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Frequent, year-round monitoring reveals significant shorebird abundances in northern Manila Bay, Philippines

Hui Zhen Tan[1,3‡*], Movin Nyanasengeran[1‡] & Irene C. Dy[2]

[1] *Department of Biological Sciences, National University of Singapore, Singapore*
[2] *St. George Trading, Caloocan City, Metro Manila, Philippines*
[3] *Current address: School of Biological Sciences, University of Auckland, Auckland, New Zealand*
[‡] *These authors contributed equally to this work*
[*]*Corresponding author: htan626@aucklanduni.ac.nz*

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The connectivity of habitats along a migratory bird flyway is crucial for the survival of migratory shorebirds threatened by anthropogenic loss of coastline habitats. A lack of regular monitoring in shorebird sites may prohibit accurate and comprehensive assessment of site importance and impede the identification of key sites for conservation. Here, we present a case where important shorebird areas in northern Manila Bay, Philippines have been overlooked as previous counts were mostly made outside of the actual period of peak shorebird use. Areas surveyed, namely Tanza, Pamarawan and Pampanga, host high numbers of shorebirds during migratory months, with Tanza also having considerable numbers of oversummering shorebirds. Importantly, 14 species were recorded in abundances exceeding 1% of their flyway populations. These areas in northern Manila Bay should be granted protection under the Ramsar Convention on Wetlands, and demonstrate the importance of frequent, year-round monitoring in assessing sites. Unfortunately, northern Manila Bay is under grave threat as highly destructive development and land reclamation is currently being carried out, with additional coastal development projects planned. We highlight the urgency of surveying other sites in the Philippines to prevent inadvertent loss of undervalued shorebird areas and to preserve crucial portions of the East Asian-Australasian Flyway.

Keywords

conservation

habitat loss

migration

monitoring

shorebird hotspot

East Asian-Australasian Flyway

INTRODUCTION

Human-induced habitat loss is one of the main factors responsible for the current global biodiversity crisis (Butchart *et al.* 2010). Although this acutely impacts species that occupy small geographic ranges (Pimm *et al.* 2014), migratory shorebirds which spend much of the year moving between sites are also disproportionally threatened, with population declines in almost half of all species (IWSG 2003). Coastlines, with their proximity to trade and transport networks, are also sites for concentrated human habitation (Small & Nicholls 2003) and are amongst the most exploited and degraded habitats today, threatened by encroachment for a range of economic activities including tourism (Davenport & Davenport 2006), aquaculture (Chou 1994, MacKinnon *et al.* 2012), agriculture (Chou 1994) and sand mining (Hilton & Manning 1995).

Among shorebird flyways, the East Asian-Australasian Flyway (EAAF) hosts the highest numbers of shorebirds (IWSG 2003) along with almost half of the global human population (Barter 2002). Southeast Asia, part of the EAAF, also holds some of the greatest expanses of mudflats (Murray *et al.* 2019) and mangroves (Richards & Friess 2016) globally. These factors make the EAAF crucially important for safeguarding shorebird populations while being highly threatened. Conserving the EAAF requires a multi-pronged approach as exemplified by the formation of the EAAF Partnership which coordinates concerted and collaborative efforts to protect and conserve the flyway (Yong *et al.* 2018, 2022).

Shorebirds use various sites along the EAAF for staging or refuelling when migrating between their breeding and wintering grounds (Bamford *et al.* 2008, Lei *et al.* 2019). In addition, different shorebird species are known to prefer different paths along the flyway. For instance, the Far Eastern Curlew *Numenius madagascariensis* is more abundant along the eastern portion of the EAAF compared to the Eurasian Curlew *Numenius arquata*

which is more prevalent in the western regions (Eaton *et al.* 2021). Therefore, a network of sites along the length and breadth of the flyway (Chan *et al.* 2019) is needed to safeguard its full suite of species.

Despite being relatively well-known, new information on the EAAF has demonstrated that much remains to be learnt about it. For instance, areas in the southern Philippines not thought to be important for migrants were recently found to be used by overwintering Critically Endangered Chinese Crested Tern *Thalasseus bernsteini* (Nakagun *et al.* 2016). Additionally, artificial habitats such as rice fields were found to be important staging sites for godwits *Limosa spp.* (Kasahara *et al.* 2020), as was observed for Black-tailed Godwits *Limosa limosa* in San Simon, Pampanga, over seven years (I. Dy unpubl. data). In addition, archipelagic states like the Philippines and Indonesia have extensive coastlines, rice fields, fish pens, and saltpans that have not been surveyed or have only been poorly surveyed, indicating that important staging and overwintering sites might be overlooked or remain unknown (Long & Watkins 2005, Jensen 2018).

Long-running, annual shorebird monitoring programs are in place to assess long-term population trends (Mundkur *et al.* 2017). However, as shorebirds utilise sites along flyways at different times, annual surveys do not fully capture the importance of sites equally, as birds may move through key staging sites at different times in the migratory season or annual cycle. Sites need to be monitored across seasons to capture temporal patterns in shorebird arrivals and departures. Identifying the patterns of site use is key to sustaining shorebird populations by preserving connectivity along the flyway (Studds *et al.* 2017).

This study addresses a gap in knowledge of site usage by shorebirds migrating along the EAAF and provide an accurate assessment of peak counts. In particular, we performed frequent, year-round monitoring of three under-surveyed areas in the Philippines and report fluctuations in abundance and diversity of shorebirds across migratory cycles.

