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Authors: Aarif, K.M., Kaiser, Sara A., Nefla, Aymen, and Almaroofi, Sama

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Over-summering abundance, species composition, and habitat use patterns at a globally important site for migratory shorebirds

K.M. Aarif,[1†] Sara A. Kaiser,[2,5*†] Aymen Nefla,[3] and Sama Almaroofi[4,6]

ABSTRACT—The Indian subcontinent is the primary wintering ground and stopover site for migratory shorebirds to refuel along the Central Asian and South Asian Flyways. Despite the conservation importance of this region for migratory shorebirds, we lack information on the distribution and abundance of over-summering shorebirds—migrants that remain on their wintering grounds during the breeding season—to evaluate the impacts of anthropogenic change on this poorly understood life history strategy. We conducted weekly surveys of over-summering shorebirds at mudflats, mangroves, and sand beaches at the Kadalundi-Vallikkunnu Community Reserve on the southwest coast of India, 2005–2018. We examined long-term patterns of over-summering shorebird abundance, species composition, and habitat use and estimated proportional changes in over-summering abundance of each shorebird species documented at this globally important site. Over the 14 yr study, we documented 7 over-summering species, including Lesser Sand Plover (*Charadrius mongolus*), Whimbrel (*Numenius phaeopus*), Greater Sand Plover (*Charadrius leschenaultia*), Kentish Plover (*Charadrius alexandrinus*), Common Sandpiper (*Actitis hypoleucos*), Ruddy Turnstone (*Arenaria interpres*), and Pacific Golden-Plover (*Pluvialis fulva*). Mean abundance and species richness were higher at mudflats than at mangroves and sand beaches, with fewer individuals and species observed over-summering after 2010. Mudflats also had the highest species diversity and evenness compared to mangroves and sand beaches. Management plans that aim to restore vulnerable mudflats and mangroves and to reduce anthropogenic threats such as sand mining and waste dumping are needed to prevent the loss of important over-summering, foraging habitat for migratory shorebirds in southern India and along the Central Asian and South Asian Flyways. *Received 23 January 2019. Accepted 24 November 2019.*

Key words: Central Asian and South Asian Flyways, conservation, habitat use, India, over-summering, shorebirds

[1] Division of Animal Behaviour, Department of Zoology, University of Calicut PO, Malappuram District, Kerala, India

[2] Center for Conservation Genomics, Smithsonian Conservation Biology Institute, National Zoological Park, Washington, DC, USA

[3] Research Unit of Biodiversity and Population Biology, Department of Biology, Faculty of Sciences of Tunis, University of Tunis, Tunis, Tunisia

[4] Marine Science Centre, University of Basrah, Garamatt Ali, University Campus, Basrah, Iraq

[5] Current address: Cornell Lab of Ornithology, Cornell University, Ithaca, NY, USA

[6] Current address: Department of Sustainability Sciences, Lakehead University - Orillia Campus, Orillia, ON, Canada

* Corresponding author: sak275@cornell.edu

† These authors contributed equally.

Abundancia durante el verano, composición de especies y patrones de uso de hábitat en un sitio globalmente importante para aves playeras migratorias

