Avian Research

RESEARCH

Open Access

Coastal wetlands in Lianyungang, Jiangsu Province, China: probably the most important site globally for the Asian Dowitcher (*Limnodromus semipalmatus*)

Ziyou Yang[1], Jing Li[1], Yongxiang Han[2], Chris J. Hassell[3], Kar-Sin Katherine Leung[4], David S. Melville[5], Yat-tung Yu[6], Lin Zhang[1] and Chi-Yeung Choi[7*]

Abstract

Background: Despite an increasing number of surveys and a growing interest in birdwatching, the population and distribution of Asian Dowitcher (*Limnodromus semipalmatus*), a species endemic to the East Asian–Australasian and Central Asian Flyways, remains poorly understood, and published information about the species is largely outdated. In boreal spring 2019, over 22,432 Asian Dowitchers were recorded in a coastal wetland at Lianyungang, Jiangsu Province, China, constituting 97.5% of its estimated global population.

Methods: In 2019 and 2020, we conducted field surveys at Lianyungang to determine the numbers of Asian Dowitchers using the area during both southward and northward migrations. We also assessed the distribution and abundance of Asian Dowitchers elsewhere along the China coast by searching literature and consulting expert opinion.

Results: The coastal wetlands of Lianyungang are the most important stopover site for Asian Dowitchers during both northward and southward migrations; they supported over 90% of the estimated global population during northward migration in two consecutive years (May 2019 and 2020). This area also supported at least 15.83% and 28.42% (or 30.74% and 53.51% using modelled estimates) of the global population during southward migration in 2019 and 2020 respectively. Coastal wetlands in the west and north of Bohai Bay also have been important stopover sites for the species since the 1990s. Although comprehensive, long-term monitoring data are lacking, available evidence suggests that the population of the species may have declined.

Conclusions: The high concentration of Asian Dowitchers at Lianyungang during migration means the species is highly susceptible to human disturbances and natural stochastic events. The coastal wetlands of Lianyungang should be protected and potentially qualify for inclusion in China's forthcoming nomination for World Heritage listing of Migratory Bird Sanctuaries along the Coast of Yellow Sea-Bohai Gulf of China (Phase II) in 2023. Additional research is needed to understand Asian Dowitchers' distribution and ecology, as well as why such a high proportion of their population rely on the Lianyungang coast.

Keywords: Lianyungang, *Limnodromus semipalmatus*, Shorebird, Stopover ecology, Yellow Sea, World Heritage

Background

The Asian Dowitcher (*Limnodromus semipalmatus*), also known as the Asiatic Dowitcher, is a medium-large shorebird that migrates along the East Asian–Australasian

*Correspondence: choimo@yahoo.com
[7] School of Environmental Science and Engineering, Southern University of Science and Technology, Shenzhen 518055, China
Full list of author information is available at the end of the article

and Central Asian Flyways. It breeds during the boreal summer in freshwater wetlands in steppe regions in disjunct areas extending from Russia, through Mongolia to north-east China, and spends the non-breeding season in coastal areas in Southeast Asia and Northwest Australia; small numbers also occur in the Indian subcontinent (Birdlife International 2016; Mundkur et al. 2017). China's Yellow Sea coast serves as an important stopover region for Asian Dowitchers during both northward and southward migrations (Barter 2002; Yang et al. 2019).

The Asian Dowitcher was first listed in IUCN's Red Data Book in 1977 as "rare" (King 1981); currently it is listed as "Near Threatened", based on a 2008 global population estimate of 23,000 birds (BirdLife International 2016). This population estimate is currently adopted by Wetlands International (2020) in their Waterbird Population Estimates 5, which identifies the 1% threshold (viz. 230) used under Criterion 6 for the identification of Wetlands of International Importance under the Ramsar Convention (2012). Wetlands International (2020) also notes that the population is declining. Conklin et al. (2014) noted that "insufficient data exist to evaluate suspected population declines due to habitat degradation on the flyway", while Hansen et al. (2016) estimated the population as 14,000.

On 13 May 2019, our survey team counted 22,432 Asian Dowitchers (97.5% of its estimated global population- Wetlands International (2020)) on the Qingkou Estuary tidal flat at Lianyungang, Jiangsu Province, China (Yang et al. 2019), this being by far the highest number of the species recorded at a single site along the East Asian–Australasian Flyway (hereafter EAAF). It was unclear, however, whether the high number in 2019 was a rare incident due to factors such as poor weather, or whether birds regularly stage at Lianyungang. It was also unclear whether any other sites in China support (or used to support) a significant number of Asian Dowitchers. To answer these questions, we: (1) conducted field surveys on the Lianyungang coast during southward migration in 2019, and both northward and southward migrations in 2020; (2) examined the species' moult status and determined the adult:juvenile ratio during the field surveys, and (3) 93 collated data from literature, as well as unpublished count data, to better understand the distribution and numbers of Asian Dowitchers in China.

Methods

Abundance, passage dates, adult:juvenile ratio and moult at Lianyungang

We scheduled all surveys around high spring tides when shorebirds are concentrated, thus facilitating counting. During northward migration in 2020, we conducted three surveys in late March, late April and mid-May respectively. During southward migration in 2019 and 2020, we conducted six and five surveys respectively between July and October. We spread the southward migration surveys over four months, because Asian Dowitchers are thought to pass through China from July to October (Higgins and Davies 1996; Y. Han pers. obs.). Each survey lasted three to five days depending on how many Asian Dowitchers were present in the study area. For example, surveys in August lasted longer than those in July and October, because the sheer number of Asian Dowitchers was much higher in August, and we conducted surveys repeatedly over several days to allow more accurate assessment of the number of Asian Dowitchers among the high number of Black-tailed Godwits (*Limosa limosa*) and Bar-tailed Godwits (*Limosa lapponica*) present.

We adopted a survey protocol similar to that used for the northward migration survey in 2019 (Yang et al. 2019). During each survey, a group of four to ten observers split into at least three groups to count shorebirds at the Linhong Estuary (119.25° E, 34.79° N), Qingkou Estuary (119.21° E, 34.83° N) and Xingzhuang Estuary (119.19° E, 34.88° N) tidal flats as well as the high-tide roosts (e.g. aquaculture or undeveloped ponds nearby; Fig. 1). The numbers of Asian Dowitchers were recorded using [×20–60] spotting scopes mounted on tripods, ×8–10 binoculars, and cameras, during three survey periods: (1) immediately before high tide when shorebirds stayed on tidal flats near the seawall; (2) during high tide when shorebirds moved closer to the seawall or were at supratidal high-tide roosts; and (3) immediately after high tide when shorebirds dispersed or returned to the tidal flat from high tide roosts. In addition to tidal flats, supratidal high-tide roosts were also an important target of our surveys because shorebirds aggregated at sites inside the seawall, especially during very high tides which inundated the entire tidal flat (Choi et al. 2014a, 2019; Jackson et al. 2019, 2020).