METHODS

Study area and survey methods

Located in Luzon, Philippines, Manila Bay is a large, sheltered bay with a coastline of approximately 190 km (Fig. 1). It is the estuary of more than 20 river systems, with over 20,000 ha of wetland habitat (Jensen 2018). Almost one quarter (27.3 million people) of the Philippines' population live in Manila Bay's catchment area, with the City of Manila, the Philippines' capital city, bordering Manila Bay to the east (Jacinto *et al.* 2006, Cruz & Shimozono 2021). We surveyed northern Manila Bay, which encompasses large areas of mudflats, the largest being that in Taliptip, Bulacan, where Far Eastern Curlew and Eurasian Curlew are recorded regularly (Jensen 2018). Taliptip is flanked by Tanza Navotas mudflat on one side and Pamarawan coastline and saltpans on the other.

Our surveys were conducted by ICD on five sites within three areas in northern Manila Bay (Fig. 1). A total of 231 site surveys were conducted over the duration of three migratory cycles (26 Sep 2020–20 Feb 2023), an average of one site survey every 2–3 days (Table S1). Considering the different geography among sites, survey methods were modified for each site to maximise coverage.

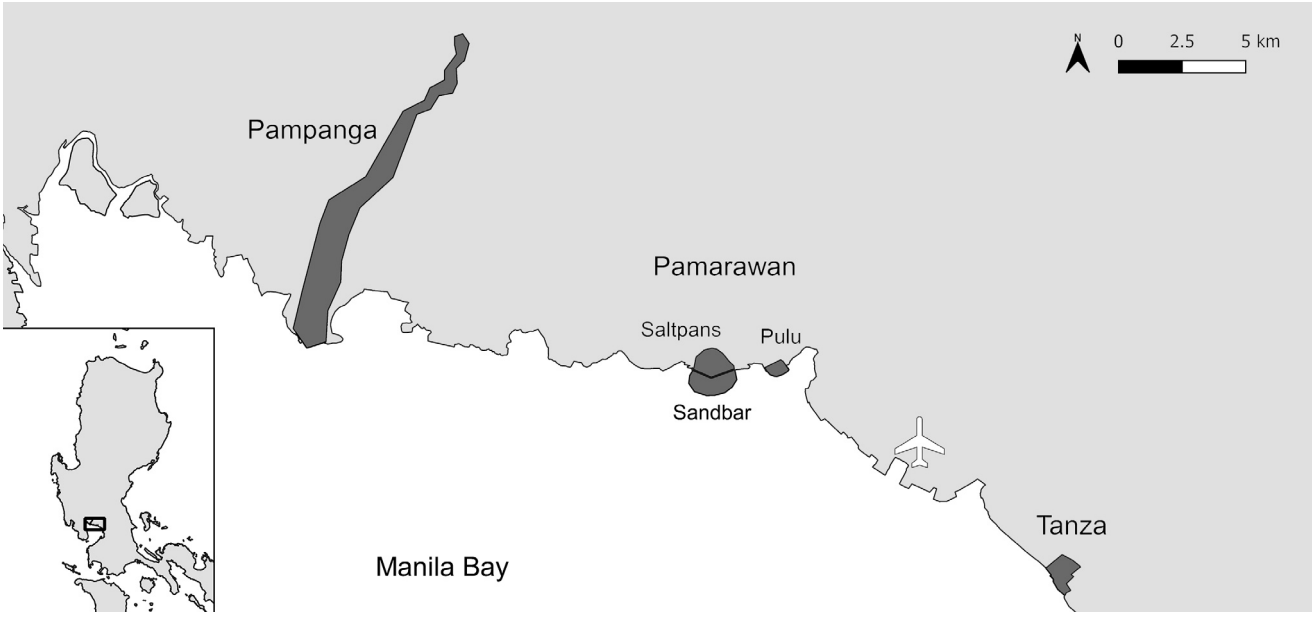

Fig. 1. Location of survey areas in northern Manila Bay, namely Tanza (1 survey site), Pamarawan (3 survey sites) and Pampanga (1 survey site). Map inset shows location of Manila Bay on Luzon. Location of the New Manila International Airport between Pamarawan and Tanza is indicated by the plane symbol.

The first area, Tanza (14.68591°N, 120.93012°E), is situated in the east of northern Manila Bay and consists of one survey site comprising a tidal mudflat used to moor fishing and commercial vessels, a reclaimed area with an elevated dirt track and pockets of low-lying substrate, as well as a natural tidal mudflat adjacent to mangroves (Fig. 1). Each survey lasted 3–4 hrs and began with scanning the entire site from a dike before following a consistent transect. Surveys were only carried out during fair weather but across all tidal conditions as birds were still present at high tide due to the availability of supratidal habitat.

The second area, Pamarawan, is located west of Tanza and consists of three survey sites (Fig. 1). The three sites and their survey durations are: (1) Pulu Pulu mudflat ('Pulu'; 14.758513°N, 120.825435°E), 2 hrs; (2) Paombong sandbar ('Sandbar'; 14.753694°N, 120.798183°E) and Pamarawan mudflat (14.754146°N, 120.805001°E), 5–6 hrs; and (3) Pamarawan saltpans ('Saltpans'; 14.763188°N, 120.800976°E; 14.762128°N, 120.805089°E), 3–4 hrs. Each survey began with scanning the fish pens for perched birds before surveying all sites starting at the one with the lowest tide level. Surveys were only carried out during fair weather and at low tide, except for the saltpans which were surveyed both at high and low tide. Boat surveys were also carried out at fish pens around the Pamarawan area.

The third area, Pampanga (14.7823517°N, 120.6593657°E), sits in the west of northern Manila Bay and consists of one survey site comprising a long stretch of the Pampanga River, including multiple barangays (communities) from the municipalities of Calumpit, Masantol, and Macabeb to a mid-section before the river mouth (Fig. 1). Each survey lasted 5 hrs, began at the river mouth and was conducted upriver from roads immediately adjacent to Pampanga River. Surveys were only carried out during fair weather and at low tide to target shorebirds and at high tide to detect other waterbirds such as gulls.

