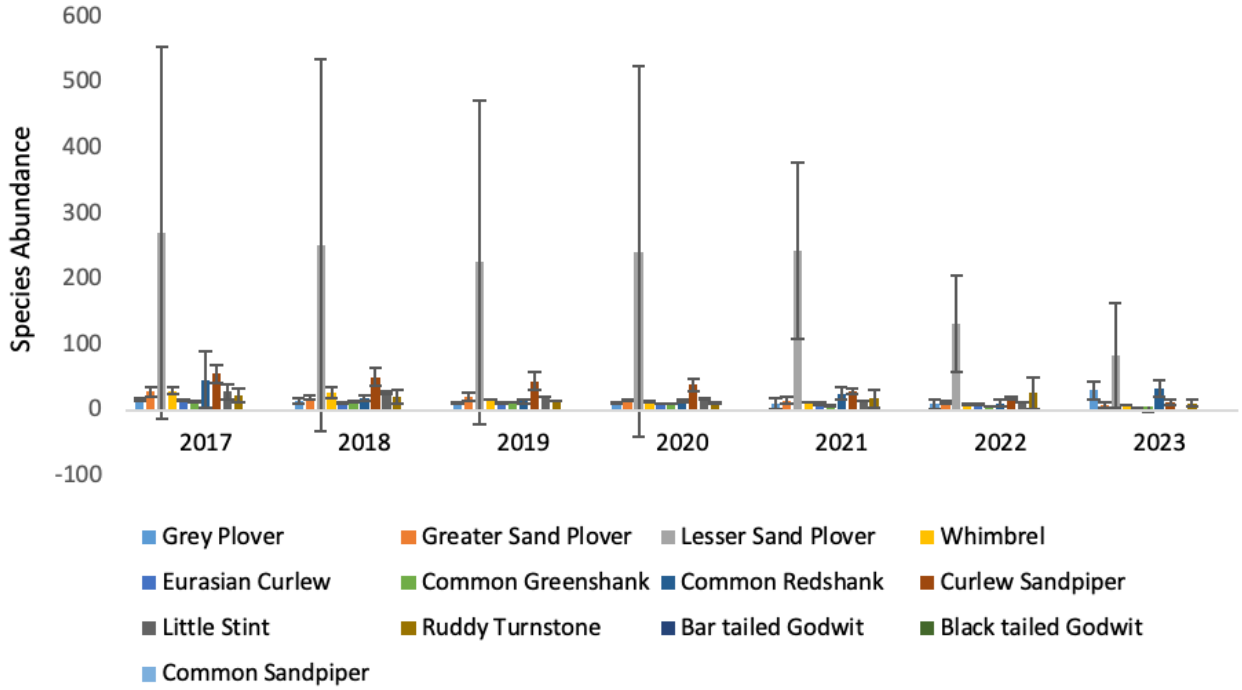

Figure 4. Abundance of over-summering shorebirds in Dhanushkodi Lagoon.

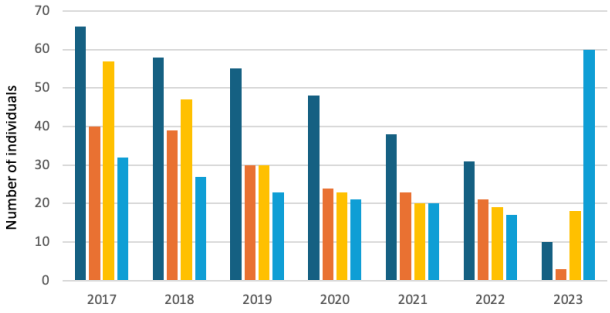

Figure 5. Abundance of over-summering Grey Plover in the study sites from 2017 to 2023.

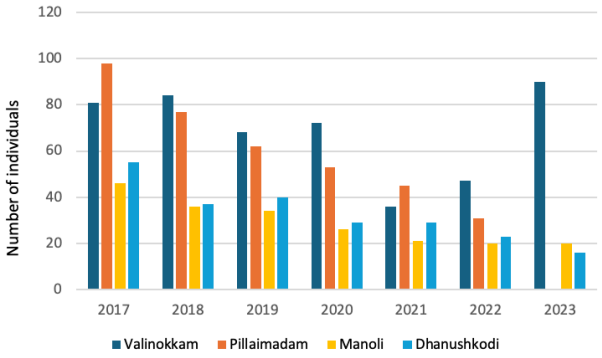

Figure 6. Abundance of over-summering Greater Sand Plover in the study sites from 2017 to 2023.

