The bird community in a coastal wetland in East China and its spatial responses to a wind farm

Yinrui Cheng1,2,3 · Yong Zha1,2,3 · Wenmin Zhang1,2,3 · Geng Wei1,2,3 · Chuan Tong4 · Dandan Du5

Received: 27 August 2021 / Accepted: 8 November 2021 / Published online: 15 November 2021
© Akadémiai Kiadó Zrt. 2021

Abstract
Coastal wetlands in East China are essential stopover places for birds along the East Asian-Australian Flyway. However, numerous wind turbines have been built in or near these wetlands in recent years, which might disturb the bird community in the area. Therefore, investigating the bird community and its responses to wind farms in coastal wetlands of East China is of great significance for bird conservation. In the spring and autumn of 2019 and 2020, we investigated the bird community in the Rudong coastal wetland in East China using point counts and analysed the relationship between bird number and distance to the wind farm boundary through partial correlation analysis. A total of 11 orders and 103 species of birds, including four endangered species, were observed during our survey. Charadriiformes was the dominant taxon in the wetland. Passeriformes exhibited high species richness but low numbers. The results of partial correlation analysis indicated that birds’ responses to the wind farm varied depending on their dominance and category: dominant and subdominant birds tended to avoid the wind farm, whereas rare birds tended to approach them; aquatic birds were alert to the wind farm, whereas terrestrial birds better adapted to them. We concluded that the dominant aquatic birds, including the endangered species Calidris tenuirostris, were most negatively impacted by the wind farm; the occasional birds and rare aquatic birds might be disturbed by wind farms but not significantly so; and the rare terrestrial birds were least disturbed by or even benefited from the wind farm.

Keywords Dominance · Aquatic birds · Endangered species · Wind turbine · Coastal wetland

Introduction
The coastal wetlands in East China are essential stopover places for birds along the East Asian-Australian Flyway (EAAF) (Cao et al., 2009; Yong et al., 2018). Numerous aquatic birds stop in these wetlands to accumulate energy reserves before or after they fly over the Yellow Sea (Fig. 1a) (Ma et al., 2006); moreover, some terrestrial birds also rest in these wetlands during their migration (Yong et al., 2015). For threatened species in the flyway, such as Calidris pygmaea and Tringa guttifer, these wetlands are crucial for future survival (Peng et al., 2017; Yang et al., 2020). In recent decades, bird surveys have been conducted in some coastal wetlands of East China (Bai et al., 2015; Ma et al., 2009; Peng et al., 2017). However, most of these surveys focussed on shorebirds or endangered species, whereas investigations of entire communities are limited. Thus, further observations of the bird community are necessary for bird conservation in the area.

Wind energy is increasingly used for electricity generation because it is clean and renewable (Herbert et al., 2014; Kumar et al., 2016). Recent reports have shown that the capacity of the world’s wind farms is growing at ~ 10% per year and reached 744 GW by the end of 2020, covering more than 7% of the global electricity demand (WWEA, 2021). Despite the benefits of wind power generation, considerable research has shown that wind turbines are disadvantageous
to birds. First, birds can be killed by collisions with wind turbines (Grodsky et al., 2013; Newton & Little, 2009). Bird carcass collection in a coastal wind farm showed that collisions accounted for ~ 3% of bird deaths (Newton & Little, 2009). Second, birds tend to avoid wind farms behaviourally (Plonczkier & Simms, 2012; Villegas-Patraca et al., 2014). Specifically, they usually change their migration routes and stopover sites due to wind farms, and this expenditure of energy could induce an increase in fatal casualties during their migration (Hilgerloh et al., 2011). Third, constructions of wind turbines and attached facilities can induce fragmentation and functional loss of bird habitat (Marques et al., 2020; Pruett et al., 2009), which is essential for bird foraging and breeding.

China is the largest energy consumer worldwide (Yang et al., 2017). In terms of sustainable development, China hosts over one-third of the world’s wind power capacity (WWEA, 2021; Yang et al., 2017). In recent years, numerous wind farms have been established in the coastal areas of East China (He et al., 2016; Wang et al., 2019), which might disturb wetland bird communities. In this context, we wish to know the bird community composition in wetlands with wind farms in the region; we also wonder if all the species in the community tend to avoid the wind farms, and if not, whether we can uncover some rules underlying their responses. These issues have great significance for protecting birds in the EAAF. In this paper, we investigated the bird community in the Rudong coastal wetland of East China, where wind turbines have been installed and analysed the relation between bird number and distance to wind farms. The main objectives of this study were to (1) provide community data for bird studies on the EAAF; (2) explore the implications of wind farms for bird communities; and (3) provide recommendations for future bird conservation in the area.

Materials and methods

The study area

Our research was conducted in the Rudong coastal wetland (120°56′32″ ~ 121°12′35″E, 32°29′47″ ~ 32°39′12″N), East China (Fig. 1a). The wetland has a northern subtropical monsoon climate, with an annual mean temperature of 14.8 °C. The wetland exhibits simple landscapes. *Spartina alterniflora* is the dominant vegetated marsh plant and occupies almost the whole vegetated area. The wetland is located in the longest muddy coast in China, and the bare lands are almost composed of mudflats. The wetland image shown in Fig. 1b was extracted from Landsat 8 OLI images (02:30:14Z, May 3rd, 2020), which were taken at the middle-tide level.

Many birds in the EAAF, including the endangered species *Calidris pygmaea, Calidris tenuirostris,* and *Platalea minor,* stop in the Rudong coastal wetland during their migration (Ma & Chen, 2018; Yang et al., 2020). However, hundreds of wind turbines (capacity of each turbine ~ 3 MW, hub height ~ 90 m, rotor diameter ~ 110 m, distances between neighbouring turbines 0.6–1.2 km) have been established within and near the wetland since 2013 (Fig. 1b), which might disturb the bird community in the area.
Bird survey

We used point counts to investigate the bird community in the Rudong coastal wetland (Bibby et al., 2000; Ralph et al., 1995). A total of 40 census points were randomly established in the wetland (Fig. 1b). For the independence of each point, the points were separated by a distance of at least 800 m. The counting radius and duration at each point were 100 m and 5 min, respectively. Before the survey, we divided the 40 points into 4 groups, with 10 neighbouring points in each group. The 4 groups of points were assigned to 4 teams of trained observers (2 observers per team) one by one.