Species identification and exact counts were recorded during surveys. Equipment used during surveys included: Swarovski ATX spotting scope 85 mm, Swarovski 10x32 EL Binoculars, Nikon MONARCH 7 10x42 mm Binoculars, Canon EOS 7D Mark II & EF400 mm f/5.6L USM, Canon EOS R5 & RF100–500 mm f/4.5-7.1L IS USM, Samsung Galaxy Note 8, and Garmin altimeter.

Data management and analyses

Survey results were processed in R v.4.2.0 (R Core Team 2022) to prepare data for analyses and visualisation. For the purposes of this paper, we define shorebirds as species from the order Charadriiformes (e.g. sandpipers, plovers, terns, gulls) and waterbirds as species from the orders Anseriformes, Ciconiiformes, Gruiformes, Suliformes, Pelecaniformes, and Podicipediformes. Common and scientific names follow the IOC World Bird List v.13.1, except for Lesser Sand Plover for which we follow the agreed split of two subspecies: Siberian Sand Plover *Charadrius mongolus* (formerly Lesser Sand Plover) and Tibetan Sand Plover *Charadrius atrifrons* following draft World Bird List v.13.2 (Gill *et al.* 2023, IOC World Bird List 2023). For each species, we retrieved IUCN Red List status and population information, including 1% thresholds, from the Waterbird Populations Portal (IUCN 2020, Wetlands International 2022)

For each species, counts per site over the entire survey period were visualised using *ggplot2* (Wickham 2016). To investigate total waterbird abundance in Pamarawan, which is the only area with more than one survey site, we added up shorebird and waterbird counts from all sites but only if they were recorded within the same day, to avoid double-counting across days. We defined records as over-summering if they were of any migratory species present from 1 Jun–15 Jul (Aarif *et al.* 2020).

Counts were further analysed to elucidate ecological patterns. For species exceeding 1% of their flyway population, we calculated density distributions from raw counts using *ggridges* (Wilke 2022) and presented the results on an appropriate scale respective to each species. To characterise phenology of shorebird migration to northern Manila Bay, we used high frequency survey data from Tanza during the period 16 Jul 2021 (post over-summering) through 22 Nov 2021. We further removed species with fewer than 20 records and with a maximum count lower than 30 individuals, to improve our inference of peak migration. Cumulative abundance of each species is visualised against month using *ggridges* and the period of peak migration is the time bounded by the 20th and 80th percentiles of the cumulative abundance (Bart *et al.* 2007).

RESULTS

A total of 76 shorebird and waterbird species were recorded during our surveys, of which 53 were shorebirds (Table S2, Fig. S1). We recorded four globally threatened shorebird species: Far Eastern Curlew, Great Knot *Calidris tenuirostris*, Nordmann's Greenshank *Tringa guttifer*, and Sharp-tailed Sandpiper *C. acuminata*, with another nine species that are Near Threatened (Table 1). Our surveys also yielded the first country record of Little Gull *Hydrocoloeus minutus* (7 Sep–23 Oct 2021; Fig. S1d), as well as multiple records of national rarities including the Common Ringed Plover *Charadrius hiaticula*, Pied Avocet *Recurvirostra avosetta*, Dunlin *Calidris alpina*, Little Stint *C. minuta*, and Temminck's Stint *C. temminckii* (Fig. S1). Owing to the high frequency of our surveys, we were able to collect multiple records of these rarities, including eight of the first 10 national records of Little Stint (Figs. S1c & S3).

Of the 53 shorebird species recorded, 14 (26.4%) exceeded 1% of the flyway population. Eight species exceeded their respective thresholds multiple times over the course of our surveys, especially Broad-billed Sandpiper *Calidris falcinellus* and Siberian Sand Plover which did so 37 and 46 times respectively (Figs. 2 & S1). Many of these species

Table 1. Shorebirds of conservation concern (IUCN 2020) recorded in northern Manila Bay and the highest count that was recorded in each survey site. Abbreviations: EN = Endangered, VU = Vulnerable, NT = Near Threatened.

Common name	Scientific name	IUCN Red List status	1% flyway population threshold	Highest count				
				Tanza	Pamarawan			Pampanga
					Pulu	Sand-bar	Salt-pans	
Far Eastern Curlew	*Numenius madagascariensis*	EN	350	18	4	3	4	0
Great Knot	*Calidris tenuirostris*	EN	4,300	1,256	378	3,126	1,182	0
Nordmann's Greenshank	*Tringa guttifer*	EN	10	0	5	4	1	0
Sharp-tailed Sandpiper	*Calidris acuminata*	VU	850	5	0	18	6	0
Asian Dowitcher	*Limnodromus semipalmatus*	NT	280	30	17	89	86	0
Bar-tailed Godwit	*Limosa lapponica*	NT	2,500	82	58	33	3	0
Black-tailed Godwit	*Limosa limosa*	NT	1,600	81	1,693	3,895	3,867	0
Curlew Sandpiper	*Calidris ferruginea*	NT	900	210	310	310	480	2
Eurasian Curlew	*Numenius arquata*	NT	1,000	13	2	2	3	0
Eurasian Oystercatcher	*Haematopus ostralegus*	NT	110	2	0	0	0	0
Grey-tailed Tattler	*Tringa brevipes*	NT	700	41	5	17	18	0
Red Knot	*Calidris canutus*	NT	540	395	167	660	110	0
Red-necked Stint	*Calidris ruficollis*	NT	4,800	1,700	856	608	447	420