RESUMEN (Spanish)—El subcontinente indio es el principal territorio invernal y sitio de descanso para aves playeras migratorias que se reabastecen a lo largo de las rutas migratorias Central y Sur de Asia. Pese a la importancia de esta región para la conservación para playeras migratorias, carecemos de información sobre la distribución y abundancia de aquellas que permanecen durante el verano — migratorias que permanecen en sus áreas de invernada durante la estación reproductiva— para evaluar los impactos del cambio antropogénico en esta estrategia de historia de vida escasamente conocida. Hicimos reconocimientos semanales de playeros que permanecen durante el verano en marismas, manglares y playas arenosas en la reserva comunitaria Kadalundi-Vallikkunnu en la costa suroeste de la India, 2005–2018. Examinamos los patrones de largo plazo de abundancia durante el verano, composición de especies, uso de hábitat y cambios proporcionales estimados en la abundancia veraniega de cada especie de playera documentada en este sitio de importancia global. Durante los 14 años de estudio, documentamos 7 especies residentes de verano, incluyendo los chorlos *Charadrius mongolus*, *C. leschenaultia*, *C. alexandrinus* y *Pluvialis fulva*, el zarapito *Numenius phaeopus*, el andarríos *Actitis hypoleucos* y el vuelvepiedras *Arenaria interpres*. La abundancia media y riqueza de especies fueron más altas en marismas que en manglares y playas arenosas, con menos individuos y especies observados durante los veranos después de 2010. Las marismas también tuvieron la más alta diversidad y uniformidad de especies comparado con manglares y playas arenosas. Los planes de manejo que tienen como objetivo restaurar marismas, manglares vulnerables y reducir las amenazas antropogénicas como la extracción de arena y arrojar desechos son necesarios para evitar la pérdida de hábitat importante para estancias de verano y forrajeo para playeras migratorias en el sur de la India y a lo largo de las rutas migratorias Central y Sur de Asia.

Palabras clave: rutas migratorias Central y Sur de Asia, conservación, uso de hábitat, India, permanencia durante el verano, playeros

Global declines in migratory shorebirds represent one of the largest conservation crises facing birds. Particularly on their southern wintering

grounds, shorebirds experience increasing threats from coastal development and habitat loss. Migratory shorebirds that remain on their wintering grounds (i.e., nonbreeding grounds) throughout the breeding season are described as over-summering (Cramp et al. 1985, Soto-Montoya et al. 2009). Individuals that over-summer appear to be sexually immature birds (McNeil et al. 1994, Soto-Montoya et al. 2009), but may also include adults in relatively poor condition unable to meet the energetic demands and risks of migration (McNeil et al. 1994, Vieira 2016). Over-summering may therefore represent an important life history strategy for migratory shorebirds and the conservation of over-summering sites may be crucial for successful recruitment into populations of migratory shorebirds. This phenomenon has been reported in 15 families of migratory shorebirds in Asia and Australasia (Chowdhury 2012). Over-summering is most prevalent in the Charadriidae and Scolopacidae families (McNeil et al. 1994) and has been infrequently reported along the Central Asian and East Asian–Australasian Flyways, in Bangladesh (Li et al. 2009, Chowdhury 2012), and in southern Africa (Tree 1972, Spearpoint et al. 1988). However, the distribution and abundance of over-summering shorebirds are largely unknown in these and other regions outside of the Western Hemisphere (McNeil et al. 1994).

The Indian subcontinent is a primary wintering ground for shorebirds migrating along the Central Asian and South Asian Flyways and is an important stopover site for shorebirds migrating between the east and west coasts of India (Balachandran 2006, Sandilyan et al. 2010, Aarif et al. 2014). Over-summering shorebirds have been recorded on the east coast of India, although the reports are infrequent and spatially and temporally patchy (Balachandran 2006, Sandilyan et al. 2010, Kannan and Pandiyan 2012). Specifically, over-summering shorebirds, mostly Pacific Golden-Plover (*Pluvialis fulva*) and Terek Sandpiper (*Xenus cinereus*), have been observed in Odisha on Chilika Lake, which is the largest wintering ground for migratory shorebirds in India (Nayak 2006). Whimbrel (*Numenius phaeopus*) have also been observed over-summering in Odisha in the Bhitarkanika Mangroves, which is the second largest mangrove wetland in India and a biodiversity hotspot (Nayak 2006). In contrast, over-summering by shorebirds on the west coast of India is not well documented (Aarif and Prasadan 2014).

