

3

王昱熙¹ 谢彦波¹ Nyambayar Batbayar⁵ 朱宝光⁴ 董树斌⁴ Anna Barma⁷
Anton Sasin⁶ 曹 垒^{2,3*}

1 (, 230026) 2 (, 100085)
3 (, 100049) 4 (, , 156332)
5 (, 14210)
6 (, 675000)
7 (, 690003)
: , 2016–2018
6 (*Anser indicus*) 5 (*Platalea leucorodia*) 10 (*Ciconia*
boycciana) , 4 844,592
, 21 , 3
: 3 ,
, ; 3 ,
(49.0%) (26.2%) (22.5%) , (42.1%) (19.8%) (19.6%)
, (49.8%) (34.5%) (4.6%) ; 50%
, 50% 1.6% 0, 2
, 3 , 3
,
: ; ; ; ; ;

Discussion of existing protection for three waterbirds' habitats in the Yellow River basin nature reserves, based on satellite tracking

Yuxi Wang¹, Yanbo Xie¹, Nyambayar Batbayar⁵, Baoguang Zhu⁴, Shubin Dong⁴, Anna Barma⁷, Anton Sasin⁶, Lei Cao^{2,3*}

1 University of Science and Technology of China, Hefei 230026, China

2 Research Center for Eco-Environmental Sciences,

: 2020-08-16; : 2021-01-18

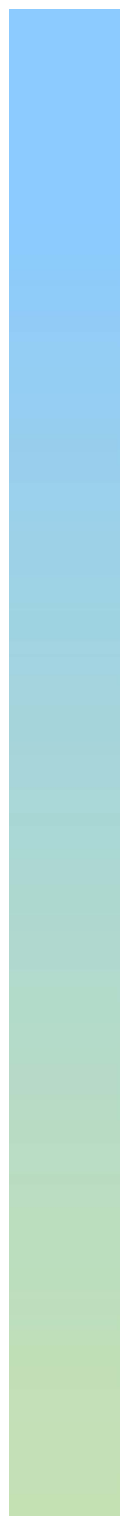
: (Sino BON)

* Author for correspondence. E-mail: caolei@ustc.edu.cn

China, Mongolia and Russia. During the tracking period, 844,592 pieces of high-frequency GPS tracking data were obtained, we analyzed the duration that these birds spent in the Yellow River basin and, the land cover types during their stay. Then we simulated the home range of the three species using kernel density estimation. The results showed that the Yellow River basin wetlands are used as a stopover site during the migration of these three waterbirds. Some juveniles of the Eurasian Spoonbills use the land as a summering area, and some of the Oriental Storks use it as a wintering area. There are differences in land cover of three waterfowl in the Yellow River basin. The Bar-headed Goose used the grassland (49.0%), bare land (26.2%) and water (22.5%). The Eurasian Spoonbill used the cropland (42.1%), grassland (19.8%) and wetland (19.6%). The Oriental Stork used the wetland (49.8%), cropland (34.5%) and water (4.6%). Our study found that 50% of the home range of the Bar-headed Goose overlaps with the existing nature reserves, while the homes range of the Eurasian Spoonbill and the Oriental Stork only overlap 1.6% and 0 with existing nature reserves, respectively. The habitats of these latter two species are in need of greater protection. At the same time, by analyzing the proportion of land types in the coverage area, we found that the birds' utilization of bare land, grassland and cropland is more passive, while the utilization of wetland and water is active. The results detail the movement and living characteristics of three waterfowl in the Yellow River. Given the lack of overlap between their habitats and existing nature reserves, it will be important to establish comprehensive protected areas for Eurasian Spoonbills and Oriental Storks as part of further development of the Yellow River nature reserves.

Key words: Bar-headed Goose; Eurasian Spoonbill; Oriental Stork; satellite telemetry; Yellow River nature reserve; protection status

, (Kanai et al, 2002; (IUCN, 2010) Higuchi et al, 2004; Shimazaki et al, 2004); Ueta (2003) (*Haliaeetus pelagicus*) ; , 2019) - Bishop (2015) , (East Asian-Australasian Flyway) (Central Asian Flyway) (West (Anser indicus) Pacific Flyway) (Wetlands International, “ ” 2013) , (Grus japonensis) (G. leucogeranus) (G. vipio) (G. (Joppa et al, 2008; Juffe-Bignoli et al, 2014) monacha) (Ciconia Boyciana) 3 : (, 2017; , (, 2020) 2017 , 2018; , 2018; , 2018; , 2,750 , 2018) 1,470,000 km², 14.9%, 2 (NBS, 2017) , (Volker et al, 2015), 157 , (IUCN, 2010) - , (Berthold & Terrill, 1991), , ,