had counts well in excess of their 1% thresholds, with Broad-billed Sandpiper and Siberian Sand Plover exceeding 3% of the flyway population and Kentish Plover *Charadrius alexandrinus*, Black-tailed Godwit (which includes the newly described subspecies *bohaii;* Zhu *et al.* 2021, 2023) and Pacific Golden Plover *Pluvialis fulva* exceeding 2% (Figs. 2 & S1). Six of the 14 species, namely Black-tailed Godwit (Fig. S2a), Broad-billed Sandpiper (Fig. S2b), Marsh Sandpiper *Tringa stagnatilis*, Red Knot *Calidris canutus*, Caspian Tern *Hydroprogne caspia*, and Little Tern *Sternula albifrons*, are new high-count records for Manila Bay. This also brings the total number of shorebird species in Manila Bay ever recorded to exceed the 1% threshold to 18, and to 22 when including all waterbirds (Jensen 2018). All three areas surveyed had shorebird populations that exceeded the 1% threshold (Figs. 2 & S1). When waterbird counts were summed per area, total waterbird abundance exceeded 20,000 birds on three days in Pamarawan and Pampanga (Fig. 3).

Outside of the migratory seasons, northern Manila Bay continues to support over-summering populations of more than half of all shorebird species recorded (31 species; Table S2, Fig. S1), a number considerably higher than at other sites along the EAAF (Aarif *et al.* 2020), even in cases where surveys had been conducted over longer periods of time. Over-summering species included globally threatened species such as the Great Knot and Far Eastern Curlew and other Near Threatened species (Curlew Sandpiper *Calidris ferruginea*, Black-tailed Godwit, and Bar-tailed Godwit *Limosa lapponica*). In Tanza, considerable numbers of over-summering shorebirds were recorded, with most of them being immatures (Table S2).

Dates of peak migration varied between and within shorebird families. Peak southward migration dates for Charadriidae, Laridae and Recurvirostridae started later in September (Fig. 4a–c), while those for Scolopacidae started earlier in August and therefore exhibited a wider range of dates (Fig. 4d). Within Scolopacidae, some species peaked earlier in the migratory season (e.g. Terek Sandpiper *Xenus cinereus*) while others peaked later (e.g. Marsh Sandpiper; Fig. 4d). Leg flags and rings were regularly sighted during our surveys, with 44 tagged birds in Tanza and 31 in Pamarawan across 12 species. Many birds observed carrying leg flags and rings were tagged in Kamchatka, several sites in China, Australia and Taiwan, as well as in other countries (Table S3).

Beyond shorebirds, our regular monitoring efforts also recorded several notable waterbirds of global conservation concern. This includes the Critically Endangered Christmas Frigatebird *Fregata andrewsi*, Endangered Black-faced Spoonbill *Platalea minor*, and Vulnerable Chinese Egret *Egretta eulophotes* (Table S2). We also recorded nationally rare birds including Common Shelduck *Tadorna tadorna* (first record for Tanza), as well as species rarely recorded in the Manila Bay area such as Roseate Tern *Sterna dougallii* (first Tanza record), White Stork *Ciconia ciconia*, Red-footed Booby *Sula sula*, and Black-faced Spoonbill (Table S2).