In this study, we examined patterns of abundance, species composition, and habitat use of over-summering shorebirds on the west coast of India in the Kadalundi-Vallikkunnu Community Reserve over a 14 yr period. This site has been recognized as a critical estuarine wetland for shorebirds in India (Aarif et al. 2011, Aarif et al. 2014), as well as a site of global importance for the conservation of shorebirds migrating along the Central Asian and South Asian Flyways (Aarif et al. 2014). Despite the conservation importance of this site for migratory shorebirds, published data on over-summering from this region is lacking. Quantifying habitat use for foraging by over-summering shorebirds would aid in implementing habitat management actions at community reserves throughout India to support the highest biodiversity of shorebirds and to reverse global declines and recover migratory shorebird populations. Our aims were to (1) examine patterns of over-summering shorebird abundance, species richness, diversity, and evenness among habitats and years; and (2) quantify the yearly proportional changes in over-summering abundance of each shorebird species documented at this globally important site.

Methods

The Kadalundi-Vallikkunnu Community Reserve (KVCR) was designated in 2008 as one of 4 community reserves in India spanning ~154 ha in area (Aarif et al. 2011). The KVCR (11°7′N, 75°50′E) is located at the estuary of the Kadalundi River, which drains into the Arabian Sea on the southwest coast of Kerala (Fig. 1). Before entering the Arabian Sea, the Kadalundi River bifurcates into 2 channels and encircles the small island of Balathuruth. The raised sandbars on the western and southern shores of Balathuruth separate the lagoon from the Arabian Sea. The estuary is 81 ha in area and is bordered by coconut groves, a few scattered patches of mangroves, and human habitation. During low tide, ~8 ha of mudflats are exposed, providing foraging grounds for 29 long-distance migrant and 2 local migrant shorebirds (Aarif et al. 2011, 2014). The KVCR is an important wetland conservation area for shorebirds but also provides significant socioeconomic and