The bird surveys were carried out in 2019 and 2020. Because the bird migration peak in East China’s coastal wetlands occurs in spring and autumn (Ma et al., 2009), the counts were performed from March to May (spring) and from September to November (autumn) in the two years. The counts were conducted in the first 3 h after dawn and at middle or low tide under fair weather conditions. During the surveys, birds seen or heard around the points were all recorded, but those flew in or flew across the point were ignored. Binoculars (Nature DX ED 10×50, Celestron, the USA) were used for observation. Bird flocks were recorded by cameras (EOS 700D, Canon, Japan) with spotting scopes (Ultima 80, Celestron, the USA) and were counted after the surveys.

The point counts were repeated 10 times per season per year; thus, each season comprised 20 replicates over the two-year period. To minimize the differences in artificial errors between census points, each season a team turned to another group of points after 5 replicates of point counts. Thus, the observation at each census point in a season was finished by 4 teams, and each team contributed 5 replicates. Finally, the point count result in each season was obtained by summing the 20 replicates. The total number of a species was the sum of its numbers at the 40 points.

Bird community composition

We divided species dominance into 4 classes according to the proportion (F) of the total number of a species to that of all species, i.e. dominant species (F > 5%), subdominant species (2% < F ≤ 5%), occasional species (1% < F ≤ 2%), and rare species (F ≤ 1%) (Lenz, 1990). Moreover, we divided the recorded birds into two general categories. Birds of Charadriiformes, Ciconiiformes, Anseriformes, Gruiformes, and Podicipediformes were all regarded as aquatic birds, whereas those of Passeriformes, Falconiformes, Coraciiformes, Columbiformes, Cuculiformes, and Galliformes were regarded as terrestrial birds.

Determination of geographical factors

In this study, we determined the distance (m) between each census point and the wind farm boundary (DW) in Fig. 1b. DW was given a negative value if the point was located within the wind farm. Birds’ spatial responses to wind farms were evaluated according to the relationship between bird number and DW.

Moreover, we considered three other factors that might disturb our point count results: the distance (m) between each census point and the suburbs (DR), the distance (m) between each census point and the sea (DS), and the vegetation area (m²) surrounding (100 m radius) each census point (VA) (Chapman & Reich, 2007; Ma & Chen, 2018; Niemuth et al., 2006). These three factors are also determined in Fig. 1b.

Statistical analysis

We focus on the relationship between bird number and DW; however, bird distribution was determined by multiple geographical factors. To eliminate the disturbances of other factors, partial correlation analysis was used to reveal the relationship. During partial correlation analysis, the factors DR, DS, and VA were all set to controlled factors; thus, their disturbances on the correlation between bird number and DW were removed. A positive partial correlation coefficient indicated that the bird number increased with DW, whereas a negative coefficient indicated a decrease. Redundancy analysis (RDA) was conducted to compare the effect of wind farms on bird communities with those of other factors. The point count results were standardized by Hellinger transformation before RDA (Borcard et al., 2011). To show the RDA results more clearly, bird species were divided into Groups A and B in each season. Species in Group A had higher RDA scores, and their scores were magnified by 2.5 times; those in Group B had low RDA scores, and the scores were magnified by 15 times. Stepwise regression was used to verify our conclusions. Factors with low significance or high multicollinearity were all eliminated from the regression model. During partial correlation analysis, the factors with low significance or high multicollinearity were all eliminated from the regression model. Partial correlation analysis, RDA, and stepwise regression were performed in RStudio 1.3.959.

The relationship between bird number and environmental factor might be biased if bird community was spatial autocorrelated. Thus, we used the global Moran’s I index to examine the spatial autocorrelation of the community. A positive Moran’s I index indicated an aggregated distribution, whereas a negative index indicated the dispersal. The spatial autocorrelation would be nonsignificant if z scores were lower than 1.96 and significant at the p > 0.05 level. The spatial autocorrelation test was performed in ArcGIS 10.2 (ESRI, USA).
Results

A total of 52,571 birds of 11 orders and 103 species were counted during the survey. A total of 30,609 birds of 88 species were recorded in spring, while 21,962 birds of 78 species were recorded in autumn (Table 1). Charadriiformes was the dominant order in the wetland, comprising 43 species and 95.8% of the total count over the two seasons. Passeriformes comprised 39 species, which was the second highest richness. However, the passerines in the community were mostly rare species, and they comprised only 2.7% of the total count. Other recorded bird orders included Ciconiiformes, Anseriformes, Gruiformes, Podicipediformes, Coraciiformes, Columbiformes, Cuculiformes, Falconiformes, and Galliformes. These nine orders had low species richnesses and bird numbers; they comprised only 21 species and only 1.5% of the total count.

**Calidris alpina** was the most common species in both spring and autumn. It comprised 18.5% and 24.0% of the total counts in spring and autumn, respectively. Other dominant species included *Calidris ruficollis*, *Charadrius alexandrinus*, *Calidris tenuirostris*, and *Tringa nebularia* (spring). The subdominant species included *Xenus cinereus*, *Numenius phaeopus*, *Calidris acuminata*, *Charadrius mongolus*, etc.

According to the IUCN Red List of threatened species (IUCN, 2021), 10 of the 103 recorded species are near threatened, three of them are vulnerable, three are endangered (*Calidris tenuirostris*, *Numenius madagascariensis*, and *Platalea minor*), and one is critically endangered (*Calidris pygmaea*).

The partial correlation coefficients showed that the numbers of most dominant and subdominant birds were positively correlated with DW (Fig. 2). In spring, 76.9% (10 of 13) of the dominant and subdominant bird species exhibited positive correlations, and 7 of them had significant positive correlations ($p < 0.05$). The percentage was 90.9% (10 of 11) in autumn, and 7 of the dominant and subdominant bird species had significant positive correlations ($p < 0.05$). Moreover, the total numbers of dominant and subdominant birds were all significantly and positively correlated with DW ($p < 0.05$) (Table 2), indicating that dominant and subdominant birds tended to avoid the wind farm.

In contrast, the numbers of most rare birds were negatively correlated with DW. A total of 73.2% (52 of 71) and 60.3% (38 of 63) of the rare bird species exhibited negative correlations in spring and autumn, respectively. However, most of these correlations were nonsignificant because the rare birds were low in number and were recorded at only a few points. Nevertheless, the total number of rare birds exhibited a significant negative correlation ($p < 0.05$) with DW (Table 2), indicating that rare birds tended to approach the wind farm. The partial correlation coefficients of occasional birds, however, showed no obvious tendencies (Fig. 2 and Table 2). Their responses to the wind farm were unclear and might be a transitional type between those of dominant/subdominant birds and rare birds.