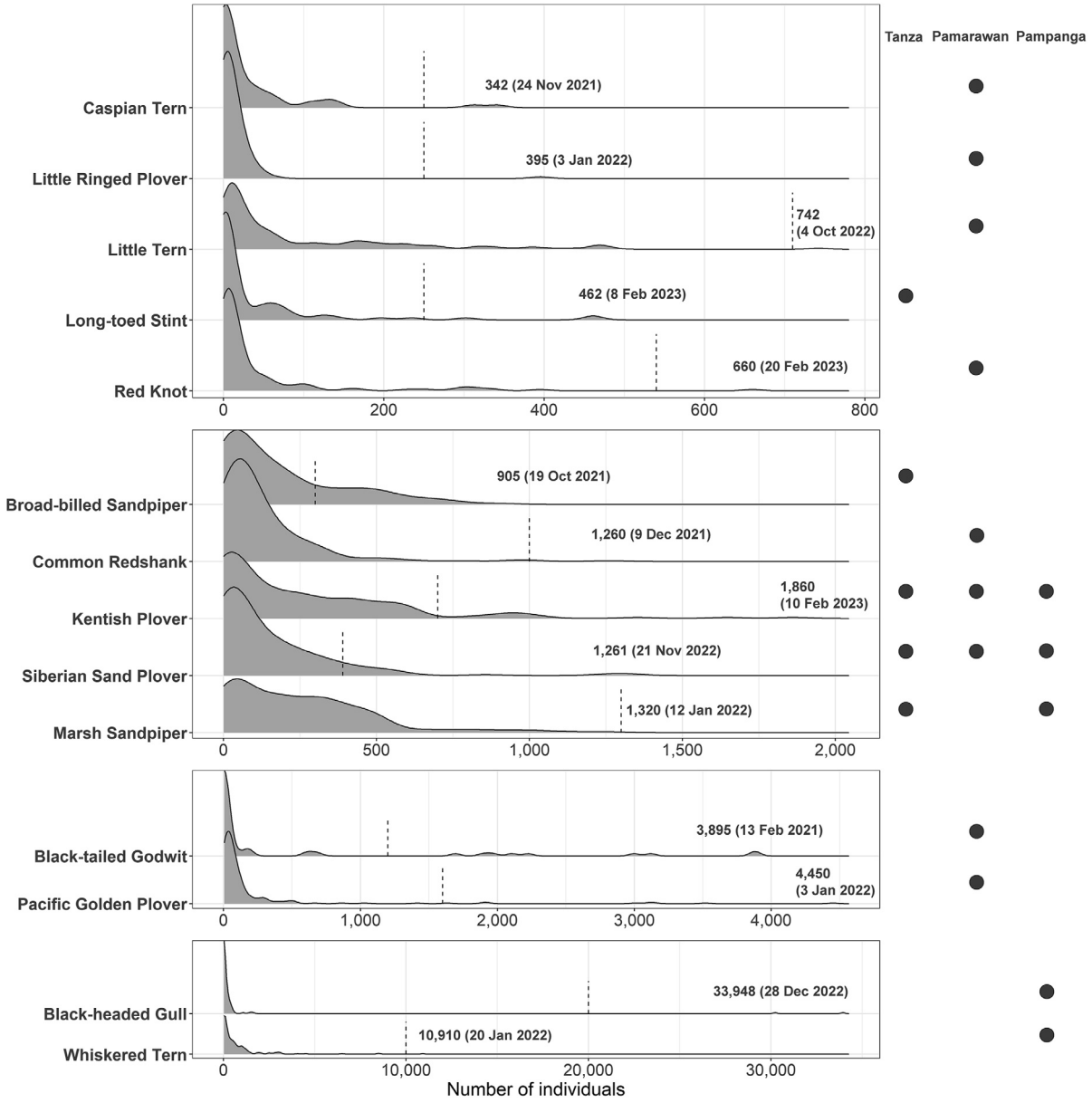

Fig. 2. Density distribution of counts for species exceeding 1% of their flyway population threshold (indicated by the vertical dashed line), with highest count and date of highest count labelled. Information about the area(s) where counts exceeding 1% of flyway population were recorded is provided in the panel on the right, with dark grey circles indicating presence of such counts.

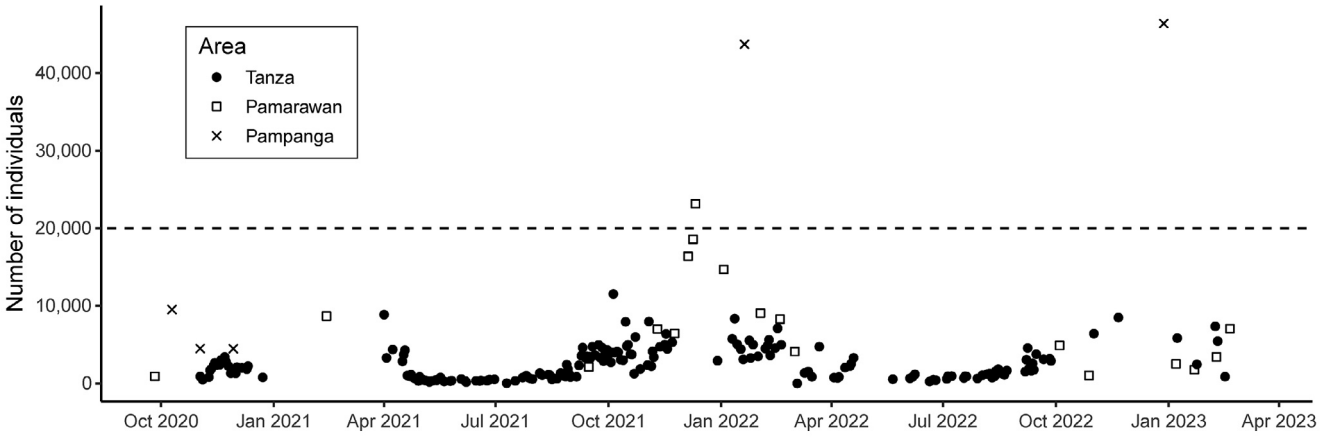

Fig. 3. Total counts of waterbirds per area per survey date.