(, 2010; , 2011 ; 35,171 , 5
, 2017) 2016 2018 2019 75,643 , 10 91,577
(47°47' N, Wang (2018) “
133°40' E) Bastak ” “ ” “ ”
10 , HQXS Ornitela ,
(1) HQXS Ornitela (Wang et al,
, 2018) “ ” (NSD)
GPS 10 150 km/d NSD 150
, 1 , km, NSD 75 km/d
2020 6 1 OS001 NSD 300 km , NSD
OS008 , 8 ,
Ornitela ,
10 min, 12 h; HQXS
1 h, 24 h, 304,592 48 h, 1
(3) (*Platalea*) ,
, ,
(Carboneras et al, 2016) , R dplyr
(, 2008; , 2016 ; ,
, 2018) 5 2018 /
7 16 Jiree River , 4 /
1 , Ornitela , 1
(1) ,
2019 12 31 2 ,
1 , 3 2
1 ES005
, 4 ,
10 min, 12 h,
251,230 **1.4**
1.3 ArcGIS 10.2 (ESRI, 2013)
, ,
10 km × 10 km ,
, kml ,
,
(, 2002) , R data.table 100%,
6
,
(2011) 100% ,
(2016) , 3% ,
© 生物多样性 Biodiversity Science

3% , 10% , 20% 2 (BHG003 BHG005)
, 50% , , 149 d,
1.5 (Kie et al, 2010) 111.2 d,
, 75.3%; 62.2 d,
25.3 d, 40.7% (1), MtoT
, MtoA
R adehabitatHR 4 (BHG001 BHG002 BHG004
(Calenge, 2006) BHG006) /
401.9 d,
109.8 d, 27.3%;
90% 75% 50% 40.7 d, (1)
, MtoT , MtoA
, (2) ,
(Alerstam, 2011), (2)
5 ,
ArcGIS 10.2 ,
50% (1) ,
466.2 d,
172.9 d, 37.1% (1)
39.1 d, 32.9 d,
84.1% (1) 2 (ES001 ES003) 2
3 ,
1.6 10 m FROM-GLC10 (Gong et al,
2019) , R raster (2)
Excel 2016 10
, ArcGIS 10.2 , 3 (OS002 OS003
, Excel OS007) 2 , 2
2016 , ArcGIS 10.2 (1) ,
((2)
, 3 ,
2
2.1 3
(1)
Zhang (2020) , 6 3
(MtoT) **2.2 3**
- / (MtoA) MtoT