To estimate the total number of Asian Dowitchers during the survey, while minimising the chance of double counting, we first added up the number of individuals recorded across all survey sites during each observation period (i.e. before, during and after high tide). Then, we used the largest sum among the three observation periods as the most conservative estimate for the species on that day. We repeated the above procedure for each survey day and used the highest estimate within the survey period as the final estimate of the number of Asian Dowitchers at Lianyungang.

During southward migration, we classified Asian Dowitchers as juveniles (birds hatched in the year when the survey was conducted) or adults (birds hatched before the year when the survey was conducted) based on

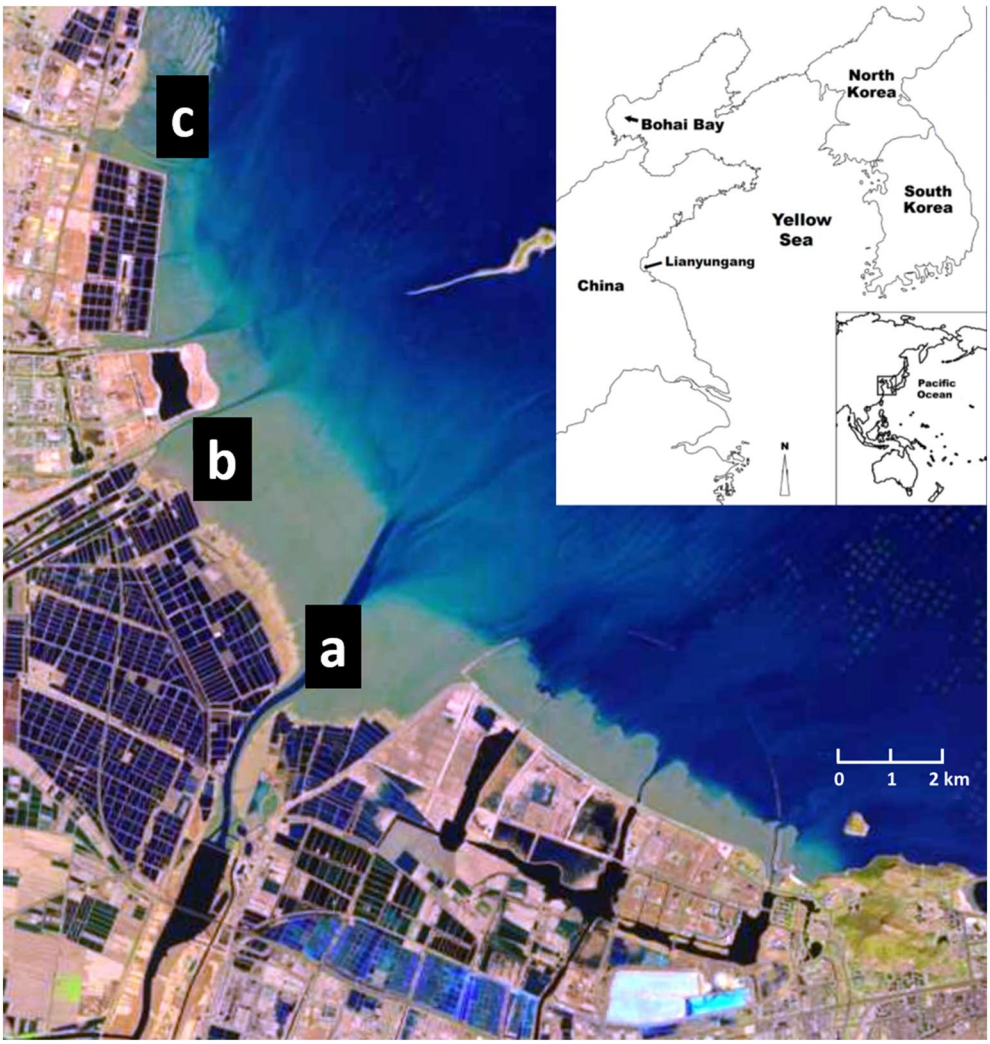

Fig. 1 Map of the study area in Lianyungang and its location in northern Jiangsu Province, China (inset). Letters denote the locations of (**a**) Linhong Estuary, (**b**) Qingkou Estuary and (**c**) Xingzhuang Estuary tidal flats. Most of the coastline is bounded by concrete seawalls, areas immediately on the landward side of the seawall were mostly claimed in 2011. The major type of land use inside the seawall is aquaculture or undeveloped ponds (shown in the darkest blue, mainly rectangle-shaped). A salt pond complex (shown in different shades of blue) and a wastewater basin (shown in the lightest blue) are also present south of Linhong Estuary. Other colours denote dry land. Base image courtesy of Landsat

plumage characters described by Prater et al. (1977) and Zhang and Zhang (2018)—generally adult birds still showed some breeding plumage, whereas juveniles were washed buff with streaking on the breast; adult plumage was more worn, whereas juvenile coverts, mantle and scapulars were relatively fresh and neatly arranged, with clear pale buff fringes. We used the age data to estimate the adult:juvenile ratio during southward migration in 2019 and 2020. In the long-term, adult:juvenile ratio may provide insights into the annual productivity of Asian Dowitchers.

We used Thompson's model to estimate the average arrival dates, stopover durations and departure dates for all Asian Dowitchers during southward migration in 2019 and 2020 (Thompson 1993; Rogers et al. 2010; Choi et al. 2016). Previous studies have shown that shorebirds such as Spoon-billed Sandpiper (*Calidris pygmaea*) and Nordmann's Greenshank (*Tringa guttifer*) spend an extended period on China's Jiangsu coast to moult their primary feathers during southward migration (Yang et al. 2020). To determine whether Asian Dowitchers also undergo primary moult during southward migration stopover, whenever possible we photographed birds as they were stretching their wings, taking off, landing or flying and examined these for evidence of primary moult (Yang et al. 2020). Additional opportunistic photographs

of Asian Dowitchers taken during southward migration between 2011 and 2018 on the Lianyungang coast were included in the analysis.

Abundance and distribution in China

To better understand the distribution and abundance of Asian Dowitchers in China, we acquired data from two regular surveys: the China Coastal Waterbird Census (hereafter CCWC) and the Yellow Sea-Bohai Region Coordinated Waterbird Survey (hereafter YSBRCWS). The CCWC is organised by volunteer birdwatchers along the coast of China (Bai et al. 2015). Between 2013 and 2019, CCWC surveys were made in 25 locations along China's coast; some locations were surveyed monthly for the 7 years while others were surveyed irregularly from year to year (Choi et al. 2020). The YSBRCWS is a coordinated annual survey led by staff members of nature reserves and wetland parks, as well as professionals and volunteers from universities, research institutes and NGOs. The YSBRCWS took place each year in April from 2016 to 2019, and recorded waterbirds at 23 sites around the Yellow Sea and Bohai Bay (Chen et al. 2016, 2017, 2018; Chen and Lv 2019).