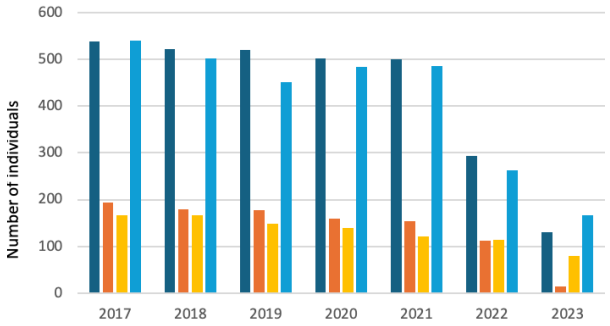

Figure 7. Abundance of over-summering Lesser Sand Plover in the study sites from 2017 to 2023.

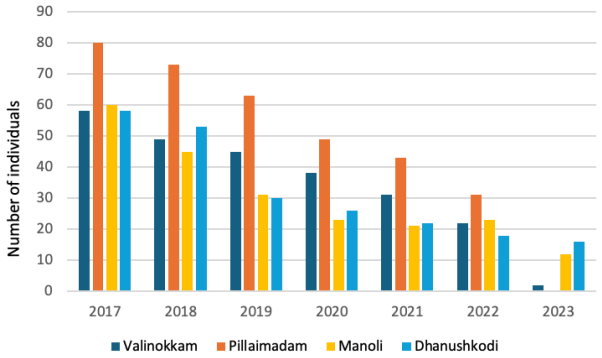

Figure 8. Abundance of over-summering Whimbrel in the study sites from 2017 to 2023.

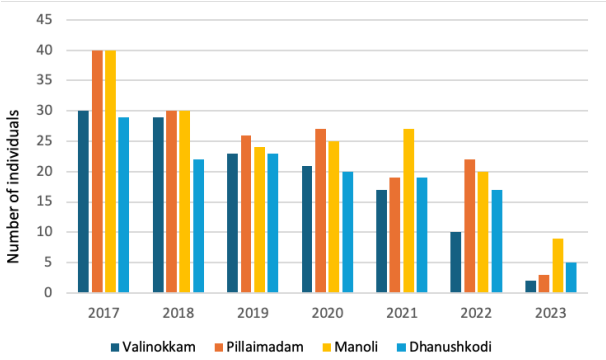

Figure 9. Abundance of over-summering Eurasian Curlew in the study sites from 2017 to 2023.

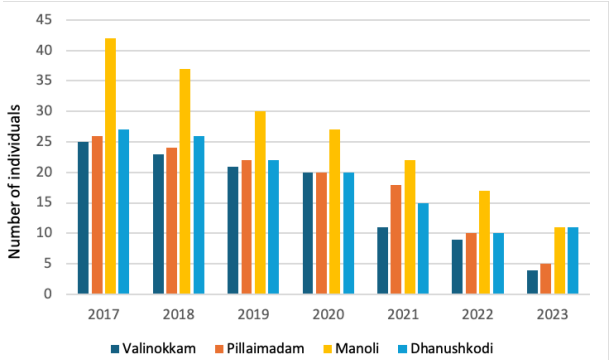

Figure 10. Abundance of over-summering Common Greenshank in the study sites from 2017 to 2023.

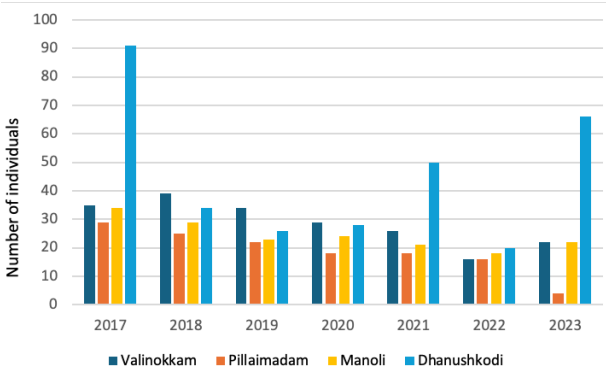

Figure 11. Abundance of over-summering Common Redshank in the study sites from 2017 to 2023.