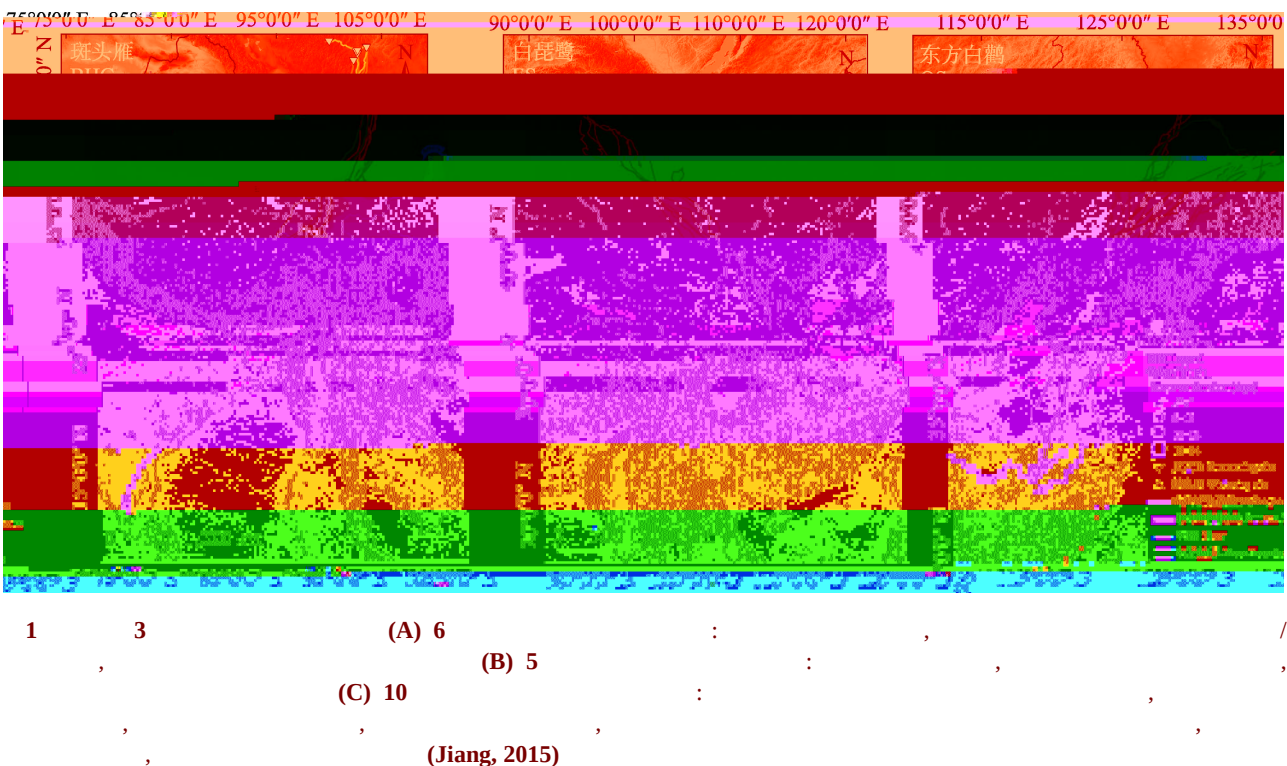


Fig. 1 The map of the migration route of three waterbirds by tracking their life history. (A) The spring and autumn migration routes of 6 Bar-headed Geese. The breeding area is Mongolia, and the wintering areas are Shigatse of Tibet of China and India/Bangladesh. The Species mainly stops in the Yellow River basin. (B) The spring and autumn migration routes of 5 Eurasian Spoonbills. The breeding area is Mongolia, the wintering area is the middle and lower reaches of the Yangtze River, and it stops or spends summer in the Yellow River basin during migration. (C) The spring and autumn migration routes of 10 Oriental Storks, overwintering in the Yellow River basin. The red line represents the autumn migration route, the yellow line represents the spring migration route, the inverted triangle represents the summering sites, the forward triangle represents the wintering sites, the green circle represents the location and period of the stopover in the Yellow River basin, the blue line represents the Yellow River and the Yangtze River and the light blue shadow represents the Yellow River basin (Jiang, 2015).

1
Table 1 Activities and utilization types of three migratory waterbirds in the Yellow River basin (YRB)

Species	Population	Season	Staging in YRB (d)	Mig08 0 0 7MCID 26 >>BDC 0.851 scn 333.66 293.22 76.8 12.36 re f* B
---------	------------	--------	--------------------	---