The rare birds in the wetland comprised terrestrial birds and aquatic birds (Fig. 2 and Table 2). These two groups had different responses to the wind farm. As shown in Fig. 2, 81.8% (27 of 33) and 70.4% (19 of 27) of the terrestrial bird species exhibited negative correlations with DW in spring and autumn, respectively. Moreover, the total number of terrestrial birds had a significant negative correlation with DW ($p < 0.05$) (Table 2). By comparison, only 65.8% (25 of 38) and 52.8% (19 of 36) of the aquatic birds were negatively correlated with DW in spring and autumn, respectively, and the correlation between the total number of aquatic birds and DW was nonsignificant ($p > 0.05$). The above comparisons indicate that the aquatic birds were more alert to the wind farms, whereas the terrestrial birds better adapted to them.

Discussion

**Bird community composition and the endangered species**

The dominant species recorded in this study were generally consistent with those detected in previous shorebird surveys of nearby wetlands (20 ~ 50 km from our study area, without wind farms) (Peng et al., 2017). However, previous surveys indicated that the dominant species accounted for 72.3 ~ 94.6% of the total number of aquatic birds (Peng et al., 2017), whereas the proportions were ~ 62% in this study. (For comparison, only aquatic birds were considered.) The proportions were much lower in our study area, probably because many dominant birds had been driven away by the wind farm.

Despite low bird number, the rare species comprised ~ 80% species in the entire community in the Rudong coastal wetland. In addition to aquatic birds, terrestrial birds were also common among the rare species, accounting for ~ 40% of them. Thus, we conclude that the wetland is rich in both aquatic and terrestrial bird species. Moreover, the proportion of rare birds (~ 8%) in our study (for comparison, only aquatic birds were considered) was much higher than that (~ 3%) in nearby wetlands (20 ~ 180 km from our study area, without wind farms) (Ge et al., 2009; Ma et al., 2006; Peng et al., 2017), which indicates that rare birds were less affected by the wind farm than dominant birds.
Table 1 Composition of the bird community in the Rudong coastal wetland