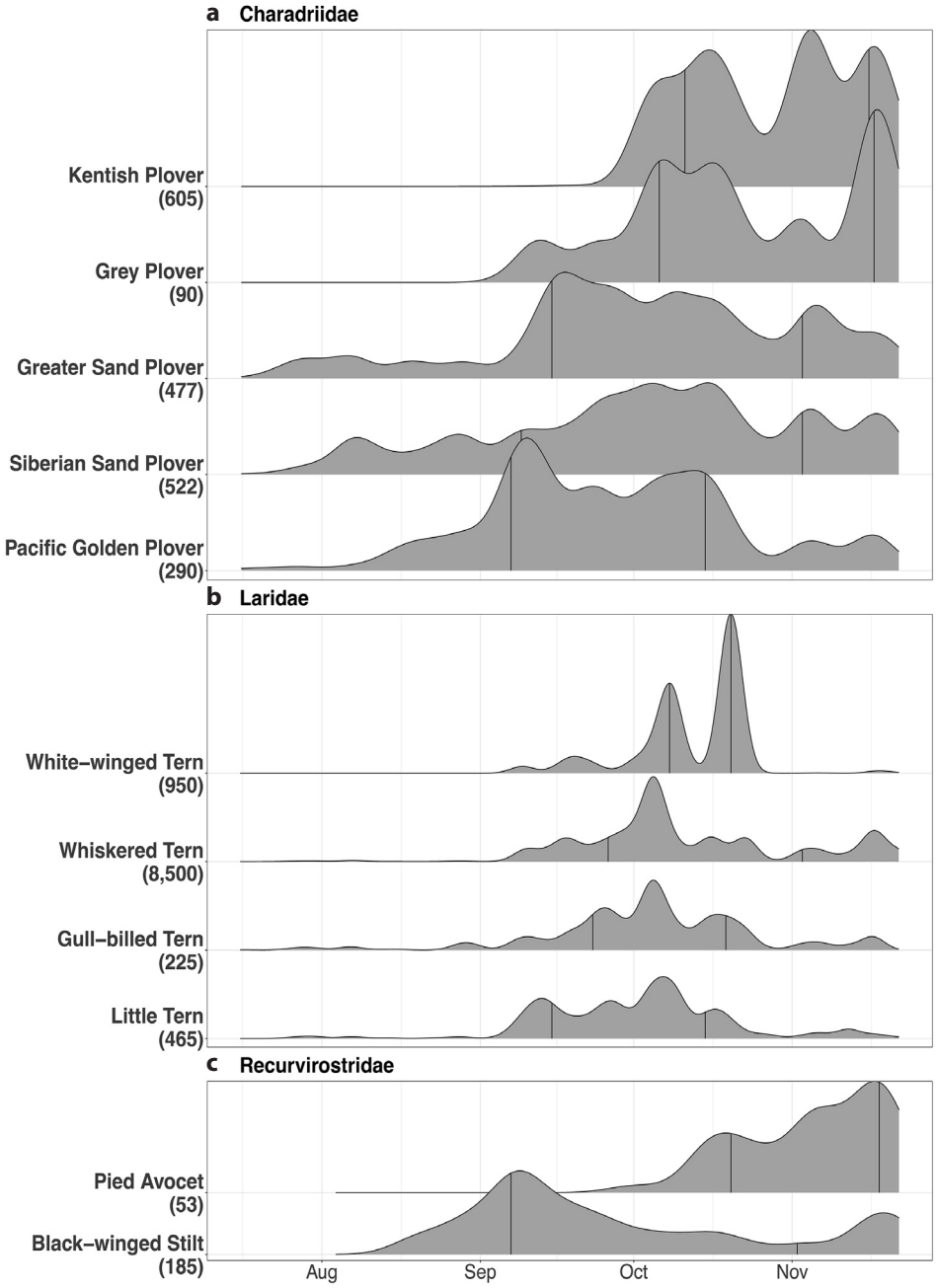

Fig. 4. Migration phenology of Charadriiformes species recorded in Tanza during southward migration in 2021. Vertical black lines represent the 20th and 80th percentiles of the cumulative abundance of each species, indicating the period of peak migration. Numbers below species names indicate the maximum count recorded during this period.

DISCUSSION

Importance of northern Manila Bay to shorebirds

Our study highlights the importance of northern Manila Bay for migratory shorebirds, including many globally threatened and nationally rare species (Tables 1 & S1, Fig. S1). This supports recognition of northern Manila Bay as a migratory shorebird site of high richness and abundance, and a key site for shorebirds in the Philippines (Li *et al.* 2009, Mundkur *et al.* 2017). It has been declared an Important Bird and Biodiversity Area (IBA No. PH010) by Birdlife International and a Key Biodiversity Area (KBA No. 25) by the Department of Environment and Natural Resources (DENR) (Mallari *et al.* 2001, Conservation International Philippines *et al.* 2006). Our frequent, year-round surveys further demonstrate that northern Manila Bay is crucial for one-fifth of its shorebird species as it supports >1% of their flyway populations (Fig. 2), and that high numbers of shorebirds also utilise the Bay outside of the migratory season (Table S2, Fig. S1).

Internationally, the presence of shorebirds that were tagged at multiple other EAAF shorebird sites suggests that northern Manila Bay plays a role in connectivity along the EAAF. During southward migration, some