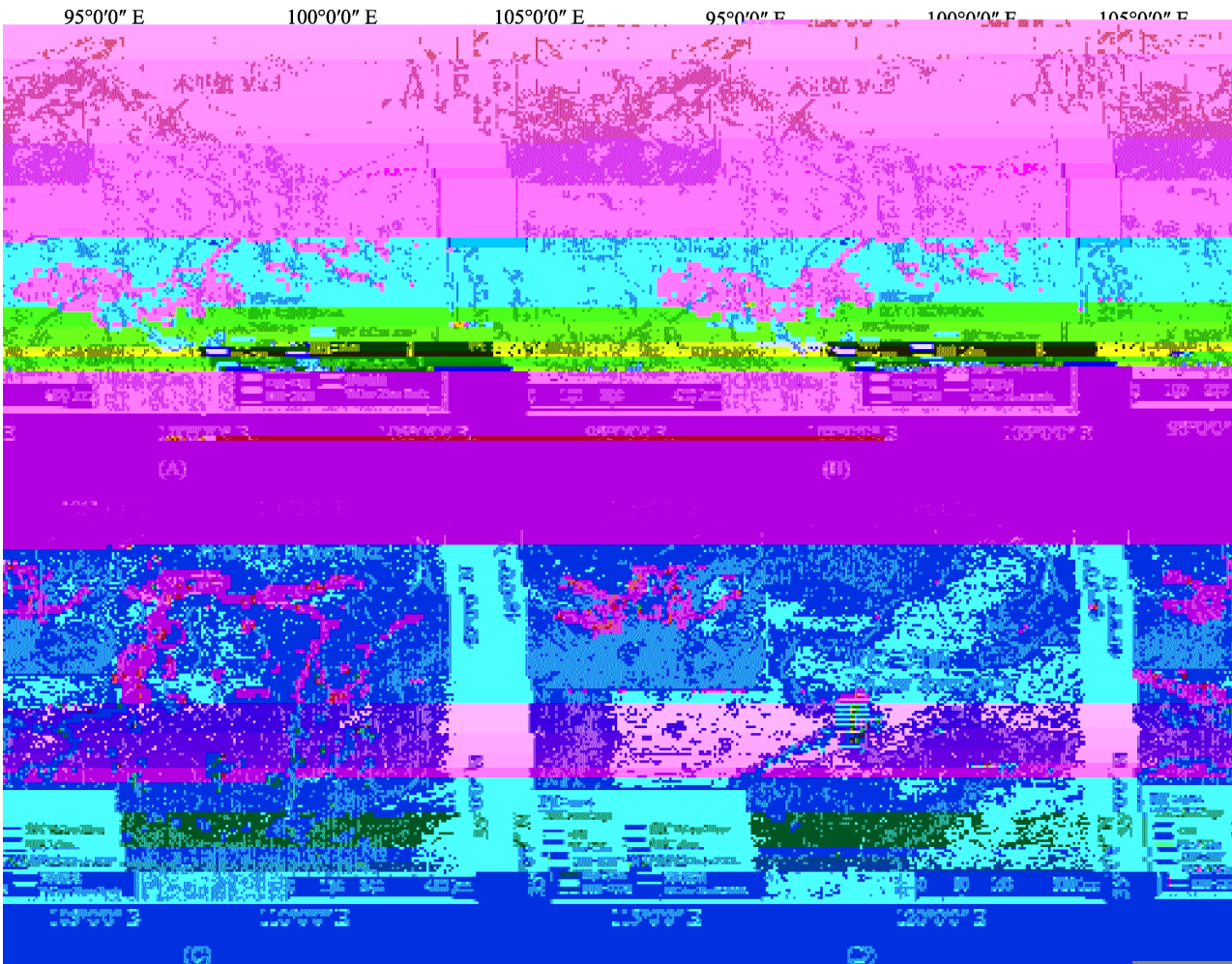


Fig. 2 Density diagram of the sites of three waterbirds in the Yellow River basin. (A) and (B) showed the important habitats of the MtoT population and the MtoA population of the Bar-headed Goose; (C) showed the important habitat of the Eurasian Spoonbill; (D) showed the important habitat of the Oriental Stork. The blue line is the Yellow River, the white line is the boundary of the Yellow River basin, and the area shaded by the green grid is the Yellow River basin nature reserves. The site density of the Yellow River basin is marked with 3% (blue), 3% (green), 10% (yellow), 20% (orange) and 50% (red) (Jiang, 2015).

(49.0%) (26.2%) (22.5%) (19.6%) (11.1%) (2) , 50% (2.3%) 2 3 , 1.1% 1.6%, , 50% 17.8 6.9 (28.5%) (3.4%), (2), , 8.7 16.9 , (2) , 330.6 km² (90%) 63,064.6 km² 91.7 km² (75%) 8.1 km² (50%) (3) (90%) 31,660.7 km² (75%) 6,428.4 km² (50%) (, 2 : (49.8%) 3) (42.1%) (19.8%) (34.5%) (2) 50%