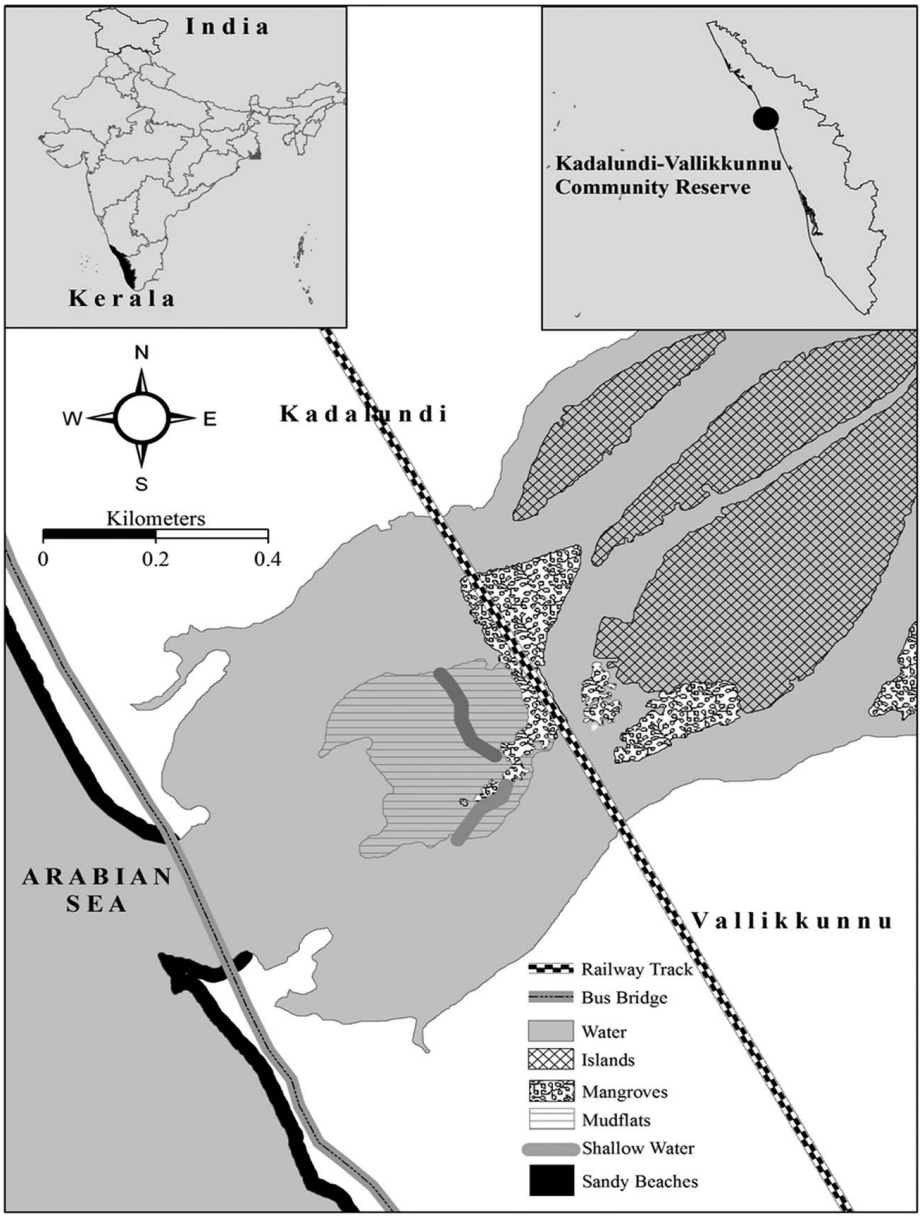

Figure 1. Study area and locations of the estuarine habitats and oceanic beaches where bird counts were conducted at the Kadalundi-Vallikkunnu Community Reserve (KVCR). Inset maps show the location of the KVCR (11°7′N, 75°50′E) in the state of Kerala and southwest coast of India.

livelihood services (e.g., fishing, oyster farming, and sand mining) for the local people.

Migratory shorebirds usually arrive to their wintering grounds at the KVCR in August and depart between March and May. We surveyed shorebirds once a week during the over-summering period (1 Jun–15 Jul) from 2005 to 2018 using direct visual counts (Hoves and Bakewell 1989). We counted shorebirds in 3 habitat types using binoculars (10×50) and a spotting scope (14×70) between 0600 h and 1100 h at 2 scanning points both at mudflats (sand beaches were extensions of mudflats) and mangroves at low tide. We began counts 5 min after arrival to the scanning point to allow shorebirds to acclimate to human presence. We placed a video camera (Sony Handycam HDR-CX-130E) at each scanning point to record shorebird activity during each survey period in each habitat simultaneously. We transcribed video recordings to verify direct counts and to check for

duplicate counts of individuals. However, most species were observed in small numbers with the exception of flocking Lesser Sand Plovers (*Charadrius mongolus*). When observing shorebirds with binoculars and spotting scopes was challenging under wet conditions, we used only count data from video recordings to determine shorebird abundance. We calculated the yearly proportional change in mean abundance between 2005 and 2018 for each over-summering species.

We investigated the relative importance of the 3 different foraging habitats for supporting over-summering shorebirds. We compared the abundance and species richness (S, total number of species) among mudflats, mangroves, and sand beaches and tested for yearly differences and the interaction between habitat and year using 2 ANOVA models. For each habitat and year, we calculated species diversity using the Shannon-Wiener index ($H' = \Sigma_i^S[P_i \times \ln(P_i)]$), where P_i is the proportion of a species i relative to S (Shannon and Wiener 1963), and species evenness using Pielou's equitability index ($J = H'/\ln S$) (Pielou 1966). We compared species diversity and evenness to determine which of the 3 habitats were more used by over-summering shorebirds for foraging across years using the Kruskal-Wallis test. We examined parametric models for homoscedasticity using Levene's test and for normality of model residuals using a one-sample Kolmogorov–Smirnov test at a 95% confidence level. We log-transformed species abundance and richness to reduce heteroscedasticity. All analyses were conducted in program R 3.5.1 (R Development Core Team 2018).