| Species number | Spring | Autumn |
|----------------|--------|--------|
|                | Bird order | Scientific name | Common name | Total number | Bird order | Scientific name | Common name | Total number |
| 1              | Char     | Calidris alpina | Dunlin       | 5652+++      | Char     | Calidris alpina | Dunlin       | 5272+++      |
| 2              | Char     | Calidris ruficollis (NT) | Red-necked Stint | 4808+++      | Char     | Charadrius alexandrinus | Kentish Plover | 3626+++      |
| 3              | Char     | Charadrius alexandrinus | Kentish Plover | 3780+++      |         |                              |              |
| 4              | Char     | Calidris tenuirostris (EN) | Great Knot | 2226+++      | Char     | Calidris tenuirostris (EN) | Great Knot | 1404+++      |
| 5              | Tringa nebularia | Common Greenshank | Common Greenshank | 1803+++      | Calidris acuminata | Sharp-tailed Sandpiper | 1026+++      |
| 6              | Xenus cinereus (NT) | Terek Sandpiper | Terek Sandpiper | 1468++       | Xenus cinereus | Terek Sandpiper | 912 ++       |
| 7              | Numenius phaeopus | Whimbrel | Whimbrel | 1073++       | Numenius phaeopus | Whimbrel | 745 ++       |
| 8              | Calidris acuminata | Sharp-tailed Sandpiper | Sharp-tailed Sandpiper | 987++       | Calidris acuminata | Sharp-tailed Sandpiper | 602 ++       |
| 9              | Charadrius mongolus (NT) | Lesser Sand Plover | Lesser Sand Plover | 978++       | Charadrius leschenaultii | Lesser Sand Plover | 541 ++       |
| 10             | Calidris canutus (NT) | Red Knot | Red Knot | 822++        | Calidris canutus (NT) | Red Knot | 422 +        |
| 11             | Charadrius leschenaultii | Greater Sand Plover | Greater Sand Plover | 816++       | Chroicocephalus saundersi (VU) | Saunders's Gull | 469 ++       |
| 12             | Arenaria interpres | Ruddy Turnstone | Ruddy Turnstone | 789++       | Calidris canutus (NT) | Red Knot | 180 +        |
| 13             | Pluvialis squatarola | Grey Plover | Grey Plover | 657++       | Limosa lapponica (NT) | Bar-tailed Godwit | 396 +        |
| 14             | Numenius arquata (NT) | Eurasian Curlew | Eurasian Curlew | 617+        | Passer montanus | Eurasian Tree Sparrow | 327 +        |
| 15             | Limosa lapponica (NT) | Bar-tailed Godwit | Bar-tailed Godwit | 556+        | Numenius arquata (NT) | Eurasian Curlew | 236 +        |
| 16             | Chroicocephalus saundersi (VU) | Saunders's Gull | Saunders's Gull | 467+        | Arenaria interpres | Ruddy Turnstone | 180 +        |
| 17             | Tringa brevipes (NT) | Grey-tailed Tattler | Grey-tailed Tattler | 382+        | Calidris alba | Sandering | 4           |
| 18             | Calidris alba | Sanderling | Sanderling | 34          | Calidris ferruginea (NT) | Curlew Sandpiper | 27           |
| 19             | Calidris ferruginea (NT) | Curlew Sandpiper | Curlew Sandpiper | 34          | Calidris pygmaea (CR) | Spoon-billed Sandpiper | 8           |
| 20             | Calidris melanotos | Pectoral Sandpiper | Pectoral Sandpiper | 26          | Calidris subminuta | Long-toed Stint | 13           |
| 21             | Calidris subminuta | Long-toed Stint | Long-toed Stint | 12          | Chroicocephalus ridibundus | Black-headed Gull | 179          |
| 22             | Chroicocephalus ridibundus | Black-headed Gull | Black-headed Gull | 197         | Gelochelidon nilotica | Gull-billed Tern | 48           |
| 23             | Gallinago gallinago | Common Snipe | Common Snipe | 7           | Haematopus ostralegus (NT) | Eurasian Oystercatcher | 3           |
| 24             | Gelochelidon nilotica | Gull-billed Tern | Gull-billed Tern | 80          | Himantopus himantopus | Black-winged Stilt | 2           |
| 25             | Haematopus ostralegus (NT) | Eurasian Oystercatcher | Eurasian Oystercatcher | 9          | Larus canus | Mew Gull | 62           |
| 26             | Himantopus himantopus | Black-winged Stilt | Black-winged Stilt | 9           | Larus crassirostris | Black-tailed Gull | 14           |
| 27             | Larus canus | Mew Gull | Mew Gull | 58          | Larus mongolicus | Mongolian Gull | 133          |
| Species number | Spring | Autumn |
|----------------|--------|--------|
|                | Bird order | Scientific name | Common name | Total number | Bird order | Scientific name | Common name | Total number |
| 28             | Larus crassirostris | Black-tailed Gull | 17 | Limosa limosa | Black-tailed Godwit | 40 |
| 29             | Larus mongolicus | Mongolian Gull | 97 | Numenius madagascariensis | Far Eastern Curlew | 162 |
| 30             | Limicola falcinellus | Broad-billed Sandpiper | 18 | Pluvialis squatarola | Grey Plover | 153 |
| 31             | Limosa limosa (NT) | Black-tailed Godwit | 268 | Recurvirostra avosetta | Pied Avocet | 24 |
| 32             | Numenius madagascariensis (NT) | Far Eastern Curlew | 15 | Sterna hirundo | Common Tern | 21 |
| 33             | Pluvialis fulva | Pacific Golden Plover | 216 | Sterna albisflons | Little Tern | 9 |
| 34             | Recurvirostra avosetta | Pied Avocet | 18 | Tringa brevipes (NT) | Grey-tailed Tattler | 100 |
| 35             | Sterna hirundo | Common Tern | 14 | Tringa erythropus | Spotted Redshank | 7 |
| 36             | Sterna albifrons | Little Tern | 45 | Tringa glareola | Wood Sandpiper | 210 |
| 37             | Tringa erythropus | Spotted Redshank | 21 | Tringa hypoleucos | Common Sandpiper | 20 |
| 38             | Tringa glareola | Wood Sandpiper | 42 | Tringa stagnatilis | Marsh Sandpiper | 18 |
| 39             | Tringa hypoleucos | Common Sandpiper | 16 | Tringa totanus | Common Redshank | 19 |
| 40             | Tringa totanus | Common Redshank | 299 | Cico | Ardea alba | Great Egret | 10 |
| 41             | Vanellus cinereus | Grey-headed Lapwing | 2 | Ardea cinerea | Grey Heron | 7 |
| 42             | Cico | Ardea alba | Great Egret | 28 | Bubulcus ibis | Cattle Egret | 8 |
| 43             | Ardea cinerea | Grey Heron | 26 | Egretta garzetta | Little Egret | 195 |
| 44             | Bubulcus ibis | Cattle Egret | 8 | Egretta intermedia | Intermediate Egret | 18 |
| 45             | Egretta garzetta | Little Egret | 168 | Anse | Anas falcata (NT) | Falcated Duck | 8 |
| 46             | Egretta intermedia | Intermediate Egret | 108 | Anse | Anas penelope | Eurasian Wigeon | 16 |
| 47             | Platalea minor (EN) | Black-faced Spoonbill | 8 | Anas platyrhynchos | Eastern Spot-billed Duck | 15 |
| 48             | Anse | Anas falcata (NT) | Falcated Duck | 23 | Anas zonorhyncha | Eastern Spot-billed Duck | 15 |
| 49             | Anas platyrhynchos | Eastern Spot-billed Duck | 37 | Grui | Anas zonorhyncha | Eastern Water Rail | 1 |
| 50             | Anas querquedula | Garganey | 9 | Rallus aquaticus | Eastern Water Rail | 1 |
| 51             | Anas zonorhyncha | Eastern Spot-billed Duck | 31 | Pass | Tachybaptus ruficollis | Little Grebe | 6 |
| 52             | Grui | Falica atra | Common Coot | 6 | Acrocephalus bistrigiceps | Black-browed Reed warbler | 4 |
| 53             | Porzana pusilla | Baillon's Crake | 4 | Acrocephalus tangerin (VU) | Manchurian Reed Warbler | 1 |
| 54             | Rallus aquaticus | Eastern Water Rail | 3 | Anthus richardi | Richard's Pipit | 7 |
| Species number | Spring                        | Autumn                        |
|---------------|-------------------------------|-------------------------------|
|               | Bird order | Scientific name | Common name | Total number | Bird order | Scientific name | Common name | Total number |
| 55            | Podi       | Tachybaptus ruficollis | Little Grebe | 7           |            | Cecropis daurica | Red-rumped Swallow | 22          |
| 56            | Pass       | Acrocephalus orientalis | Oriental Reed warbler | 4           |            | Cisticola jun-cidis | Zitting Cisticola | 3           |
| 57            | Alauda gulgula |              | Oriental Skylark | 4           |            | Cyanopica cyanus | Asian Azure-winged Magpie | 42          |
| 58            |            | Cecropis daurica | Red-rumped Swallow | 28          |            | Emberiza pal-lasi | Pallas's Bunting | 6           |
| 59            |            | Cisticola jun-cidis | Zitting Cisticola | 6           |            | Emberiza pusilla | Little Bunting | 14          |
| 60            |            | Cyanopica cyanus | Asian Azure-winged Magpie | 25          |            | Ficedula mugi-maki | Mugimaki Flycatcher | 4           |
| 61            |            | Emberiza cioides | Meadow Bunting | 17          |            | Fringilla monti-fringilla | Brambling | 14          |
| 62            |            | Emberiza rutila | Chestnut Bunting | 15          |            | Hirundo rustica | Barn Swallow | 21          |
| 63            |            | Ficedula mugi-maki | Mugimaki Flycatcher | 6           |            | Lanius schach | Long-tailed Shrike | 18          |
| 64            |            | Ficedula zanthopygia | Yellow-rumped Flycatcher | 6           |            | Luscinia cal-lio | Siberian rubythroat | 7           |
| 65            |            | Fringilla monti-fringilla | Brambling | 40          |            | Luscinia cyane | Siberian Blue Robin | 1           |
| 66            |            | Hirundo rustica | Barn Swallow | 61          |            | Motacilla tschutschensis | Eastern Yellow Wagtail | 9           |
| 67            |            | Lanius schach | Long-tailed Shrike | 22          |            | Muscicapa grisesticta | Grey-streaked Flycatcher | 20          |
| 68            |            | Locustella lanceolata | Lanceolated Warbler | 4           |            | Muscicapa latirostris | Brown Flycatcher | 5           |
| 69            | Locustella pleskei (VU) | Pleske's Grasshopper-warbler | 8           |            | Paradoxornis heudei (NT) | Reed Parrotbill | 69          |
| 70            |            | Luscinia cal-lio | Siberian rubythroat | 4           |            | Phylloscopus borealis | Arctic Warbler | 8           |
| 71            |            | Motacilla tschutschensis | Eastern Yellow Wagtail | 10          |            | Phylloscopus coronatus | Eastern Crowned Warbler | 3           |
| 72            |            | Muscicapa grisesticta | Grey-streaked Flycatcher | 14          |            | Phylloscopus tenuilipes | Pale-legged Leaf-warbler | 8           |
| 73            |            | Paradoxornis heudei (NT) | Reed Parrotbill | 36          |            | Pycnonotus sinensis | Light-vented Bulbul | 10          |
| 74            |            | Paradoxornis webbianus | Vinous-throated Parrotbill | 8           |            | Remiz conso-brinus | Chinese Penduline Tit | 98          |
| 75            |            | Parus major | Great Tit | 10          |            | Turdus hortulo-rum | Grey-backed Thrush | 6           |
| 76            |            | Passer montanus | Eurasian Tree Sparrow | 225         |            | Turdus obscurus | Eyebrowed Thrush | 8           |
| 77            |            | Phoenicurus auroreus | Daurian Redstart | 8           |            | Cora | Halcyon pileata | Black-capped Kingfisher | 1           |
| 78            |            | Phylloscopus coronatus | Eastern Crowned Warbler | 6           |            | Gall | Phasianus colchicus | Common Pheasant | 10          |
Table 1 (continued)