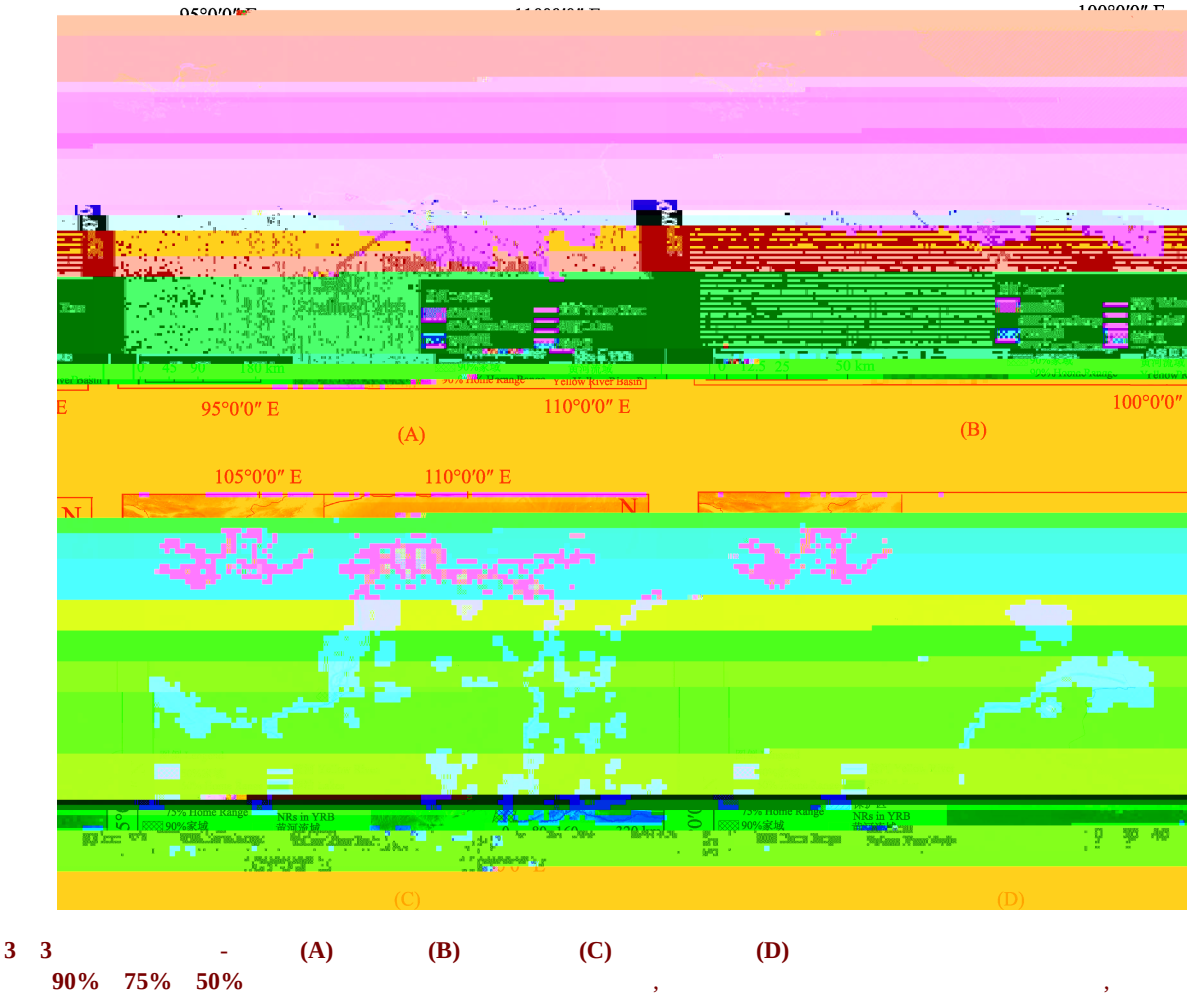


Fig. 3 The home range of three waterbirds in the Zhaling-Eling lake (A), Muli Town (B), Hetao Plain (C), and the Yellow River Delta (D). The black shade, the yellow shade and the red shade are 90%, 75%, and 50% of the home range fitted. The blue line is the Yellow River, the green grid shaded area is the Yellow River basin nature reserves, the white line area is the boundary of the Yellow River basin, and the blue area is the lakes.

Table 2 Three important habitats of waterbirds in the Yellow River basin and land use in their home ranges

Species	Habitat	Cropland	Forest	Grassland	Shrubland	Wetland	Water	Artificial surface	Bare land
Bar-headed Goose	Muli Town	0.0%	0.0%	49.0%	0.0%	2.3%	22.5%	0.0%	26.2%
	— Zhaling-Eling lake	0.0%	0.0%	50.9%	0.0%	6.4%	14.7%	0.0%	28.0%
	50% Home range-50%	0.0%	0.0%	84.9%	0.0%	0.5%	1.2%	0.0%	13.4%
	75% Home range-75%	0.0%	0.0%	74.4%	0.0%	0.3%	5.7%	0.0%	19.6%
	90% Home range-90%	0.0%	0.0%	66.8%	0.0%	0.6%	7.7%	0.0%	24.9%
Eurasian Spoonbill	Hetao Plain	42.1%	0.7%	19.8%	0.0%	19.6%	11.1%	3.3%	3.4%
	50% Home range-50%	55.2%	0.1%	7.4%	2.2%	1.1%	1.6%	3.9%	28.5%
	75% Home range-75%	34.5%	1.5%	13.9%	1.3%	0.8%	1.5%	2.5%	44.0%
	90% Home range-90%	31.7%	2.7%	27.7%	0.4%	0.5%	0.9%	3.8%	32.3%
Oriental Stork	Yellow River Delta	34.5%	0.0%	4.5%	0.0%	49.8%	4.60%	6.6%	0.0%
	50% Home range-50%	69.8%	0.0%	0.1%	0.0%	0.1%	14.3%	15.7%	0.0%
	75% Home range-75%	61.0%	0.0%	0.6%	0.0%	0.6%	24.0%	13.7%	0.1%
	90% Home range-90%	64.5%	0.0%	3.3%	0.0%	2.7%	19.1%	8.1%	2.3%

33

Table 3 Overlapping in the Yellow River basin nature reserves and home ranges of three waterfowl

	Home range	Area (km ²)	Overlapping area (km ²)	Overlapping rate
Bar-headed Goose	50%	370.9	370.9	100.0%
	75%	1,427.1	1,427.1	100.0%
	90%	3,394.6	3,386.1	99.8%
Eurasian Spoonbill	50%	6,428.4	105.2	1.6%
	75%	31,660.7	951.6	3.0%
	90%	63,064.6	3,090.4	4.9%
Oriental Stork	50%	8.1	0.0	0.0%
	75%	91.7	27.2	29.6%
	90%	330.6	76.6	23.2%

, 0.1%,

,

(2)

3

, :

,

,

2.3

3

, 90% 75% 50%

3,386.1 km²(99.8%) 1,427.1 km²

(100.0%)

10 1 , ,

2

1 , ,

3.2 3

, , ,

, 11 19 ,

(*Potamogeton pusillus*) (*Triglochin maritimum*) (, 2020) , , 2 (, 2014)