Results

Over the 14 yr study, we documented 7 migratory shorebird species over-summering at the KVCR (3,644 individuals), including Lesser Sand Plover, Whimbrel, Greater Sand Plover (*Charadrius leschenaultia*), Kentish Plover (*Charadrius alexandrinus*), Common Sandpiper (*Actitis hypoleucos*), Ruddy Turnstone (*Arenaria interpres*), and Pacific Golden-Plover. Three species were recorded in all habitat types, two species were observed foraging only at mudflats and mangroves, one species was observed foraging only at mudflats and sand beaches, and one species was seen foraging only at mangroves (Table 1). Mean abundance was significantly affected by habitat (ANOVA: $F = 16.55$, df = 2, $P < 0.001$) but not year ($F = 2.10$, df = 13, $P = 0.15$). However, the effect of habitat on mean abundance depended on the year ($F = 2.35$, df = 26, $P < 0.01$). Mean abundance and species richness were higher at mudflats than at mangroves and sand beaches, with fewer individuals and species observed in each habitat after 2010 (Table 1, Fig. 2a, 3a). Species richness was significantly affected by habitat ($F = 9.19$, df = 2, $P < 0.001$; Fig. 2b), year ($F = 4.09$, df = 13, $P < 0.001$; Fig. 3b), and the interaction between habitat and year ($F = 1.80$, df = 26, $P = 0.013$). The Shannon-Wiener diversity index varied significantly among habitats (Kruskal-Wallis: $H = 7.86$, df = 2, $P = 0.019$; Fig. 2c) and years ($H = 30.33$, df = 13, $P = 0.004$; Fig. 3c). Likewise, the Pielou's equitability index varied significantly among habitats ($H = 7.59$, df = 2, $P = 0.022$; Fig. 2d) and years ($H = 29.73$, df = 13, $P = 0.005$; Fig. 3d). The highest and lowest values of both indices were recorded at mudflats and mangroves, respectively (Fig. 2). All 7 species declined over the 14 yr period (Table 2).

Discussion

Southern India is a globally important wintering site for shorebirds migrating along the Central Asian and South Asian Flyways. Shorebird abundance has decreased by 40% in the Pichavaram mangroves of Tamil Nadu on the east coast (Sandilyan et al. 2010) and by 44% in the KVCR on the west coast (Aarif et al. 2014). Mean abundance and species richness of the 7 shorebird species over-summering at the KVCR were higher at mudflats than at mangroves and sand beaches, with fewer individuals and species observed over-summering after 2010. These over-summering abundance patterns are similar to those on the east coast of India (Balachandran 2006, Kannan and Pandiyan 2012). These patterns might indicate regional declines during the over-summering period, possibly from accelerated habitat loss and anthropogenic threats common to both the east and west coasts of India (Sandilyan et al. 2010, Aarif et al. 2014) or declines in breeding productivity, which requires further study. Mudflats had higher species diversity and evenness compared to mangroves and sand beaches at the KVCR,

Table 1. Mean ± SD abundance and habitat use of over-summering shorebirds at mudflats, mangroves, and sand beaches observed at the Kadalundi-Vallikkunnu Community Reserve, Southern India, 2005–2018.

Species	Mudflats	Mangroves	Sand beaches
Lesser Sand Plover	22.9 ± 34.6	10.3 ± 26.5	5.9 ± 20.8
Whimbrel	0.7 ± 1.9	0.2 ± 0.8	0.9 ± 1.7
Greater Sand Plover	0.6 ± 2.7	0.6 ± 3.1	0.01 ± 0.1
Kentish Plover	0.4 ± 2.0	0.3 ± 2.6	–
Common Sandpiper	0.1 ± 0.5	0.02 ± 0.2	–
Ruddy Turnstone	0.02 ± 0.1	–	0.02 ± 0.1
Pacific Golden-Plover	–	0.02 ± 0.2	–

demonstrating that mudflats supported the highest diversity with individuals distributed more evenly across species.