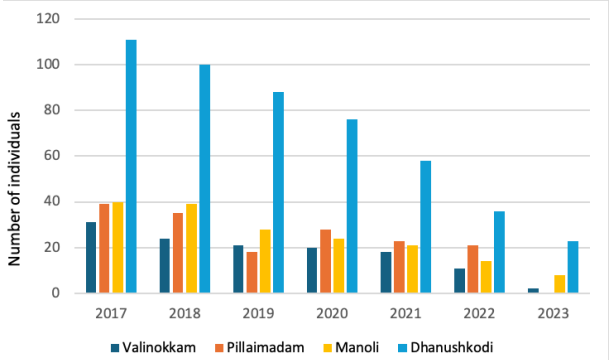

Figure 12. Abundance of over-summering Curlew Sandpiper in the study sites from 2017 to 2023.

two species were abundant in all sites. The occurrence of globally threatened species like Bar-tailed Godwit, Black-tailed Godwit, Curlew Sandpiper, and Eurasian Curlew during over-summering periods further reflects the importance of these study sites for the shorebirds of the CAF.

The present findings also indicate fluctuations in species diversity and richness of over-summering shorebirds, with notable increases in certain species – Grey Plover in Dhanushkodi, Little Stint & Greater Sand Plover in Pillaimadam. Additionally, three new species—Black-tailed Godwit, Bar-tailed Godwit and Common Sandpiper—were recorded in 2023, in the Dhanushkodi Lagoon. Similarly, previous studies from the eastern coast of India have documented five over-summering shorebird species in Chilika Lake, Odisha (Balachandran et al. 2009), 10 species in Point Calimere, Tamil Nadu (Balachandran & Thirunavakarasu 2009), and 12 species in GoM, Tamil Nadu (Daniel et al. 2007).

In Valinokkam, the decline of eight over-summering shorebird species over the study period suggests potential long-term negative impacts, such as habitat degradation or changes in prey availability. However, the marginal increase in Greater Sand Plover and Little Stint populations during the over-summering period could indicate localized changes in conditions. Since this is a man-made lagoon, one exclusively dependent on the seawater pumped for salt extraction, the local factors play a major role in species diversity and richness. Pillaimadam exhibited a concerning trend of drastic reductions in all over-summering shorebird species populations throughout the study period, emphasizing the need for targeted conservation efforts. The strategy of over-summering, where certain portions of the shorebird populations spend significant durations in areas that are largely undocumented and lacking proper protection, might contribute to this decline (Ntiamoa-Baidu 1991). This is similar to our two study sites, Valinokkam and Pillaimadam, as both are unprotected areas. Insufficient conservation efforts targeted at this specific phase of their life cycle could be a contributing factor to the observed trends in shorebird populations

The decline in over-summering shorebird abundance across all study sites (Tables 1–4) suggests an ongoing

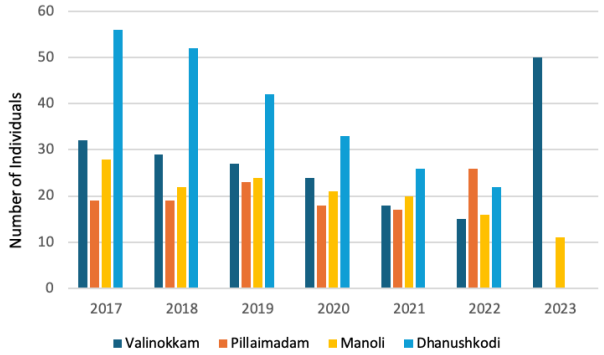

Figure 13. Abundance of over-summering Little Stint in the study sites from 2017 to 2023.

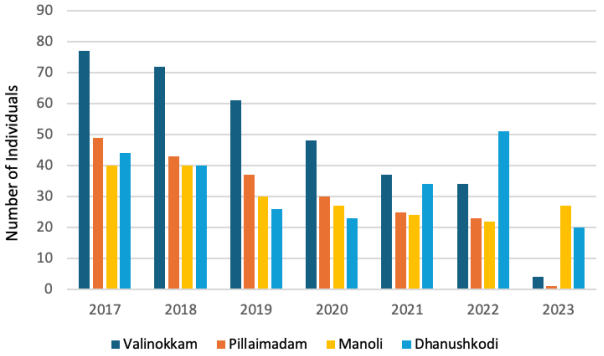

Figure 14. Abundance of over-summering Ruddy Turnstone in the study sites from 2017 to 2023.