Besides these regular surveys, we examined opportunistic records such as sightings submitted to eBird (Sullivan et al. 2009, 2014) and the China Bird Report Centre (hereafter CBRC). On eBird, we downloaded China's Asian Dowitcher records up to April 2019. Similarly, we retrieved all the Asian Dowitcher records since 2009 from CBRC's current (http://www.birdreport.cn/) and earlier (http://www.szbird.org.cn/birdtalker.net/index.asp) websites. Observations prior to 2010 were not readily available online, so we obtained those records by referring to the printed copies of the annual China Bird Report for the period 2004–2009. Before analysing data from eBird and CBRC, we treated multiple observations with the same location coordinates, date and abundance as duplicates, and dropped all but one observation within each group of duplicates, so every observation retained in our analysis would be independent.

All statistical analyses were performed in R v.3.4.3 (R Core Team 2017), except for passage date analysis where SYSTAT Version 12 was used instead (Systat Software Inc 2007).

Results

Passage dates and abundance in Lianyungang

During southward migration, Asian Dowitchers started arriving in Lianyungang in mid-July. Plumage characters suggested that these early-arriving individuals were adults (that had possibly failed to breed successfully), rather than immatures that had only undertaken a partial northward migration. The number of Asian Dowitchers peaked in early August in both years, reaching at least 3640 and 6537 individuals on 4 August in 2019 and 2020 respectively (Fig. 2). Two weeks after the peak, numbers dropped by a few thousands. The great majority of Asian Dowitchers had departed by early September and no more than 400 individuals were recorded after 4 September. Few Asian Dowitchers were observed at Lianyungang in October (3 juveniles in 2019, and three individuals in 2020 that were too distant to determine their age; Fig. 2).

Based on our modelled estimates, during southward migration Asian Dowitchers arrived at Lianyungang on 17 July ± 0.3 (SD) days on average and departed on 4 Aug ± 18.9 days in 2019, with an average stopover duration of 18.4 days ($n = 6$ rounds of survey). In 2020, the average arrival date, departure date and stopover duration were 26 July ± 11 days, 15 August ± 17 days and 20 days, respectively ($n = 5$ rounds of survey). The modelled cumulative total number of Asian Dowitchers using Lianyungang were 7071 individuals in 2019 (4937–9204 individuals 95% confidence interval) and 12308 (5341–19275 individuals 95% confidence interval) in 2020, which are substantially higher than the peak counts (3640 and 6537 individuals in 2019 and 2020, respectively).

During northward migration in 2020, a total of 21745 Asian Dowitchers were recorded on 12 May when 82.55% individuals were at Qingkou Estuary tidal flat and the remainder at Linhong Estuary high tide roosts. No Asian Dowitchers were recorded in March, and only small numbers in April (1730 individuals on 20 April) and June (34 individuals on 20 June), suggesting that Asian Dowitchers passed by Lianyungang in a narrower time window during northward than on southward migration.

Adult:juvenile ratio and moult in Lianyungang

In 2019 and 2020, we did not record any juvenile Asian Dowitcher prior to August. On 4 August 2020 amongst the 498 individuals whose plumage details were clearly visible, 8.03 ± 1.22 (SE) % were juveniles, and the juvenile ratio was similar over the next 2 weeks (Additional file 1: Fig. S1). The proportion of juveniles reached 11.8 ± 2.54 (SE) % ($n = 161$) on 19 August 2019 and 20.0 ± 1.59 (SE) % ($n = 630$) on 4 September 2019. By 18 September 2019 and 2020, up to 90% of the Asian Dowitchers observed during the survey were juveniles. All three Asian Dowitchers observed on 2 October 2019 were juveniles (Additional file 1: Fig. S1). In general, juvenile arrival and departure times at Lianyungang were later than those of the adults. Although we did not record any juveniles until early August, photos from previous years showed that juveniles (at least one individual) appeared at Lianyungang as early as 31 July in 2011.

We examined 244 photographs of Asian Dowitchers taken opportunistically at Lianyungang during southward

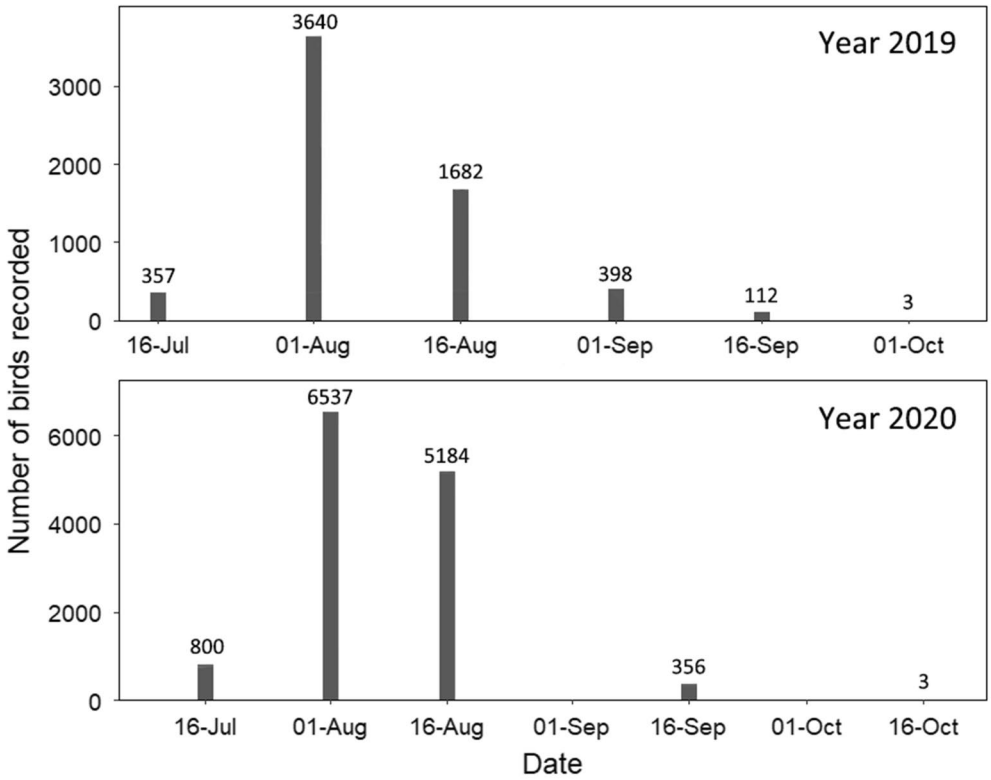

Fig. 2 The number of Asian Dowitchers recorded at the Lianyungang coast in autumn 2019 and 2020. Each bar represents a single survey

migration between 2011 and 2020. A total of 346 birds (including 270 adults, 59 juveniles and 17 individuals with unclassified age) had extended wings; none were in active primary moult or showed signs of arrested/suspended moult of the primaries.

Abundance and distribution in China

Combining the observation records from all sources, Lianyungang, as well as the North and North-west Bohai Bay in China are the most important stopover sites for Asian Dowitchers (Fig. 3). Observations from the CCWC show that from 2013 to 2019, Asian Dowitchers were recorded at 12 sites along China's coast, but Lianyungang was the only site with over 1% of the global population. The only site with close to 1% of the population (230) was Rudong in southern Jiangsu, with 200 individuals recorded in July 2016. Combining the CCWC records with our survey results, we found that between 2013 and 2020 Lianyungang's Qingkou Estuary tidal flat supported > 10% of the global population in 6 of the 8 years during northward migration and in 2 years during southward migration (Table 1).