The 7 species of shorebirds over-summering at the KVCR have been documented over-summering at other sites in South Asia; none of these species are currently listed as near threatened or endangered (IUCN 2016). The Lesser Sand Plover was the most abundant species over-summering at the KVCR. This species and the Greater Sand Plover were previously reported over-summering in the Kadalundi estuary from 1988 to 1990 (Kurup 1991). We reported 5 additional species of shorebirds during the over-summering period (Whimbrel, Kentish Plover, Common Sandpiper, Ruddy Turnstone, and Pacific Golden-Plover), which included 4 of the 15 shorebird species documented over-summering in Bangladesh (Chowdhury 2012).

The importance of over-summering as a life history strategy for migratory shorebirds is not well understood (McNeil et al. 1994, Kannan and Pandiyan 2012). Some Arctic and north-temperate shorebird species that winter in the southern hemisphere display delayed maturity—immatures remain on their wintering grounds in nonbreeding plumage during their first breeding season and

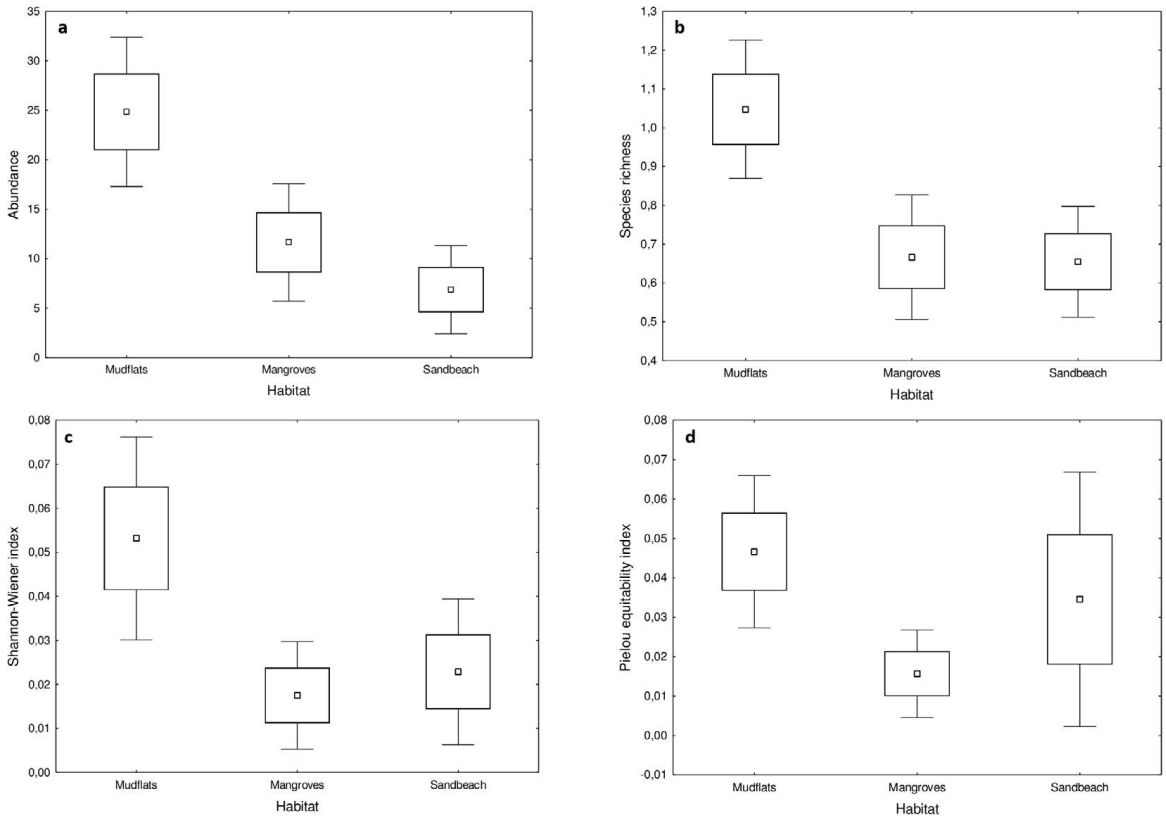

Figure 2. Mean (± SE) abundance (a), species richness (b), species diversity (Shannon-Weiner index) (c), and evenness (Pielou's equitability index) (d) of over-summering shorebirds among habitats at the Kadalundi-Vallikkunnu Community Reserve.

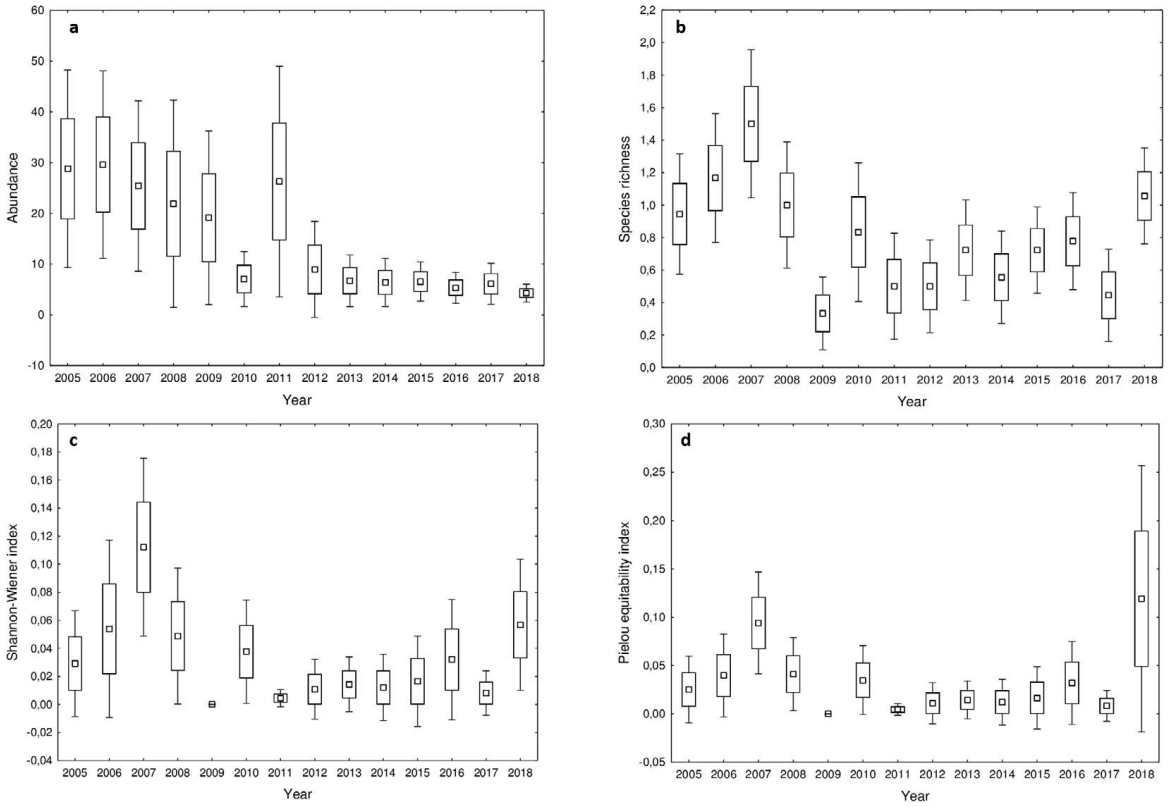

Figure 3. Mean (± SE) abundance (a), species richness (b), species diversity (Shannon-Weiner index) (c), and evenness (Pielou's equitability index) (d) of over-summering shorebirds among years at the Kadalundi-Vallikkunnu Community Reserve.