| Species number | Spring | Autumn |
|----------------|--------|--------|
|                | Bird order | Scientific name | Common name | Total number | Bird order | Scientific name | Common name | Total number |
| 79             | Phylloscopus inornatus | Yellow-browed Warbler | 20          |             |            |            |            |             |
| 80             | Phylloscopus tenellipes | Pale-legged Leaf-warbler | 20          |             |            |            |            |             |
| 81             | Pycnonotus sinensis | Light-vented Bulbul | 32          |             |            |            |            |             |
| 82             | Remiz conso-brinus | Chinese Penduline Tit | 48          |             |            |            |            |             |
| 83             | Spodiopsar sericeus | Red-billed Starling | 7           |             |            |            |            |             |
| 84             | Turdus cardis | Japanese Thrush | 9           |             |            |            |            |             |
| 85             | Cora | Upupa epops | Common Hoopoe | 2           |             |            |            |             |
| 86             | Colu | Spilopelia chinensis | Eastern Spotted Dove | 1 |             |            |            |             |
| 87             | Cucu | Cuculus polio-cephalus | Lesser Cuckoo | 1 |             |            |            |             |
| 88             | Falc | Falco tinnunculus | Common Kestrel | 1 |             |            |            |             |

The species numbers of dominant, subdominant, and occasional species are arranged according to bird number. The species numbers of rare species are arranged according to taxonomy.

Char.: Charadriiformes; Pass.: Passeriformes; Gall.: Galliformes; Grui.: Gruidae; Anse.: Anseriformes; Podi.: Podicipediformes; Cico.: Ciconiiformes; Cora.: Coraciiformes; Colu.: Columbiformes; Cucu.: Cuculiformes; Falc.: Falconiformes

The superscripts with brackets represent the endangered categories according to IUCN (2021). NT: near threatened; VU: vulnerable; EN: endangered; CR: critically endangered. The species of least concern have no superscript.

The superscripts ++, +++, and + indicate dominant species, subdominant species, and occasional species, respectively. Rare species have no superscript.

Fig. 2 The partial correlation coefficients between bird numbers and DW. A positive value indicates that the bird number increased with DW, whereas a negative value indicates a decrease. The red, orange, green, and purple marks represent the dominant, subdominant, occasional, and rare species, respectively. The solid marks indicate aquatic birds, whereas the open marks indicate terrestrial birds. Triangles indicate significant correlations at the $p<0.05$ level. The species numbers are those in Table 1.
Four endangered species, i.e. *Calidris tenuirostris*, *Numenius madagascariensis*, *Platalea minor*, and *Calidris pygmaea*, were recorded during our survey. The population sizes of the 4 species are decreasing, and habitat loss is the main reason for the decreases (IUCN, 2021). Recent reports showed that the estimated population sizes of the 4 species in the EAAF were ~290 thousand, ~32 thousand, ~3500, and ~450, respectively (IUCN, 2021; Ma & Chen, 2018). In this study, *Calidris tenuirostris* was still a dominant species in the area, but *Numenius madagascariensis*, *Platalea minor*, and *Calidris pygmaea* were rarely observed. The different dominances induced their different responses to the wind farm.

### Spatial responses of the bird community to the wind farm

Our results showed that birds’ responses to wind farms might vary depending on their dominance and category. The variation in responses with dominance might be related to the following reasons. The dominant and subdominant species (‘dominant and subdominant’ is written as ‘dominant’ below), which are characterized by very high numbers of individuals, often fly in large groups, whereas the rare species fly singly or in small groups. Previous studies reported that larger bird groups have higher collision risks with obstacles because they have more social interactions (Croft et al., 2013, 2015), which can filter the information of obstacle cues and then disturb individuals’ avoidance (Croft et al., 2013, 2015). Thus, the dominant species tended to avoid high collision risks, whereas the rare species could better avoid collisions when flying in the wind farm. Another reason for this phenomenon might be interspecific competition. Many studies have shown that dominant species usually govern the optimal resource, and subordinate species are often driven to seek novel resources to reduce competition (Freshwater et al., 2014; McKinney et al., 2011; Pimm & Pimm, 1982). In this study, the dominant species were more concentrated in the undisturbed portion of the wetland; thus, many rare species chose to forage in or near the wind farm, which were less utilized by the dominant species. In this respect, we think that wind farms might act as refuges for rare species.

The difference in responses between aquatic and terrestrial birds might be related to their morphologies. Aquatic birds, which mainly inhabit open seashores, usually have high wing aspect ratios, i.e. long and narrow wings (Norb erg, 2004; Sheard et al., 2020). This wing form has a high lift-to-drag ratio and smaller wing–tip vortices, making it more suitable for gliding, soaring, and continuous flight (Norb erg, 2004). However, long and narrow wings have low aerodynamic roll torque and a high moment of inertia, which reduces flight manoeuvrability and results in a higher turn radius and longer take-off distance (McFarlane, 2014; Norberg, 2004). Moreover, aquatic birds usually have short
tails (Thomas, 1997; Thomas & Balmford, 1995), which is disadvantageous for maintaining stability and balance in flight and turning (Thomas & Balmford, 1995). In conclusion, aquatic birds have low flight maneuverability, which may hinder them from avoiding wind turbines and incline them to stay away from wind farms. In contrast, terrestrial birds inhabit cluttered environments such as forest and spend much of their foraging time climbing, clinging and hanging. They usually have low wing aspect ratios (i.e. broad and rounded wings) and long tails, which are more suitable for maneuverable short flights (Norberg, 2004). Correspondingly, terrestrial birds can better avoid obstacles such as wind turbines; thus, they are more adaptable to wind farms.