Between 2016 and 2019, Asian Dowitchers were recorded at seven sites of the YSBRCWS, but the only site with > 1% of the global population estimate was Luannan (Additional file 1: Fig. S2), with 263 individuals in 2016. All other sites had fewer than 50 individuals. Regular birdwatching activity in Hong Kong since 1958 and systematic shorebird monitoring in the Mai Po—Inner Deep Bay Ramsar Site which started in 1998 suggest that Asian Dowitchers migrate through the area annually, but only in small numbers (Carey et al. 2001). Out of the 41 northward migration counts from 1958 to 1998, as well as 34 peak counts in northward migration seasons between 1999 to 2016, only four exceeded the 1% global estimates [> 300 individuals in 1985 and 1991 (Carey et al. 2001); 540 on 2 May 2003 (Yu et al. 2004); 428 on 28 April 2008 (Anon 2009)].

As to opportunistic observations, there were 951 independent eBird observations of Asian Dowitchers, covering 14 provinces of China, with the earliest record from 1986. Among these observations, 11.46% reported the presence of Asian Dowitchers without any abundance information and 86.96% with a reported abundance of fewer than 230 individuals (1% estimate of its global population). Only 1.58% (15 observations) reported more than 230 Asian Dowitchers (Additional file 1: Fig. S3). These 15 observations clustered around Tianjin's Hangu coast ponds (117.98° E, 39.22° N, in North-west Bohai Bay; Additional file 1: Fig. S2) during northward

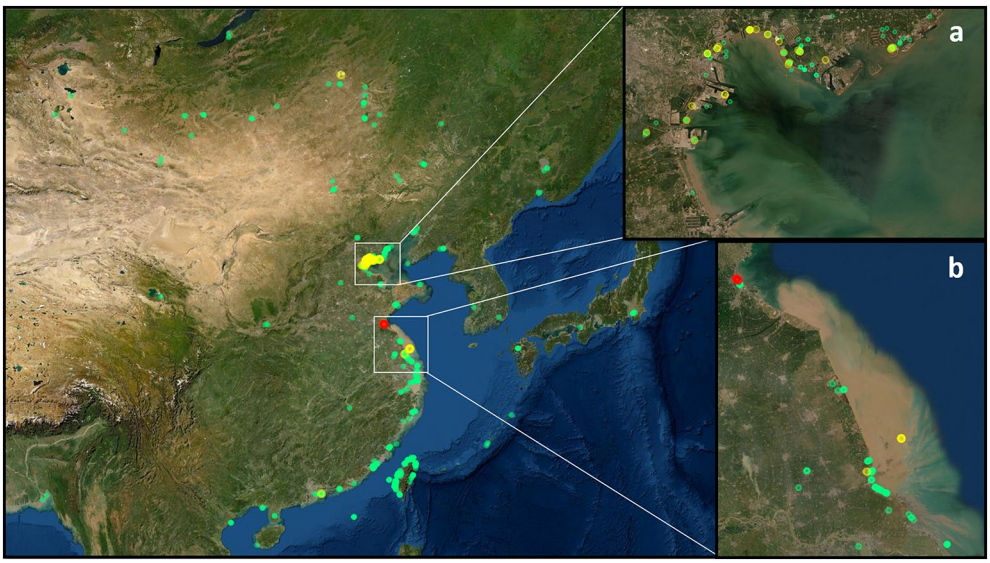

Fig. 3 The distribution of Asian Dowitchers in East Asia based on observations made between 1987 and 2019. Red, yellow and green dots denote sites where over > 10%, 1–10% and < 1% of the Asian Dowitcher global population was recorded respectively. The area of Bohai Bay (**a**) and Lianyungang coast (**b**) are enlarged in the inset maps. Basemap courtesy of © Esri

Table 1 The maximum number of Asian Dowitchers recorded at Lianyungang's Qingkou and Linhong Estuary tidal flats during northward (March–May) and southward (July–October) migration seasons from 2013 to 2019

	2013	2014	2015	2016	2017	2018	2019	2020
Northward migration	*2800*	1001	153	*3000*	*3000*	*7730*	*22,432*	*21,745*
	12 May	10 Apr	3 May	7 May	13 May	7 May	13 May	12 May
Southward migration	800	700	500	10	1000	511	*3640*	*6537*
	22 Jul	1 Aug	25 Jul	19 Aug	17 Jul	11 Aug	18 Aug	4 Aug

Counts over 1% of the population (230) are underlined. Counts over 10% are shown in italics

migration, and the Hebei coast (118° E, 39° N, in the North Bohai Bay) during both southward and northward migrations. Thirteen out of the 15 observations were submitted by members of the Global Flyway Network (hereafter GFN) who have been visiting Hangu and Luannan annually since 2009 to survey shorebirds during northward migration and whose records show that China's Bohai Bay supported over 1% of the global population of Asian Dowitchers in 8 of the 10 years between 2010 and 2020 (GFN, unpublished data). In particular, Hangu coast supported 1754 and 1703 Asian Dowitchers in May 2017 and 2018 respectively (Table 2).

Between 2002 and 2019, 235 opportunistic observations of Asian Dowitchers were submitted to the CBRC, of which 95.32% included abundance information (Additional file 1: Fig. S4). Those observations show that the Tianjin coast regularly supported over 230 Asian Dowitchers from 2005 to 2015, especially during southward migration. The only other site with > 1% of the population was Shi Jiu Tuo (also known as "Happy Island"; 118.82° E, 39.13° N) in North Bohai Bay (Additional file 1: Fig. S2), with 260 individuals in May 2005.

Discussion

Despite an increasing number of field records over time (Additional file 1: Fig. S5), identification of important stopover sites and determination of population trends of Asian Dowitcher remain challenging. The latest field records along the EAAF indicate that during both northward and southward migration stopovers, this species is strongly concentrated in two regions, namely Lianyungang and Bohai Bay, with the former repeatedly holding almost the entire global population (> 94.5%) of this species during northward migration. This highlights the global importance of this site.