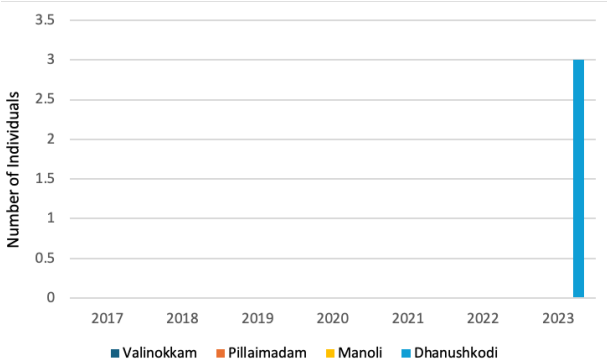

Figure 15. Abundance of over-summering Bar-tailed Godwit in the study sites from 2017 to 2023.

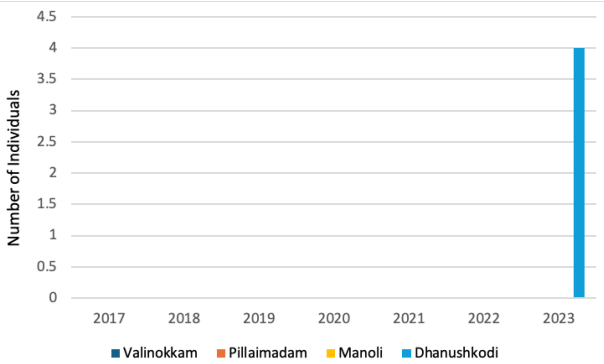

Figure 16. Abundance of over-summering Black-tailed Godwit in the study sites from 2017 to 2023.

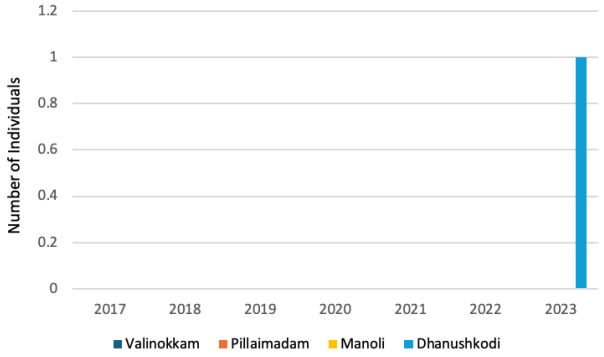

Figure 17. Abundance of over-summering Common Sandpiper in the study sites from 2017 to 2023.

habitat degradation issue, as reflected by the overall global decline in shorebird populations, particularly within the Central Asian flyway including regions like Dhanushkodi (Rashiba et al. 2023). The Shannon index values indicated fluctuations in species diversity over the study period, with a notable peak in 2023, particularly at Manoli Island (H = 2.25). The increase in over-summering shorebird diversity could be attributed to various factors including favourable environmental conditions and reduced anthropogenic pressures due to the lesser fishermen activities on this uninhabited island. Conversely, 2020 and 2021 marked low diversity of over-summering shorebirds across all sites, potentially due to disturbances such as habitat loss. Specifically, the substratum hardening and mangrove encroachments to the mudflats reduce the area of foraging in Manoli Island (Byju et al. 2023c) and the impact of infrastructure development including new roads in Dhanushkodi Lagoon witnessed a substantial decrease in overall shorebird abundance over a few decades.

This research provides valuable insights into the dynamics of over-summering shorebird populations along the southeastern coasts of Tamil Nadu. The decline observed, particularly in species with probing beaks, emphasizes the need for further conservation efforts. The variation in abundance among lagoons underscores the importance of site-specific conservation strategies to preserve these ecologically significant habitats including non-protected ones.

Image 2. Manoli Island. © H. Byju.

Image 3. Dhanushkodi Lagoon. © H. Byju.

Image 4. Valinokkam Lagoon. © N. Raveendran.

Image 5. Pillaimadam Lagoon. © H. Byju.

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