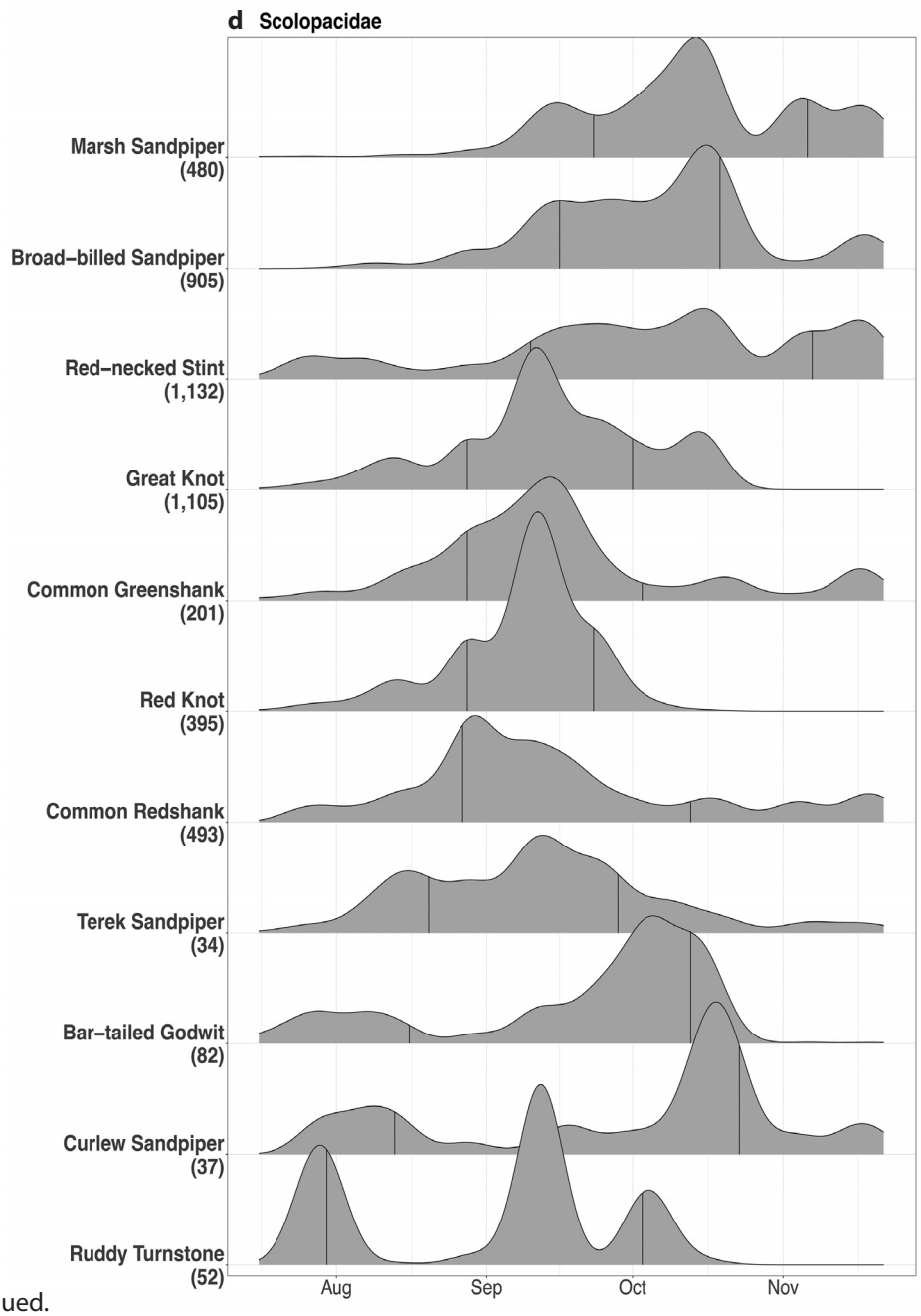

Fig. 4. continued.

shorebirds decrease sharply in abundance after the peak migration period (Figs. 4 & S1), suggesting that these species utilise northern Manila Bay as a stopover site for refuelling, which is crucial for shorebird survival (Murray & Fuller 2015). Additionally, Manila Bay sits on both the EAAF and the West Pacific Flyway (EAAFP 2018), the latter of which is mostly the Pacific Ocean with relatively few landmasses. Manila Bay is one of the few stopover sites available for shorebirds continuing further south onto other wintering areas.

High numbers and records of over-summering shorebirds

Our study adds to a growing recognition that over-summering sites, which have long been overlooked, are integral to shorebird population recruitment and persistence (Navedo & Ruiz 2020) and should be included in conservation assessments. Over-summering birds are thought to mainly comprise sexually immature birds or adults in poor condition (McNeil *et al.* 1994, Soto-Montoya *et al.* 2009). Over-summering has been hypothesised to be a strategy for immature birds to reduce risks associated with migration, given the low probability of successful breeding in the birds' first year (McNeil *et al.* 1994, Summers *et al.* 1995). Some studies suggest that high numbers of over-summering immature individuals are indicative of annual recruitment (Chowdhury 2012). Tanza and Pamarawan, by hosting over-summering immature shorebirds, could play an underappreciated role in the long-term viability of the populations of these species, especially in the case of Endangered shorebirds whose small population sizes would

be greatly aided by even small numbers recruiting each year (Finn 2010, Melville *et al.* 2016).

The regularity of over-summering records for Little Stints and Dunlins might suggest a need to re-evaluate the notion that they are merely vagrants in the Philippines (Fig. S1). Particularly noteworthy in our surveys were records of Little Stint in various states of plumage wear and of various ages, including immatures, suggesting that this migration path is regularly used by the species, as opposed to being accidental incursions by individuals (Fig. S3).

Protection and conservation of northern Manila Bay

We have demonstrated that Tanza, Pamarawan, and Pampanga each fulfil at least two criteria for qualifying as Wetlands of International Importance under the Ramsar Convention on Wetlands (Ramsar Convention Bureau 2016). Each of our survey areas 'support vulnerable, endangered, or critically endangered species or threatened ecological communities' (criterion 2; Tables 1 & S2, Fig. S1) and 'regularly supports 1% of the individuals in a population of one species or subspecies of waterbird' (criterion 6; Figs. 2 & S1). We also recorded some instances of waterbird abundance exceeding 20,000 individuals (criterion 5: 'regularly supports 20,000 or more waterbirds'; Fig. 3) which could be confirmed with long-term surveys. According to these metrics, the importance of our survey areas is comparable to, or even exceeding, that of the existing Ramsar sites in the Philippines (Ramsar Sites Information Service no date).

Unfortunately, much wetland habitat in Manila has already been lost during the 20th century (PEMSEA 2004, Jensen 2018) and the trend is unabating. Multiple large-scale reclamation projects are planned for northern Manila Bay such as the Manila Bay Integrated Flood Control and Coastal Defense and Expressway Project and the New Manila International Airport (Mooyaart *et al.* 2015, Mott MacDonald 2022a), which, when complete, could drastically alter 18,000 ha of northern Manila Bay (Wetlands International 2017). In particular, the New Manila International Airport, located near our survey areas (Fig. 1), will have significant adverse impacts causing degradation and loss of habitat, disturbance and displacement of species, especially migratory species, and on water quality, even at secondary sand mining and material disposal sites (Mott MacDonald 2021, 2022a). There are likely to be additional unpredicted adverse impacts, as the assessment did not capture many of the key species that we have recorded (Mott MacDonald 2022b). Reclamation and dredging works are already in progress, with site clearance almost near completion (Ganic 2022, Republic of the Philippines Public-Private Partnership Centre 2022; Fig. S4).