In 2019, two areas in coastal China were listed as natural World Heritage sites (UNESCO 2019) for their significance as migratory bird sanctuaries. China is currently preparing the nomination proposal documents for additional sites for World Heritage listing under Migratory

Table 2 Sites where > 1% of Asian Dowitchers population (230) were recorded

Site	Maximum count	Date recorded	Season	References
Lianyungang	22,432	13 May 2019	NM	Yang et al. (2019)
Lianyungang	6537	4 August 2020	SM	This study
North Bohai Bay (Shi Jiu He/Daqing He, Hebei)	1100	12 May 1994	NM	Barter (2002)
North Bohai Bay (Luannan, Hebei)	1754	8 May 2017	NM	Hassell et al. (2019)
North-west Bohai Bay (Tianjin coast)	966	10–14 May 2000	NM	Barter et al. (2001)
North-west Bohai Bay (Tianjin coast)	420	1 August 2010	SM	Conklin et al. (2014)
North-west Bohai Bay (Tanggu, Tianjin coast)	1447	17 July 2009	SM	This study
Bohai Bay	1153	2 May 2002	NM	Barter et al. (2003)
Yancheng (coast between Zhou Gang and Dou Long Gang)	840	Between 22 April and 3 May 2001	NM	Barter (2002)
Yancheng (Dongsha Shoals)	664	May 1996	NM	Wang and Barter (1998)
Yancheng (Dongsha Shoals)	1320	1 September 1997	SM	Wang and Barter (1998)
Deep Bay (incl. Mai Po and Futian)	540	2 May 2003	NM	Yu et al. (2004)

NM and SM are abbreviations for northward and southward migration respectively. Only the highest count at each site during each migration period is shown in the table

Bird Sanctuaries along the Coast of Yellow Sea-Bohai Gulf of China (Phase II). In 2019, representatives from the Lianyungang Municipal Bureau of Natural Resources and Planning proposed the inclusion of Lianyungang to the tentative list to ensure the integrity of the migratory waterbird habitat (Wen 2019). Several sites on the Hebei coast (including Luannan) were also on the list proposed in 2019 (Wen 2019). It is to be hoped that these will be successfully nominated in 2023, but this will require the development and implementation of appropriate management actions.

Critical stopover sites for Asian Dowitcher

Although fewer dowitchers were recorded on southward than northward migration the maximum single-day count at Lianyungang during southward migration in 2019 and 2020 still represented a significant proportion of the global population. This, together with the discovery that over 90% of Asian Dowitchers were recorded on a single day in two consecutive springs (Yang et al. 2019), indicate that Lianyungang coast is the most important stopover site for Asian Dowitchers.

The large number of Asian Dowitchers on the Lianyungang coast is not a one-off event, because high numbers were also recorded here in the past. The relatively low numbers reported before 2019 could be the result of a lack of observers (only one observer in most of the previous surveys) and the limited time spent counting Asian Dowitcher when other waterbird species also needed to be counted. It is also worth noting that the peak number during southward migration in 2020 was almost 1.8 times higher than that in 2019. Likewise, their number on 18 August 2020 was three times as high as that on the same date in 2019. We think that this is because we managed to find more high-tide roosts where Asian Dowitchers congregated in 2020, rather than a major change in numbers present.

Although Asian Dowitchers do not undergo primary moult in Lianyungang, our modelled estimates and peak count records indicate that as many as 65,000 individuals stayed here for approximately 3 weeks in 2019 and 2020 during southward migration. Three satellite-tagged Asian Dowitchers from Mongolia stayed at Lianyungang for 21, 29 and 36 days (A. Gungaa pers. comm.). These stopover durations are much longer than Great Knots (*Calidris tenuirostris*) that deposited little fuel at a temporary stopover site (2.3 ± 1.9 days), but similar to Great Knots that attained substantial fuel stores at a staging site (31.0 ± 13.6 days; Ma et al. 2013), suggesting that Lianyungang may serve as a critical staging site (Warnock 2010) for Asian Dowitchers to deposit large amounts of fuel before the next leg(s) of their migration.

The nearest high counts during southward and northward migrations outside Lianyungang were obtained in Luannan, Bohai (< 2000 in 2017). Nowhere else in China, nor elsewhere in East Asia could we find a comparable number based on records from the last 30 years. The other important stopover sites recognised in the assessment, such as Tianjin and Luannan in the North-west and North Bohai Bay, are consistent with the earlier studies (Barter 2002; Barter et al. 2003), indicating that these sites used to and continue to be important to Asian Dowitchers.

Unclear population trend

Compared to the early record of 1100 individuals (Barter 2002), the number of Asian Dowitchers at Shi Jiu Tuo has not exceeded 270 individuals since the early 2000s, suggesting a decrease of at least fourfold. However, locations with regular and consistent long-term data, such as Hong Kong and Northern Bohai Bay, did not show any consistent population trend (Additional file 1: Fig. S6). Moreover, there were relatively few Asian Dowitchers in Hong Kong, while the species was not the primary survey focus at northern Bohai Bay and therefore, not searched for comprehensively in surveys (Hassell et al. 2019). Such long-term datasets are therefore not ideal for trend analysis, as a result the overall population trend for Asian Dowitcher remains unclear.

Despite the lack of data, the population of Asian Dowitchers is believed to be decreasing (Wetlands International 2020). Coastal wetlands along the EAAF have decreased substantially in both area and environmental quality over the past few decades (Melville 1997; Chen et al. 2019; Murray et al. 2014; Melville et al. 2016), which in turn has led to the marked population declines of many migratory shorebirds relying on these habitats (Moores et al. 2016; Peng et al. 2017; Studds et al. 2017). The significant decrease in the areal extent and benthic prey resources in the endangered Yellow Sea tidal flats (Murray et al. 2015), in particular, have been recognised as a key factor contributing to shorebird population declines along the EAAF (Amano et al. 2010; Piersma et al. 2017; Studds et al. 2017; Choi et al. 2018; Zhang et al. 2018). Many migratory shorebirds which share similar habitat use patterns as Asian Dowitcher and rely heavily on coastal wetlands as their staging, stopover and/or non-breeding grounds have undergone considerable population declines (Studds et al. 2017).

Threats and gaps

The highly restricted distribution of Asian Dowitchers during their migration stopover may reflect that a unique habitat is required by the species or the fact that previously suitable habitats have been destroyed thus forcing the entire population to very limited sites (Rogers et al. 2010). The species is therefore highly susceptible to human disturbances (Jiangsu Ocean and Fisheries Bureau 2018) and natural stochastic events.

The remaining key intertidal habitats for Asian Dowitcher at Lianyungang (Chan et al. 2019; Jackson et al. 2021) and Bohai Bay (Yang et al. 2011; Murray et al. 2014; Hassell et al. 2019) have shrunk substantially due to exotic cordgrass *Spartina alterniflora* invasion and past land claim activities, with a 31.3% decrease in tidal flat extent at Lianyungang between 2000 and 2015 (Jackson et al. 2020) and a 34% decrease in tidal flat extent at western and northern Bohai Bay between 1993 and 2010 (Yang et al. 2011). This trend is likely to continue due to the "blue bay" project at Linhong Estuary, where about 1870 ha of tidal flats and shallow water area will be turned into sandy beaches and recreational areas. There have also been reports on increasing conflicts between shellfish farmers and birds on tidal flats [i.e. use of pesticides and firecrackers for deterring birds from Razor Clam (*Sinonovacula constricta*) farming on the Xingzhuang Estuary tidal flat (Y. Han pers. obs.), as reported elsewhere in the Yellow Sea region (Choi et al. 2014b)]. It is critically important to quantify and mitigate the impact of such activities on coastal wetlands, especially those where Asian Dowitchers congregate. Additionally, the lack of suitable high-tide roosts may pose a further threat as Asian Dowitchers in Lianyungang currently rely heavily on the undeveloped ponds near Linhong Estuary tidal flat for their high-tide roosts which are scheduled for development such as a 1370 ha "wetland park" tourist facility (Lianyungang Municipal Development and Reform Commission 2019) that does not take into account the needs of shorebirds. Meanwhile, aquaculture ponds can only provide suitable roosting habitat when they are drained (Jackson et al. 2019), but the current drainage schedule of Lianyungang's aquaculture ponds does not coincide with peak shorebird migration months (Z. Yang unpublished data). Asian Dowitchers are forced to use supratidal roosts when the tide height at Lianyungang is above 500 cm (Yellow Sea datum point) and so needed these areas for approximately 14 and 17 days in May and August respectively. There is a need to conserve and manage roosting habitats during the peak migration months, otherwise Asian Dowitchers will expend extra energy looking for roosts at a time when energy budgets are critical as they undertake pre-migratory fattening.