: + æ óÝz Ö j/d ó , / ‡ Æ
 ‡ ¥ ö l Ö å Æ Ö Bastak
 l Ö óÝz] · b [" æ T % 0 s ô
 l Ö b Z Y " 3 ' / ‡ ‡ 0] _
 , B Y N / i ' ä § ' @ e ¥ s 3
 b M Û ý É , } fi ¢ É+ æ

- Alerstam T (2011) Optimal bird migration revisited. *Journal of Ornithology*, 152, 5–23.
- Basic Dataset of the Yellow River Basin (2002) National Data Center for Glacier, Permafrost and Desert Science (www.ncdc.ac.cn). (in Chinese) [(2002) (www.ncdc.ac.cn).] (accessed on 2020-08-01)
- Beatty WS, Kesler DC, Webb EB, Raedeke AH, Naylor LW, Humburg DD (2014) The role of protected area wetlands in waterfowl habitat conservation: Implications for protected area network design. *Biological Conservation*, 176, 144–152.
- Berthold P, Terrill SB (1991) Recent advances in studies of bird migration. *Annual Review of Ecology and Systematics*, 22, 357–378.
- Bishop CM, Spivey RJ, Hawkes LA, Batbayar N, Chua B, Frappell PB, Milsom WK, Natsagdorj T, Newman SH, Scott GR, Takekawa JY, Wikelski M, Butler PJ (2015) The roller coaster flight strategy of bar-headed geese conserves energy during Himalayan migrations. *Science*, 347, 250–254.
- Bodey TW, Cleasby IR, Bell F, Parr N, Schultz A, Votier SC, Bearhop S (2018) A phylogenetically controlled meta-analysis of biologging device effects on birds: Deleterious effects and a call for more standardized reporting of study data. *Methods in Ecology and Evolution*, 9, 946
- Cai YL (2016) Investigation of wild plants in Zhaling Lake-Eling Lake Protection Zone. *Beijing Agriculture*, (3), 109–111. (in Chinese) [(2016)