According to the above analysis, we conclude that the dominant aquatic birds were most negatively impacted by the wind farm. These birds include the endangered species *Calidris tenuirostris* and some vulnerable and near-threatened species. In contrast, the rare terrestrial birds were least disturbed by even benefited from the wind farm in some respect. The situation was more complex for rare aquatic birds. Their group sizes result in low collision risk, and they have fewer dominant competitors in the wind farm. On the other hand, their morphology is disadvantageous for flying in wind farms. Thus, similar to those of the occasional species, their responses exhibited more uncertainty.

**Birds’ responses to the wind farm and other factors**

The RDA results showed that birds’ responses to DR, DS, and VA differed considerably between categories, but they did not vary significantly depending on dominance (Fig. 3). For most aquatic birds, the numbers tended to increase with a decrease in DS and with increases in DR and VA, indicating that aquatic birds tended to occur in low tidal flats and bare lands and tended to avoid suburbs. The terrestrial birds, however, were more likely to occur in the high marsh, vegetated areas, and areas near the suburbs. The above differences occurred because aquatic birds mainly feed on macrobenthos and fishes (Collis et al., 2002; Ma & Chen, 2018; Wade & Hickey, 2008), which are mainly distributed in low bare flats and shallow water, whereas terrestrial birds mainly feed on Arthropoda and seeds, which are concentrated in high marsh and vegetated areas (Muñoz et al., 2017). Moreover, the terrestrial birds in the wetland mainly came from the suburbs, whereas the aquatic birds rarely inhabited them, which induced their different responses to DR.

The biplot scores of DW are lower than those of DR, DS, and VA, indicating that the contribution of DW to the spatial variation in the community is lower than those of the other three factors. Based on the results of partial correlation analysis and RDA, we conclude that the bird community exhibits notable responses to the wind farm, but the responses are still inferior to those to suburbs, the sea and vegetation.

The stepwise regression results showed that the coefficient of DW was positive for dominant/subdominant birds and negative for rare birds (Table 3). DW was eliminated from the equations of occasional and rare aquatic birds because the responses of these birds to wind farms were nonsignificant. The above results are consistent with those of partial correlation analysis. Moreover, the coefficients of the other three factors are generally consistent with the RDA results. The occasional birds in autumn have no regression result because no factor could explain the variation in their number.

**Uncertainties and future works**

Biological distributions are usually determined by both the external environment and internal spatial autocorrelation (Fortin & Dale, 2005). However, the global Moran’s I index showed that bird numbers of different dominances and categories exhibited no significant autocorrelation in this study (z < 1.96, p > 0.05) (Table 4). Moreover, we found that only four species exhibited significant autocorrelations over the two seasons. The insignificance of spatial autocorrelation in this study was probably due to the following reasons. First, the census points were separated, and the results were independent. Second, most species in this study have densities lower than one individual per hectare; thus, their aggregation was not obvious over the wetland. Third, most birds stay in the wetland for only a few days during their migration; they have no permanent habitat in the wetland, and their occurrences exhibit great randomness. The insignificance of spatial autocorrelation also occurred in many previous point counts (Becker et al., 2013; Cherkaoui et al., 2009; Deikumah et al., 2014). To further investigate the effect of spatial autocorrelation on point count results, we think more case studies should be carried out in the future.

We focussed on the regional scale and used the parameter DW for analysis. However, more precisely, birds might also be influenced by turbine density around the census point (i.e. turbine numbers within a radius). The limitation for considering turbine density is that the density depends on the exact distance that birds can be influenced by a turbine, and this distance remains uncertain and probably varies with species (Smallwood et al., 2009; Schaub, 2012; Pearce-Higgins et al., 2009). Nevertheless, the Pearson correlation indicated that the turbine densities around (within radii of 500 m, 1 km, and 2 km) the census points exhibited significant negative correlations with DW in this study (p < 0.05). Thus, the turbine densities were approximately involved in DW. To estimate birds’ responses to wind farms more precisely, we think birds’ reaction distance to wind turbines should be further investigated in the future.
Fig. 3 Results of redundancy analysis of bird numbers and geographical factors. a Spring: Group A; b Spring: Group B; c Autumn: Group A; d Autumn: Group B. The species scores in Group A have been magnified by 2.5 times, and those in Group B have been magnified by 15 times. The red, orange, green, and purple circles represent the dominant, subdominant, occasional, and rare species, respectively. The solid circles indicate aquatic birds, whereas the open circles indicate terrestrial birds. Numbers beside the circles are the species numbers in Table 1. DW: distance to the wind farm boundary; DR: distance to the suburb; DS: distance to the sea; VA: vegetation area surrounding each census point.

Table 4 Global Moran I index of the total numbers of birds of different dominances and categories

| Dominance and category | Spring | | Autumn |
|------------------------|--------|--|--------|
|                        | Moran’s I | z  | p     | Moran’s I | z  | p     |
| Dominant               | 0.18    | 1.51| > 0.05| 0.22      | 1.83| > 0.05|
| Subdominant            | 0.20    | 1.66| 0.16  | 0.14      | 1.26| 0.05  |
| Occasional             | 0.13    | 1.18| 0.03  | 0.11      | 1.00| 0.03  |
| Rare                   |         |     |       |           |     |       |
| All                    | 0.08    | 0.78| 0.14  | 0.11      | 1.00| 0.03  |
| Aquatic                | 0.07    | 0.70| 0.11  | 0.11      | 1.00| 0.03  |
| Terrestrial            | 0.21    | 1.75| 0.15  | 0.15      | 1.34| 0.03  |
Conclusion

The Rudong coastal wetland comprises rich bird species. Charadriiformes accounts for an extremely high proportion of the total bird number, and Charadriiformes and Passeriformes comprise the majority of the species in the community. Numerous studies have demonstrated negative effects of wind farms on birds, which indicates a conflict between bird conservation and wind power development in coastal areas of East China. Nevertheless, our study suggested that birds’ responses to wind farms might vary according to their dominance and category. The most negatively impacted birds were the dominant aquatic birds in the wetlands. These birds included the endangered species *Calidris tenuirostris*, the vulnerable species *Chroicocephalus saundersi*, and some near-threatened species. Wind farms might compress the habitats of these species and then contribute to future population declines. Thus, the protection degrees of these species in the area should be upgraded. We think that retaining sufficient undisturbed intertidal mudflats, which are major foraging places for these birds, will be crucial for maintaining their population sizes in the future. The occasional birds and rare aquatic birds in the area, including the critically endangered species *Calidris pygmaea*, the endangered species *Numenius madagascariensis* and *Platalea minor*, and various vulnerable and near-threatened species, exhibit great uncertainties in their responses to wind farms. They might be disturbed by wind farms but not significantly so. We think that monitoring their population dynamics in the area is a major task for the short term. Finally, the rare terrestrial birds in the area might utilize the wind farms under interspecific competition, and they can better adapt to the wind farm environment. Thus, we conclude that these species, including the vulnerable species *Acrocephalus tangorum* and *Locustella pleskei*, would be least disturbed by or would even benefit somewhat from future wind farm construction.