There is an urgent need to understand why Lianyungang attracts such a high proportion of the global population of Asian Dowitcher. Our observations suggest that the great majority of Asian Dowitchers were moving within the 20–30 km^2 coastal area, extracting polychaetes mainly from the tidal flats between Qingkou Estuary and Linhong Estuary, but this needs to be studied through targeted research on both foraging behaviour and benthic prey stocks. The Chinese government has introduced tough regulations on land reclamation (Zhao 2018), however changes in prey stocks may still occur even when habitats are not directly destroyed, highlighting the need to monitor shorebirds' benthic food resources and maintain a healthy ecosystem (Zhang et al. 2018; Choi et al. 2017). An improved understanding of Asian Dowitchers' diet can enable a better assessment as to how they may respond to future changes. Future research should also include the use of tracking devices to better understand

the species' activity pattern in relation to foraging site selection.

One limitation of our study is that, while we obtained a reasonable estimate of the number of Asian Dowitchers at Lianyungang, because our surveys were made at high tide, we were not able to map the species' distribution in the study area throughout the tidal cycle. At high tides shorebirds are pushed into a small area of relatively high elevation (i.e. Qingkou Estuary tidal flat), however at low tide Asian Dowitchers spread out over a vast region to forage. Although all the record-breaking numbers of Asian Dowitchers were counted at the Qingkou Estuary tidal flat, field observations suggest that Asian Dowitchers move between Qingkou Estuary and the adjacent Linhong and Xingzhuang Estuary tidal flats. Therefore, it appears that the tidal flats of our study area are important to the species and worthy of conservation.

There is little current information available for key non-breeding sites in Indonesia (Li et al. 2009; Hansen et al. 2016; Iqbal et al. 2021) while breeding distributions are known to be affected by drought cycles (Melnikov 1998). Fortunately, there have been and will continue to be improved survey and monitoring efforts at the key breeding, non-breeding and staging/stopover sites. In 2021, the Chinese National Forestry and Grassland Administration and the Ministry of Agriculture uplisted Asian Dowitcher from unprotected to the Class II protection (National Forestry and Grassland Administration 2021). This change will lead to heavier penalties and may discourage the poaching of the species while more funding may be devoted to conservation and research. Future research should continue the use of tracking devices to determine migratory linkages and identify additional stopover sites, moulting grounds and key non-breeding areas of Asian Dowitchers.

Conclusions

Asian Dowitchers on migration congregate at a very limited number of sites, namely Lianyungang (> 90% global population), and to a lesser extent the west and north of Bohai Bay, during migration stopovers in China, making them very susceptible to stochastic events. We strongly recommend that the coastal wetlands of Lianyungang be nominated for World Heritage listing under Migratory Bird Sanctuaries along the Coast of Yellow Sea-Bohai Gulf of China (Phase II) in 2023 in recognition of their global importance to Asian Dowitchers, and at least 19 other species of shorebirds that have been recorded in internationally important numbers (Chan et al. 2019). The new information on highly concentrated distribution during migration stopover should be taken into consideration when reviewing the IUCN Red List Status of this species. The lack of current information on the breeding and non-breeding distribution and ecology of Asian Dowitcher highlights the urgent need for additional research.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40657-021-00272-7.

Additional file 1: Figure S1. The percentage of juvenile Asian Dowitchers recorded on the Lianyungang coast during southward migration in 2019 and 2020. **Figure S2.** The region of North and North-west Bohai Bay and its location in China (inset). **Figure S3.** The frequency distribution of different reported abundances of Asian Dowitchers in China, based on 951 independent eBird observations reported between 1986 and 2019. **Figure S4.** The frequency distribution of different reported abundances of Asian Dowitchers in China, based on 235 independent China Bird Report Centre observations reported between 2002 and 2019. **Figure S5.** The number of Asian Dowitcher coastal (circles) and inland (triangles) records in China from both regular surveys and opportunistic observations each year from 1986 to 2018. **Figure S6.** The population trend and its 95% confidence interval of Asian Dowitchers at (**a**) northern Bohai Bay during northward migration, (**b**) Hong Kong during northward migration and (**c**) Hong Kong during southward migration (note scales differ between figures).

Acknowledgements
We thank all citizen scientists who submitted their data to eBird and the China Bird Report Centre, reviewers who reviewed the data and technicians who maintain the database. We are indebted to Simba Chan, Larry Chen, Amarkhuu Gungaa, Shengwu Jiao and Gankhuyag Purev-Ochir for suggestions, comments and data collection.

Authors' contributions
C-YC, K-SKL, JL, LZ, YH and ZY participated in the surveys to collect data, C-YC, K-SKL and ZY analysed the data, ZY and C-YC led the writing. DSM, CJH and Y-TY provided valuable recommendations for the manuscript. All authors read and approved the final manuscript.

Funding
Data collection and manuscript write-up were financially supported by Zhilan Foundation, Ocean Park Conservation Foundation, Hong Kong (OPCFHK) as well as the Taihu Lake Project Centre of the Alxa SEE Foundation. C-Y Choi was financially supported by the Science and Technology Innovation Committee of Shenzhen Municipality (JCYJ20190809115207397).

Availability of data and materials
The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Spoon-Billed Sandpiper (Shanghai) Environmental Protection Technology Co., Ltd., Shanghai 201100, China. [2]Lianyungang Xugou Primary School, Lianyungang 222042, China. [3]Global Flyway Network, PO Box 3089, Broome, WA 6725, Australia. [4]Hong Kong Waterbirds Ringing Group, Mai Po Nature Reserve,

Hong Kong, China. [5]1261 Dovedale Road, RD 2 Wakefield, Nelson 7096, New Zealand. [6]Hong Kong Bird Watching Society, 7C, V Ga Building, 532 Castle Peak Road, Lai Chi Kok, Kowloon, Hong Kong, China. [7]School of Environmental Science and Engineering, Southern University of Science and Technology, Shenzhen 518055, China.