- K, Goroshko O, Ueta M, Smirensky S, Mita N (2004) Using a remote technology in conservation: Satellite tracking white-naped cranes in Russia and Asia. *Conservation Biology*, 18, 136–147.
- Huang ZQ, Che CG, Tan HT, Bi ZG, Liu WH, Zhang XT, Zhang SY, Li DL (2018) Investigation on the diversity and population of waterbird in the Yellow River Delta Nature Reserve. *Journal of Shandong Forestry Science and Technology*, 48, 41–45, 48. (in Chinese with English abstract) [, , , , , , (2018) , 48, 41–45, 48.]
- IUCN (International Union for Conservation of Nature) (2010) The Ramsar Handbooks for the Wise Use of Wetlands, 4th edn. Ramsar Convention Secretariat, Gland, Switzerland.
- Jiang H (2015) Global administrative boundary data. National Earth System Science Data Center, National Science & Technology Infrastructure of China. <http://www.geodata.cn>, accessed on 2020-08-01.
- Joppa LN, Loarie SR, Pimm SL (2008) On the protection of “protected areas”. *Proceedings of the National Academy of Sciences, USA*, 105, 6673–6678.
- Juffe-Bignoli D, Burgess ND, Bingham H, Belle EMS, de Lima MG, Deguignet M, Bertzky B, Milam AN, Martinez-Lopez J, Lewis E (2014) Protected Planet Report 2014. UNEP-WCMC, Cambridge, UK.
- Kanai Y, Nagendran M, Ueta M, Markin Y, Rinne J, Sorokin AG, Higuchi H, Archibald GW (2002) Discovery of breeding grounds of a Siberian Crane *Grus leucogeranus* flock that winters in Iran, via satellite telemetry. *Bird Conservation International*, 12, 327–333.
- Kays R, Crofoot MC, Jetz W, Wikelski M (2015) Terrestrial animal tracking as an eye on life and planet. *Science*, 348(6240).
- Kie JG, Matthiopoulos J, Fieberg J, Powell RA, Cagnacci F, Mitchell MS, Gaillard JM, Moorcroft PR (2010) The home-range concept: Are traditional estimators still relevant with modern telemetry technology? *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365, 2221–2231.
- Li DL, Chen SH, Lloyd H, Zhu SY, Shan K, Zhang ZW (2013) The importance of artificial habitats to migratory waterbirds within a natural/artificial wetland mosaic, Yellow River Delta, China. *Bird Conservation International*, 23, 184–198.
- Li SH, Meng WY, Chen LX, Li YF, Gao RY, Ru WD, Sun MH, Dai Q, Zhang GG, Lu J (2017) The spring waterbird community and home range of the Whooper Swan *Cygnus cygnus* at the upper and middle reaches of Yellow River in Inner Mongolia, China. *Chinese Journal of Ecology*, 36, 1910–1916. (English abstract) [, , , , , , (2017) , 36, 1910–1916.]
- Lian HY, Wu LX, Cao AL, Zhang XS (2018) Bird Diversity in Shandong Yellow River Delta National Nature Reserve. *Journal of Shandong Forestry Science and Technology*, 48(4), 44–46, 62. (2018) , 48(4), 44–46, 62.]
- Liu DP (2010) Breeding Movement and Migration of Bar-headed Goose (*Anser indicus*) at Qinghai Lake and Spatial-temporal Relationship with HPAI Outbreaks. PhD dissertation. Chinese Academy of Forestry Sciences, Beijing. (in Chinese) [(2010) (*Anser indicus*) .]
- Ma CH, Ma SZ, Wei XY, Wang WL (2008) Waterbird resources in Yellow River Wetland National Nature Reserve in Mengjin, Henan. *Sichuan Journal of Zoology*, 27, 902–904. (2008) , 27, 902–904.]
- Ma YR, Wan LX, Luo HD, Jia YY (2020) Analysis of dietary of bar-headed geese inhabited in Gansu Yanchiwan National Nature Reserve in breeding period. *Journal of Arid Land Resources and Environment*, 34, 166–171. English abstract) [, , , (2020) , 34, 166–171.]
- NBS (National Bureau of Statistics) (2017) China Statistical Yearbook. China Statistics Press, Beijing.
- Shao MQ, Jiang JH, Dai NH (2016) Micro-habitat use of water birds in Poyang Lake and its response to water level during non-breeding period. *Chinese Journal of Ecology*, 35, 2759–2767. (2016) , 35, 2759–2767.]
- Shimazaki H, Tamura M, Higuchi H (2004) Migration routes and important stopover sites of endangered Oriental Storks (*Ciconia boyciana*) as revealed by satellite tracking. *Memoirs of the National Institute of Polar Research Special Issue*, 58, 162–178.
- Takekawa JY, Heath SR, Douglas DC, Perry WM, Javed S, Newman SH, Suwal RN, Rahmani AR, Choudhury BC, Prosser DJ, Yan B, Hou Y, Batbayar N, Natsagdorj T, Bishop CM, Butler PJ, Frepell PB, Milson WK, Scott GR, Hawkes LA, Wikelski M (2009) Geographic variation in Bar-headed Geese *Anser indicus*: Connectivity of wintering areas and breeding grounds across a broad front. *Wildfowl*, 59, 100–110.
- Tavares DC, Guadagnin DL, de Moura JF, Siciliano S, Merico A (2015) Environmental and anthropogenic factors structuring waterbird habitats of tropical coastal lagoons: Implications for management. *Biological Conservation*, 186, 12–21.
- Ueta M, Mcgrady MJ, Nakagawa H, Sato F, Masterov VN (2003) Seasonal change in habitat use in Steller’s Sea Eagles (*Haliaeetus pelagicus*). *Oryx*, 37, 110–114.
- Volker M, Rakhyun EK, Casey S (2015) When implementation works: A comparison of Ramsar Convention

- implementation in different continents. *Environmental Science and Policy*, 51, 95–105.
- Wang X, Barter M, Cao L, Lei JY, Fox AD (2012) Changes in the distribution and abundance of wintering Lesser White-fronted Geese *Anser erythropus* in eastern China. *Bird Conservation International*, 22(2), 128.
- Wang X, Cao L, Byskatova I, Xu ZG, Fox AD (2018) The Far East taiga forest: Unrecognized inhospitable terrain for migrating Arctic-nesting waterbirds? *PeerJ*, 6, e4353.
- Wetlands International (2013) *Waterbird Population Estimates*, 5th edn. Wetlands International, Wageningen.
- Xu W, Li X, Pimm SL, Hull V, Zhang JJ, Zhang L, Xiao Y, Zheng H, Ouyang ZY (2016) The effectiveness of the zoning of China's protected areas. *Biological Conservation*, 204, 231–236.
- Xue WW, Zhou LZ, Zhu SY, Shan K, Wang LD, Xu RX (2010) Breeding ecology of oriental white stork (*Ciconia boyciana*) in the migratory stopover site. *Chinese Journal of Applied & Environmental Biology*, 16, 828 [Chinese with English abstract] [, , , , (2010) , 16, 828–832.]
- Xue YD, Li DQ, Li J (2020) Habitat selection and migration pattern of wild Bactrian camel (*Camelus ferus*) in the Kumtag Desert, China based on satellite tracking and positioning technology. *Scientia Silvae Sinicae*, 56(10), 192 [, (2020) , 56(10), 192–198.]
- Yang XL, Jiang HX, Zou CL, Wang Y, Lin BQ, Li LS (2020) Changes in migration pattern and important stopover sites of the eastern population of Siberian cranes. *Scientia Silvae Sinicae*, 56(2), 123 [, , , , (2020) , 56(2), 123–133.]
- Zhang FY, Yang RL (1997) *Bird Migration Research of China*. China Forestry Publishing House, Beijing. (in Chinese) [, (1997) .]
- Zhang JJ, Xie YB, Li LX, Batbayar N, Deng XQ, Damba I, Meng FJ, Cao L, Fox AD (2020) Assessing site-safeguard effectiveness and habitat preferences of Bar-headed Geese (*Anser indicus*) at their stopover sites within the Qinghai-Tibet Plateau using GPS/GSM telemetry. *Avian Research*, 11, 1–13.
- Zhang L, Wang X, Zhang J, Ouyang ZY, Chan S, Crosby M, Watkins D, Martinez J, Su LY, Yu Y, Szabo J, Cao L, Fox AD (2017) Formulating a list of sites of waterbird conservation significance to contribute to China's Ecological Protection Red Line. *Bird Conservation International*, 27, 153–166.
- Zhang TT, Peng ZJ, Zhou DQ, Lu CH (2019) Research progress on habitat selection of red-crowned crane (*Grus japonensis*) in China. *Chinese Journal of Zoology*, 54, 134 [, , (2019) , 54, 134–144.]
- Zhang XC, Jin BS, Chen JK, Wu JD, Liu GH, Ma ZJ (2014) Relationship between habitat use of four waterbird species and water depth and food resource in Poyang Lake. *Chinese Journal of Zoology*, 49, 657–665. (in Chinese with English abstract) [, , , , (2014) , 49, 657–665.]
- Zhang XL, Li P, Liu LJ, Li PY, Shan K (2009) Biodiversity and its protection in the Yellow River Delta wetland. *Coastal Engineering*, 28, 33 [, , , (2009) , 28, 33–39.]