Already, a decline in shorebird numbers at Manila Bay has been observed (IUCN NL 2021), and aforementioned plans to reclaim natural coastal habitats will lead to further irrecoverable declines. The loss of this important shorebird habitat would deal a significant blow to migratory shorebirds, especially considering the paucity of other available sites. Shorebirds that exhibit site fidelity to these mudflats may also be directly impacted by construction activities or bird deterrence mechanisms when the airport is operational. Massive changes in the abiotic environment may also affect productivity of the mudflats and hence food availability for shorebirds. The situation is exacerbated by other threats that Manila Bay faces such as over-exploitation, pollution, eutrophication, and sea-level rise. If designated as a Ramsar site, habitats and shorebirds in northern Manila Bay would have increased protection against further and irreparable losses.

Past conservation successes in Manila Bay demonstrate that cooperation between public and private sectors can effect meaningful change. The 175-ha Las Piñas-Parañaque Critical Habitat and Ecotourism Area (LPPCHEA) Ramsar site was originally slated for reclamation, but proposals calling for its protection were successful (Wetlands International 2017). Considering the importance of northern Manila Bay as a shorebird habitat and the serious threats it faces, we advocate for a critical evaluation of the environmental impacts of ongoing and future development projects in Manila Bay, and for urgent and drastic action to safeguard these habitats.

While we adopt a bird-specific lens in this publication, habitat destruction in Manila Bay will also have ramifications for the hydrology of the bay, fisheries and coastal residents that depend on the integrity of the ecosystem (Both ENDS *et al.* 2021). Conversely, proper management of wetland habitats can have multiple benefits for biodiversity, the economy, and in nature-based climate solutions.

Importance of year-round surveys

There has been continued monitoring of Manila Bay by Wetlands International, the Department of Environment and Natural Resources (DENR), Wild Bird Club of the Philippines, and individual bird watchers (Mallari *et al.* 2001, Conservation International Philippines *et al.* 2006, Conklin *et al.* 2014). This includes rapid assessments like the Wetlands International and IUCN NL Manila Bay Rapid Habitat Inventory (Apr 2016, Nov 2016–Mar 2017, Jan–Apr 2018; Jensen 2018), and long-term efforts such as the annual Asian Waterbird Census which began in 1990 (Li *et al.* 2009, DENR – Biodiversity Management Bureau 2016). The Asian Waterbird Census, which is part of the International Waterbird Census, recommends that contributors count shorebirds over the second and third weeks of January, with counts from late November to February also being accepted to tabulate shorebird numbers across the EAAF (Mundkur *et al.* 2017). On a flyway level, coordinated counts over a short period of time provide estimates of total shorebird numbers (Hansen *et al.* 2022). On a site level however, this 'snapshot' does not allow the assessment of the importance of areas as staging or stopover sites for shorebirds. The period from late November to February is rather late in the migration season and most shorebirds would have already arrived in

their wintering grounds (Choi *et al.* 2016, Chan *et al.* 2019), with low numbers or even a complete absence of birds at key staging or stopover sites along the flyway.

Our surveys were carried out at an unprecedented frequency for a sustained duration. This allows us to generate, for the first time, year-round data of shorebirds at northern Manila Bay and to provide insight into the temporal trends within and across two migratory cycles. Our data demonstrate that the peak shorebird counts for Tanza and Pamarawan tend to be early in the migration season (Aug–Oct), coinciding with the earlier movements of shorebirds leaving their breeding grounds – concordant with northern Manila Bay's higher latitude compared to other Southeast Asian sites along the EAAF (Figs. 4 & S1). While we were unable to quantify peak northward migration dates, species such as Long-toed Stint *Calidris subminuta* showed large differences in counts between northward and southward migration months, suggesting differing migration strategies. Our findings underscore the need for consistent monitoring year-round to capture peak shorebird counts of all species. Year-round monitoring will also capture over-summering species and rarities. This will allow better understanding of the various values of coastal sites in the Philippines for shorebirds and ensure that these sites are not overlooked and inadvertently lost to development.

Future work for shorebird sites in the Philippines

Our surveys suggest that habitat utilisation patterns differ among species and more could be done to understand site connectivity within the Philippines. There remains great potential in northern Manila Bay for discoveries that would improve our understanding of shorebird ecology, especially with long-term monitoring. Beyond Manila Bay, other sites in the Philippines remain under-surveyed and additional key sites may yet be discovered (Yong *et al.* 2022). We recommend that shorebird surveys are conducted in some of the coastal mudflats in the northern Philippines, with priority given to those that are near Manila Bay (e.g., Lingayen Gulf), although with time, surveys should also be conducted on the bays of the Bicol Peninsula, a region where hardly any shorebird surveys have taken place (e.g., San Miguel Bay, Albay Gulf). Tracking technologies have proven to be of great utility in detecting previously unknown or inaccessible important shorebird sites and would complement long-term monitoring efforts (Chan *et al.* 2019). Securing funding and manpower to establish a list of key shorebird sites in the region and securing their future should be a priority given the rapid pace of coastal development and great risk of losing sites before we are able to recognise their value.

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ONLINE SUPPLEMENTARY INFORMATION

Table S1. Summary of survey effort for each area and site.

Table S2. Full species list of shorebirds and waterbirds recorded from frequent, year-round surveys in Tanza, Pamarawan and Pampanga, northern Manila Bay.

Table S3. Number of records of flagged shorebirds that were resighted in northern Manila Bay and the locations where they were first flagged.

Fig. S1. Counts of Charadriiformes shorebirds at Tanza, Pamarawan (Pulu, Sandbar, Saltpans), and Pampanga, northern Manila Bay.

Fig. S2. Black-tailed Godwits *Limosa limosa* in Pamarawan and Broad-billed Sandpipers *Calidris falcinellus* in Tanza.

Fig. S3. Little Stint *Calidris minuta* individuals exhibiting various plumages.

Fig. S4. Intensive construction and loss of habitat in Tanza and Pampanga.

DATA ACCESSIBILITY

For access to the survey data, please contact Irene C. Dy.

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