Received: 31 December 2020 Accepted: 28 June 2021
Published online: 08 July 2021

References

Amano T, Székely T, Koyama K, Amano H, Sutherland WJ. A framework for monitoring the status of populations: an example from wader populations in the East Asian–Australasian flyway. Biol Conserv. 2010;143:2238–47.

Anon. Shorebird monitoring at the Mai Po Inner Deep bay Ramsar Site: 2008–09. Hong Kong Bird Watching Society to the Agriculture, Fisheries and Conservation Department, Hong Kong Special Administrative Region Government; 2009. p. 50.

Bai Q, Chen J, Chen Z, Dong G, Dong J, et al. Identification of coastal wetlands of international importance for waterbirds: a review of China Coastal Waterbird Surveys 2005–2013. Avian Res. 2015;6:12.

Barter M. Shorebirds of the Yellow Sea: importance, threats and conservation status, vol. 12. Canberra: International Wader Studies; 2002.

Barter M, Li ZW, Xu JL. Shorebird numbers on the Tianjin Municipality coast in May 2000. Stilt. 2001;39:2–9.

Barter M, Riegen A, Xu Q. Shorebird numbers in Bohai Wan during northward migration. Stilt. 2003;44:3–8.

Birdlife International. *Limnodromus semipalmatus*. The IUCN red list of threatened species 2016: e.T22693351A93397892. In: IUCN red list threat species. 2016. https://www.iucnredlist.org/en. Accessed 29 Jan 2020.

Carey GJ, Chalmers ML, Diskin DA, Kennerly PR, Leader PJ, Leven MR, et al. The avifauna of Hong Kong. Hong Kong: Hong Kong Bird Watching Society; 2001.

Chan Y-C, Peng H-B, Han Y-X, Chung SS-W, Li J, Zhang L, et al. Conserving unprotected important coastal habitats in the Yellow Sea: shorebird occurrence, distribution and food resources at Lianyungang. Glob Ecol Conserv. 2019;20:e00724.

Chen K, Lv Y. Yellow Sea-Bohai region coordinated waterbird survey 2019. Summary report. Beijing: International Wetlands; 2019. (**in Chinese**).

Chen K, Bai J, Jiang M, Chen Q, Li Y, Lv Y, et al. Yellow Sea-Bohai region coordinated waterbird survey 2016. Summary report. Beijing: Wetlands International; 2016. (**in Chinese**).

Chen K, Lv Y, Chen Q. Yellow Sea-Bohai region coordinated waterbird survey 2017. Summary report. Beijing: Wetlands International; 2017. (**in Chinese**).

Chen K, Lv Y, Chen Q. Yellow Sea-Bohai region coordinated waterbird survey 2018. Summary report. Beijing: Wetlands International; 2019. (**in Chinese**).

Chen Y, Dong J, Xiao X, Ma Z, Tan K, Melville D, et al. Effects of reclamation and natural changes on coastal wetlands bordering China's Yellow Sea from 1984 to 2015. Land Degrad Dev. 2019;30:1533–44.

Choi C-Y, Gan X, Hua N, Wang Y, Ma Z. The habitat use and home range analysis of Dunlin (*Calidris alpina*) in Chongming Dongtan, China and their conservation implications. Wetlands. 2014a;34:255–66.

Choi C-Y, Battley PF, Potter MA, Ma Z, Liu W. Factors affecting the distribution patterns of benthic invertebrates at a major shorebird staging site in the Yellow Sea, China. Wetlands. 2014b;34:1085–96.

Choi C-Y, Rogers KG, Gan X, Clemens R, Bai Q-Q, Lilleyman A, et al. Phenology of southward migration of shorebirds in the East Asian-Australasian Flyway and inferences about stop-over strategies. Emu. 2016;116:178–89.

Choi C-Y, Coleman J, Klaassen M, Moffitt D, Rogers D, Skilleter G, et al. Final report: migratory shorebird monitoring—understanding ecological impact (CA12000284). Gladstone: Report produced for the Ecosystem Research and Monitoring Program Advisory Panel as part of Gladstone Ports Corporation's Ecosystem Research and Monitoring Program; 2017.

Choi C-Y, Jackson MV, Gallo-Cajiao E, Murray NJ, Clemens RS, Gan X, et al. Biodiversity and China's new Great Wall. Divers Distrib. 2018;24:137–43.

Choi C-Y, Peng H-B, He P, Ren X-T, Zhang S, Jackson MV, et al. Where to draw the line? Using movement data to inform protected area design and conserve mobile species. Biol Conserv. 2019;234:64–71.

Choi C-Y, Li J, Xue WJ. China coastal waterbird census report (Jan 2012–Dec 2019). Hong Kong: Hong Kong Bird Watching Society; 2020.

Conklin JR, Verkuil YI, Smith BR. Prioritizing migratory shorebirds for conservation action on the East-Asian Australasian Flyway. Hong Kong: WWF Hong Kong; 2014.

Hansen BG, Fuller RA, Watkins D, Rogers DI, Clemens RS, Newman M, et al. Revision of the East Asian-Australasian Flyway population estimates for 37 listed Migratory Shorebird Species. Unpublished report for the Department of the Environment. Melbourne: BirdLife Australia; 2016.

Hassell C, Boyle A, Slaymaker M, Jackett N, Piersma T. Shorebird northward migration through Bohai Bay, China, the report on the tenth field season April–June 2019. Global Flyway Netw. 2019.

Higgins PJ, Davies SJJF. Handbook of Australian, New Zealand & Antarctic birds. Volume 3: Snipe to pigeons. Melbourne: Oxford University Press; 1996.

Iqbal M, Mulyana D, Hasudungan F, Martini H, Noor YR, Setiawan A, Mulyani YA, Yustian I, Zulkifli H. Population size and trend of Asian Dowitcher Limnodromus semipalmatus in Banyuasin Peninsula, Sumatra, Indonesia. Int J Conserv Sci. 2021;12(2):577–84.

Jackson MV, Carrasco LR, Choi C-Y, Li J, Ma Z, Melville DS, et al. Multiple habitat use by declining migratory birds necessitates joined-up conservation. Ecol Evol. 2019;9:2505–15.

Jackson MV, Choi C-Y, Amano T, Estrella SM, Lei W, Moores N, et al. Navigating coasts of concrete: pervasive use of artificial habitats by shorebirds in the Asia-Pacific. Biol Conserv. 2020;247:108591.

Jackson MV, Fuller RA, Gan X, Li J, Mao D, Melville DS, et al. Dual threat of tidal flat loss and invasive *Spartina alterniflora* endanger important shorebird habitat in coastal mainland China. J Environ Manage. 2021;278:111549.

Jiangsu Ocean and Fisheries Bureau. Public statement of the environmental impacts of Blue Bay Foundation Engineering Program in Lianyun New City, Lianyungang. 2018. http://hyyyyj.jiangsu.gov.cn/art/2018/1/3/art_47689_7238186.html. **(in Chinese)**.

King WB. Endangered birds of the world: the ICPB bird red data book. Washington, DC: Smithsonian Institution Press; 1981.