Acknowledgements We sincerely thank the editors and the anonymous reviewers for their valuable comments and suggestions for this manuscript. We also thank Shanshan Chang, Lijuan Chen, Chuangqi Hu, and Yuqiao Hou for their help in our bird survey. We greatly appreciate Nanjing Normal University to support this work. We also thank Shanshan Chang, Lijuan Chen, Chuangqi Hu, and Yuqiao Hou for their help in our bird survey. We greatly appreciate Nanjing Normal University to support this work. We also thank Shanshan Chang, Lijuan Chen, Chuangqi Hu, and Yuqiao Hou for their help in our bird survey. We greatly appreciate Nanjing Normal University to support this work.

Author contributions YC contributed to the study conception and design. Data acquisition was performed by YC, YZ, GW, DD, and data analysis was performed by WZ and CT. The original draft was written by YC and YZ reviewed and edited subsequent versions of the manuscript.

Funding This work was supported by the National Natural Science Foundation of China (No. 41671428) and Nanjing Normal University.

Data availability and material All data are presented in the paper. The Landsat 8 OLI image used here is available at http://eds.ceode.ac.cn/ muds/freedataquery.

References

Bai, Q. Q., Chen, J. Z., Chen, Z. H., Dong, G. T., Dong, J. T., Dong, W. X., Fu, V. W. K., Han, Y. X., Lu, G., Li, J., Liu, Y., Lin, Z., Meng, D. R., Martinez, J., Ni, G. H., Shan, K., Sun, R. J., Tian, S. X., Wang, F. Q., … Zeng, X. W. (2015). Identification of coastal wetlands of international importance for waterbirds: A review of China Coastal Waterbird Surveys 2005–2013. *Avian Research*, 6, 12.

Becker, R. G., Paise, G., & Pizo, M. A. (2013). The structure of bird communities in areas revegetated after mining in southern Brazil. *Revista Brasileira De Ornitolgia*, 21, 221–234.

Bibby, C. J., Burgess, N. D., Hill, D. A., & Mustoe, S. H. (2000). *Bird census techniques* (2nd ed.). Academic Press.

Borcard, D., Gillet, F., & Legendre, P. (2011). *Numerical ecology with R*. Springer.

Cao, L., Tang, S., Wang, X., & Barter, M. (2009). The importance of eastern China for shorebirds during the non-breeding season. *Emu-Austral Ornithology*, 109, 170–178.

Chapman, K. A., & Reich, P. B. (2007). Land use and habitat gradients determine bird community diversity and abundance in suburban, rural and reserve landscapes of Minnesota, USA. *Biological Conservation*, 135, 527–541.

Cherkauoi, L., Selmi, S., Boukhrriss, J., Hamid, R., & Mohammed, D. (2009). Factors affecting bird richness in a fragmented cork oak forest in Morocco. *Acta Oecologica*, 35, 197–205.

Collis, K., Roby, D. D., Craig, D. P., Admanay, S., Adsins, J. Y., & Lyons, D. E. (2002). Colony size and diet composition of piscivorous waterbirds on the lower Columbia River: Implications for losses of Juvenile Salmonids to avian predation. *Transactions of the American Fisheries Society*, 131, 537–550.

Croft, S., Budgey, R., Pitchford, J. W., & Wood, A. J. (2013). The influence of group size and social interactions on collision risk with obstacles. *Ecological Complexity*, 16, 77–82.

Croft, S., Budgey, R., Pitchford, J. W., & Wood, A. J. (2015). Obstacle avoidance in social groups: New insights from asynchronous models. *Journal of the Royal Society Interface*, 12, 20150178.

Deikumah, J. P., McAlpine, C. A., & Maron, M. (2014). Mining matrix effects on West African rain forest birds. *Biological Conservation*, 169, 334–343.

Fortin, M. J., & Dale, M. (2005). *Spatial analysis: A guide for ecologists*. Cambridge University Press.
Freshwater, C., Ghalambor, C. K., & Martin, P. R. (2014). Repeated patterns of trait divergence between closely related dominant and subordinate bird species. *Ecology, 95*(8), 2334–2345.

Ge, Z. M., Zhou, X., Wang, T. H., Wang, K. Y., Pei, E., & Yuan, X. (2009). Effects of vegetative cover changes on the carrying capacity of migratory shorebirds in a newly formed wetland, Yangtze River Estuary. *China Zoological Studies, 48*(6), 769–779.

Grodsky, S. M., Jennelle, C. S., & Drake, D. (2013). Bird mortality at a wind-energy facility near a wetland of international importance. *The Condor, 115*(4), 700–711.

He, Z. X., Xu, S. C., Shen, W. X., Zhang, H., Long, R. Y., Yang, H., & Chen, H. (2016). Review of factors affecting China’s offshore wind power industry. *Renewable and Sustainable Energy Reviews, 56*, 1372–1386.

Herbert, G. M. J., Iniyan, S., & Amutha, D. (2014). A review of technical issues on the development of wind farms. *Renewable and Sustainable Energy Reviews, 32*, 619–641.

Hilgerloh, G., Michalik, A., & Raddatz, B. (2011). Autumn migration of soaring birds through the Gebel El Zeit Important Bird Area (IBA), Egypt, threatened by wind farm projects. *Bird Conservation International, 21*(4), 365–375.

IUCN (2021) The IUCN red list of threatened species. Version 2021–. Accessed 5 April 2021.

IUCN (2021) The IUCN red list of threatened species. Version 2021–. Accessed 5 April 2021.

Ma, Z. J., & Chen, S. H. (2018). Stilt, 50, 44–57.

Ma, Z. J., Choi, C. Y., Gan, X. J., Zheng, S., & Chen, J. K. (2006). The importance of Judduansha Wetlands for shorebirds during northward migration: Energy-replenishing sites or temporary stages? *Stilt, 50*, 54–57.

Ma, Z. J., Wang, Y., Gan, X. J., Li, B., Cai, Y. T., & Chen, J. K. (2009). Waterbird population changes in the wetlands at Chongming Dongtan in the Yangtze River Estuary, China. *Environmental Management, 43*, 1187–1200.