Supplementary Material

1

Appendix 1 Tracking individual information of species studied
<http://www.biodiversity-science.net/fileup/PDF/2020328-1.pdf>

2

Appendix 2 Tracking species stopover information in the Yellow River basin
<http://www.biodiversity-science.net/fileup/PDF/2020328-2.pdf>

3

3

Appendix 3 Supplementary results of land use of three waterfowl in the Yellow River basin
<http://www.biodiversity-science.net/fileup/PDF/2020328-3.pdf>

3

-

2

4

2

2

A1

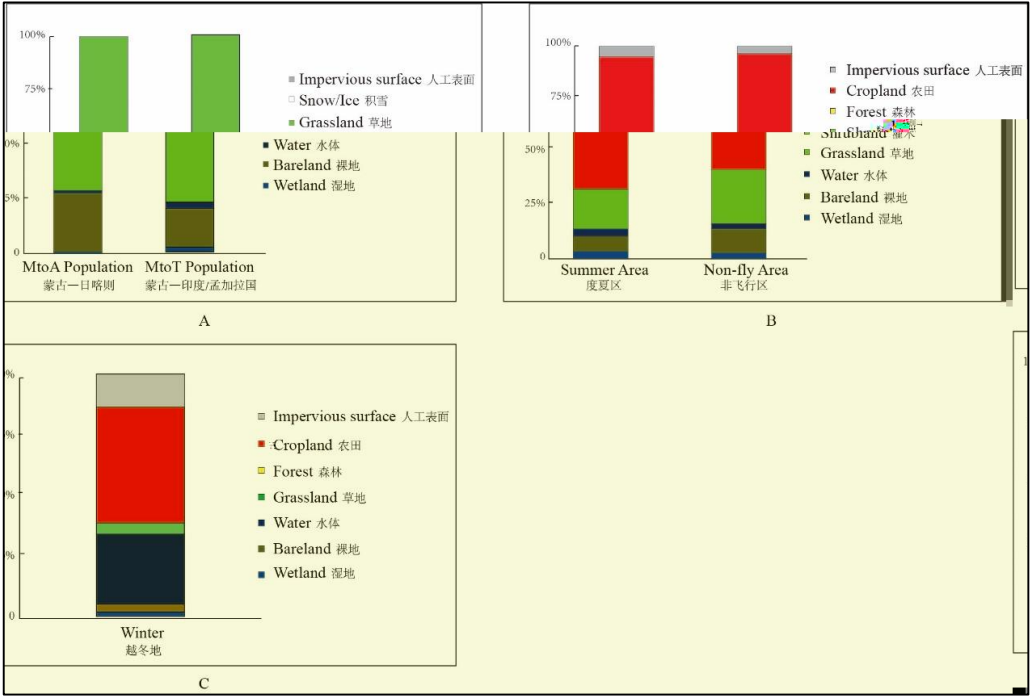
4 3

- *Anser indicus*

0 3

. 3
- .
3 3 2

A1 B D A C
& , 2 0



A2

B

C

A

& , 4
% 3 4 / 3