Li ZWD, Bloem A, Delany S, Martakis G, Quintero JO. Status of waterbirds in Asia—results of the Asian waterbird census: 1987–2007. Kuala Lumpur: Wetlands International; 2009.

Lianyungang Municipal Development and Reform Commission. Construction of a provincial wetland park at Linhong Estuary tidal flat of Lianyungang, Jiangsu (Phase I). 2019. http://www.lyg.gov.cn/zglygzfmhwz/xmjbxx/content/4309eb2d-83b4-4c05-aac0-a0a4af04223a.html.

Ma Z, Hua N, Peng H, Choi C, Battley PF, Zhou Q, et al. Differentiating between stopover and staging sites: functions of the southern and northern Yellow Sea for long-distance migratory shorebirds. J Avian Biol. 2013;44:504–12.

Melnikov YI. Population and range fluctuations of Asian Dowitcher *Limnodromus semipalmatus* in the central Asian arid zone. Int Wader Stud. 1998;10:351–7.

Melville DS. Threats to waders along the East Asian-Australasian flyway. In: Straw P, editor. Shorebird conservation in the Asia-Pacific Region. Melbourne: Australasian Wader Studies Group; 1997. p. 15–35.

Melville DS, Chen Y, Ma Z. Shorebirds along the Yellow Sea coast of China face an uncertain future—a review of threats. Emu. 2016;116:100–10.

Moores N, Rogers DI, Rogers K, Hansbro PM. Reclamation of tidal flats and shorebird declines in Saemangeum and elsewhere in the Republic of Korea. Emu. 2016;116:136–46.

Mundkur T, Langendoen T, Watkins D. The Asian Waterbird Census 2008–2015: results of coordinated counts in Asia and Australasia. Ede: Wetlands International; 2017.

Murray NJ, Clemens RS, Phinn SR, Possingham HP, Fuller RA. Tracking the rapid loss of tidal wetlands in the Yellow Sea. Front Ecol Environ. 2014;12:267–72.

Murray NJ, Ma Z, Fuller RA. Tidal flats of the Yellow Sea: a review of ecosystem status and anthropogenic threats. Austral Ecol. 2015;40:472–81.

National Forestry and Grassland Administration. Announcement by the National Forestry and Grassland Administration and the Ministry of Agriculture (No. 3 in 2021) (The List of Wildlife under Special State Protection).

2021. http://www.forestry.gov.cn/main/5461/20210205/122418860831352.html. **(in Chinese)**.
Peng H-B, Anderson GQA, Chang Q, Choi C-Y, Chowdhury SU, Clark NA, et al. The intertidal wetlands of southern Jiangsu Province, China—globally important for Spoon-billed Sandpipers and other threatened waterbirds, but facing multiple serious threats. Bird Conserv Int. 2017;27:305–22.
Piersma T, Chan Y-C, Mu T, Hassell CJ, Melville DS, Peng H-B, et al. Loss of habitat leads to loss of birds: reflections on the Jiangsu, China, coastal development plans. Wader Study. 2017;124:93–8.
Prater AJ, Marchant JH, Vuorinen J. Guide to the identification and ageing of Halarctic waders. Tring: British Trust for Ornithology; 1977.
R Core Team. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing; 2017.
Ramsar Convention. Resolution XI.8 Annex 2 (Rev. COP13). Strategic framework and guidelines for the future development of the List of Wetlands of International Importance. In: Meeting of the conference of the contracting parties to the convention on Wetlands (Ramsar, Iran, 1971)—2012 revision; 2012.
Rogers DI, Yang H-Y, Hassell CJ, Boyle AN, Rogers KG, Chen B, et al. Red Knots (*Calidris canutus piersmai* and *C. c. rogersi*) depend on a small threatened staging area in Bohai Bay, China. Emu. 2010;110:307–15.
Studds CE, Kendall BE, Murray NJ, Wilson HB, Rogers DI, Clemens RS, et al. Rapid population decline in migratory shorebirds relying on Yellow Sea tidal mudflats as stopover sites. Nat Commun. 2017;8:14895.
Sullivan BL, Wood CL, Iliff MJ, Bonney RE, Fink D, Kelling S. eBird: a citizen-based bird observation network in the biological sciences. Biol Conserv. 2009;142:2282–92.
Sullivan BL, Aycrigg JL, Barry JH, Bonney RE, Bruns N, Cooper CB, et al. The eBird enterprise: an integrated approach to development and application of citizen science. Biol Conserv. 2014;169:31–40.
Systat Software Inc. Richmond: Systat Software Inc; 2007.
Thompson JJ. Modelling the local abundance of shorebirds staging on migration. Theor Popul Biol. 1993;44:299–315.
UNESCO. World Heritage Committee Decision: 43 COM 8B3—Migratory Bird Sanctuaries along the coast of Yellow Sea-Bohai Gulf of China (Phase 1) (China). 2019. https://whc.unesco.org/en/decisions/7358/
Wang H, Barter M. Estimates of the numbers of waders in the Dongsha Islands, China. Stilt. 1998;33:41–2.
Warnock N. Stopping vs. staging: the difference between a hop and a jump. J Avian Biol. 2010;41:621–6.
Wen C. The origin of World Heritage application. China Bird Watch. 2019;130:10–6 (**in Chinese**).
Wetlands International. Waterbird population estimates. 2020. http://wpe.wetlands.org/. Accessed 30 Apr 2020.
Yang H-Y, Chen B, Barter M, Piersma T, Zhou C-F, Li F-S, et al. Impacts of tidal land reclamation in Bohai Bay, China: ongoing losses of critical Yellow Sea waterbird staging and wintering sites. Bird Conserv Int. 2011;21:241–59.
Yang Z, Han Y, Li J, Cai S, Guo J, Xiang L, et al. Significant numbers of Asian Dowitcher *Limnodromus semipalmatus* found during waterbird surveys at Lianyungang, Jiangsu province, China. Birding ASIA. 2019;58–63.
Yang Z, Lagassé BJ, Xiao H, Jackson MV, Chiang C-Y, Melville DS, et al. The southern Jiangsu coast is a critical moulting site for Spoon-billed Sandpiper *Calidris pygmaea* and Nordmann's Greenshank *Tringa guttifer*. Bird Conserv Int. 2020;30:649–60.
Yu YT, Carey GJ, Ying HK. Shorebird monitoring at the Mai Po Marshes and Inner Deep Bay Ramsar Site: 2003–2004. Hong Kong: The Hong Kong Bird Watching Society Limited; 2004.
Zhang L, Zhang M. A photographic guide to the birds of China. Volume 2, Shorebirds. Fujian: The Straits Publishing & Distributing Group; 2018.
Zhang S-D, Ma Z, Choi C-Y, Peng H-B, Bai Q-Q, Liu W, et al. Persistent use of a shorebird staging site in the Yellow Sea despite severe declines in food resources implies a lack of alternatives. Bird Conserv Int. 2018;28:534–48.
Zhao L. Reclaiming land to be restricted. In: China Daily. 2018. https://global.chinadaily.com.cn/a/201801/18/WS5a5fc6f3a310e4ebf433e61b.html.