Marques, A. T., Santos, C. D., Hanssen, F., Muñoz, A., Onrubia, A., Wikelski, M., Moreira, F., Palmeirim, J. M., & Silva, J. P. (2020). Wind turbines cause functional habitat loss for migratory soaring birds. *Journal of Animal Ecology, 89*, 93–103.

McFarlane, L. A. (2014). Avian wing morphology: intra- and interspecific effects on take-off performance and muscle function in controlling wing shape over the course of the wing stroke. *Dissertation, The University of Leeds*

McKinney, R. A., Raposa, K. B., & Cournoyer, R. M. (2011). Wetlands as habitat in urbanizing landscapes: Patterns of bird abundance and occupancy. *Landscape and Urban Planning, 100*, 144–152.

Muñoz, C. E., Ippi, S., Celis-Diez, J. L., Salinas, D., & Armesto, J. J. (2017). Arthropods in the diet of the bird assemblage from a forested rural landscape in Northern Chiloe Island, Chile: A quantitative study. *Ornitologia Neotropical, 28*, 191–199.

Newton, I., & Little, B. (2009). Assessment of wind-farm and other bird casualties from carcasses found on a Northumbrian beach over an 11-year period. *Bird Study, 56*, 158–167.

Niemuth, N. D., Estey, M. E., Reynolds, R. E., Loesch, C. R., & Meeks, W. A. (2006). Use of wetlands by spring-migrant shorebird species in agricultural landscapes of North Dakota’s drift prairie. *Wetlands, 26*(1), 30–39.

Norberg, U. M. L. (2004). Bird flight. *Acta Zoologica Sinica, 50*(6), 921–935.

Pearce-Higgins, J. W., Stephen, L., Langston, R. H. W., Bainbridge, I. P., & Bullman, R. (2009). The distribution of breeding birds around upland wind farms. *Journal of Applied Ecology, 46*, 1323–1331.

Peng, H. B., Anderson, G. Q. A., Chang, Q., Choi, C. Y., Chowdhury, S. U., Clark, N. A., Gan, X. J., Hearn, R. D., Li, J., Lappo, E. G., Liu, W. L., Ma, Z. J., Melville, D. S., Phillips, J. F., Syroechkovskiy, E. E., Tong, M. X., Wang, S. L., Zhang, L., & Zöckler, C. (2017). The intertidal wetlands of southern Jiangsu Province, China – globally important for spoon-billed sandpipers and other threatened waterbirds, but facing multiple serious threats. *Bird Conservation International, 27*(3), 305–322.

Plonczkier, P., & Simms, I. C. (2012). Radar monitoring of migrating pink-footed geese: Behavioural responses to offshore wind farm development. *Journal of Applied Ecology, 49*, 1187–1194.

Pruett, C. L., Patten, M. A., & Wolfe, D. H. (2009). It’s not easy being green: Wind energy and a declining grassland bird. *BioScience, 59*(3), 257–262.

Ralph, C. J., Droge, S., & Sauer, J. R. (1995). Managing and monitoring birds using point counts: standards and applications. In: Ralph, C. John; Sauer, John R.; Droge, Sam, technical editors. 1995. Monitoring bird populations by point counts. *Gen. Tech. Rep. PSW-GTR-149*. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station: pp. 161–168, 149, 209–224.

Schau, M. (2012). Spatial distribution of wind turbines is crucial for the survival of red kite populations. *Biological Conservation, 155*, 111–118.

Sheard, C., Neate-Clegg, M. H. C., Alioravainen, N., Jones, S. E. I., Vincent, C., MacGregor, H. E. A., Bregman, T. P., Claramunt, S., & Tobias, J. A. (2020). Ecological drivers of global gradients in avian dispersal inferred from wing morphology. *Nature Communications, 11*, 2463.

Smallwood, K. S., Rugge, L., & Morrison, M. L. (2009). Influence of behavior on bird mortality in wind energy developments. *The Journal of Wildlife Management, 73*, 1082–1098.

Thomas, A. L. R. (1997). On the tails of birds. *BioScience, 47*(4), 215–225.

Thomas, A. L. R., & Balmford, A. (1995). How natural selection shapes birds’ tails. *The American Naturalist, 146*(6), 848–868.

Villegas-Patraca, R., Cabrera-Cruz, S. A., & Herrera-Alsina, L. (2014). Soaring migratory birds avoid wind farm in the Isthmus of Tehuantepec, Southern Mexico. *PLoS One, 9*(3), e92462.

Wade, S., & Hickey, R. (2008). Mapping migratory wading bird feeding habitats using satellite imagery and field data. *Eighty-Mile Beach, Western Australia*. *Journal of Coastal Research, 24*(3), 759–770.

Wang, J. J., Zou, X. Q., Yu, W. W., Zhang, D. J., & Wang, T. (2019). Effects of established offshore wind farms on energy flow of coastal ecosystems: A case study of the Rudong offshore wind farms in China. *Ocean and Coastal Management, 171*, 111–118.

WWEA (2021) Worldwide wind capacity reaches 744 gigawatts – An unprecedented 93 gigawatts added in 2020. *https://www.windea.org/worldwide-wind-capacity-reaches-744-gigawatts/. Accessed 5 April 2021*

Yang, J. B., Liu, Q. Y., Li, X., & Cui, X. D. (2017). Overview of wind power in China: Status and future. *Sustainability, 9*, 1454.

Yang, Z. Y., Lagassé, B. J., Xiao, H., Jackson, M. V., Chiang, C. Y., Melville, D. S., Leung, K. S. K., Li, J., Zhang, L., Peng, H. B., Gan, X. J., Liu, W. L., Ma, Z. J., & Choi, C. Y. (2020). The southern Jiangsu coast is a critical mouling site for Spoon-billed Sandpiper *Calidris pygmaea* and Nordmann’s
Greenshank *Tringa guttifer*. *Bird Conservation International*, 30(4), 649–660.

Yong, D. L., Jain, A., Liu, Y., Iqbal, M., Choi, C. Y., Crockford, N. J., Millington, S., & Provencher, J. (2018). Challenges and opportunities for transboundary conservation of migratory bird in the East Asian-Australasian flyway. *Conservation Biology*, 32(3), 740–743.

Yong, D. L., Liu, Y., Low, B. W., Española, C. P., Choi, C. Y., & Kawakami, K. (2015). Migratory songbirds in the East Asian-Australasian Flyway: A review from a conservation perspective. *Bird Conservation International*, 25(1), 1–37.