Table 2. Yearly proportional changes in mean abundance of shorebird species observed at the Kadalundi-Vallikkunnu Community Reserve, Southern India, 2005–2018.

Year	Lesser Sand Plover	Whimbrel	Greater Sand Plover	Kentish Plover	Common Sandpiper	Ruddy Turnstone	Pacific Golden-Plover
2005	–	–	–	–	–	–	–
2006	−1.49	7.14	36.36	300.00	0	–	–
2007	−16.60	−48.88	33.33	−50.00	0	–	−100.00
2008	3.77	91.30	−100.00	475.00	0	–	–
2009	42.01	−100.00	–	178.26	−100.00	−100.00	–
2010	−60.80	–	−94.73	−100.00	–	–	–
2011	200.26	85.00	−100.00	–	−100.00	−100.00	–
2012	−65.83	−64.86	–	−100.00	–	–	–
2013	−32.57	284.61	–	–	–	–	–
2014	32.08	−34.00	–	–	–	–	–
2015	−27.14	60.60	–	–	–	–	–
2016	−20.39	−11.32	–	–	–	–	–
2017	−12.32	−100.00	–	–	–	−100.00	–
2018	−46.62	–	–	–	−83.33	–	–
2005–2018	−88.22	−57.14	−100.00	−100.00	−50.00	0	0

migrate north to breed in their second or third years (Loftin 1962, Summers et al. 1995). Over-summering behavior is hypothesized to have evolved as a strategy for sexually immature birds to minimize the risks during migration and the reduced probability of successfully breeding in their first year (Myers 1981, McNeil et al. 1994, Summers et al. 1995). High numbers of immature birds over-summering can indicate high annual recruitment of these species (Chowdhury 2012). A small proportion of over-summering individuals appear to be adults in poor condition. Helminth infestations on the wintering grounds have been proposed as a primary factor that reduces body condition and prevents migration by delaying pre-migratory molt and reducing fat accumulation in both sexually mature adults and immatures (McNeil et al. 1994). Individuals in poor condition would be expected to depart their wintering grounds late, reducing their migration window and time spent at each stopover site for replenishing energetic reserves en route to their breeding grounds, placing them at a disadvantage for breeding (Macwhirter et al. 2002). Both sexual maturity and adult condition appeared to be factors influencing over-summering at KVCR because most of the over-summering shorebirds we observed were immatures or adults with evident injuries. Because we observed few adults over-summering over the 14 yr study, this suggests that the KVCR contains high-quality foraging habitat during the winter for shorebirds to effectively prepare for migration and breeding.

Earlier reports indicated that the KVCR supported large numbers of both wintering and over-summering shorebirds (Uthaman and Namasivayan 1991, Aarif et al. 2011). However, 2 recent studies documented significant regional declines in species wintering on the east and west coasts of India (Sandilyan et al. 2010, Aarif et al. 2014). Both studies suggested that the declines were because of several factors, including human disturbance and altered distributions of benthic invertebrate prey from reduced nutrient enrichment. The mechanisms underlying the declines in over-summering abundance at the KVCR are unknown. Tropical wetlands and coastal habitats are under extreme anthropogenic pressure. Habitat loss, sand mining, and waste dumping are the primary anthropogenic threats for the conservation of shorebirds using mudflats, mangroves, and sand beaches in southern India (Aarif et al. 2014, Aarif and Prasadan 2014). Management plans that aim to restore vulnerable mudflats and mangroves and to reduce anthropogenic threats are needed to prevent the loss of important over-summering habitat for migratory shorebirds in southern India and along the Central Asian and South Asian Flyways.

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