Bird Conservation International (2017) 27:153–166. © BirdLife International, 2017
doi:10.1017/S095927091700003X

Formulating a list of sites of waterbird conservation significance to contribute to China's Ecological Protection Red Line

LU ZHANG, XIN WANG, JUNJIAN ZHANG, ZHIYUN OUYANG, SIMBA CHAN, MIKE CROSBY, DOUG WATKINS, JONATHAN MARTINEZ, LIYING SU, YAT-TUNG YU, JUDIT SZABO, LEI CAO and ANTHONY D. FOX

Summary

China makes a unique and vital contribution to maintaining global and regional waterbird diversity and conservation. Despite considerable historical conservation efforts, the continued loss of waterbird diversity and abundance necessitates a contemporary review of Chinese sites of conservation significance. The Ecological Protection Red Line (EPRL) was proposed by China's Central Government in 2013 to protect areas providing crucial ecosystem services and provides the opportunity for such a review to enhance waterbird conservation in China. By incorporating various sources of data, surveys and information, we identified a suite of sites of waterbird conservation significance in China, following the Ramsar Site Criteria/Important Bird and Biodiversity Area (IBA) Criteria. In total, we identified 422 sites, of which the existing 286 IBA sites formed the basis of the site safeguard network. Altogether, these sites of waterbird conservation significance constitute over 727,000 km² (7.6% of China's land surface). Over half of the area of these sites is outside China's national nature reserves, thus confirming the importance and urgency of including them in the EPRL for the effective conservation of waterbird sites. We suggest that this assessment of sites of waterbird importance offers a useful model to apply to other taxa, such as terrestrial birds and mammals.

Introduction

Mainland China makes a unique and vital contribution to maintaining global and regional waterbird diversity and conservation (BirdLife International 2014a). Many threatened species in two flyways (Central Asian Flyway and East Asian-Australasian Flyway) occur in China in large numbers (e.g. Cao *et al.* 2008a, China Coastal Waterbird Census Group *et al.* 2015). However, rapid economic development during the last three decades has created great challenges to waterbird conservation, particularly as a consequence of extensive habitat loss and degradation (State Forestry Administration 2002, de Boer *et al.* 2010, Liu *et al.* 2010, Fox *et al.* 2011, Liu *et al.* 2013, Murray *et al.* 2014) and hunting pressure (MaMing *et al.* 2012). As a result, many species in China are undergoing contractions in distribution and declines in population size (Cao *et al.* 2008c), concentrating greater numbers into fewer and smaller areas of suitable habitat (Cao *et al.* 2007, Yang *et al.* 2011, Zhang *et al.* 2011, Wang *et al.* 2012a, 2012b). Protecting these waterbird species is part of China's international responsibility to maintain regional and global biodiversity under international conventions, such as the Ramsar Convention (Ramsar Convention Secretariat 2010) and Convention on Biological Diversity (United Nations 1992). Aichi Target 11 of the Convention on Biological Diversity states that 'by 2020, at least 17% of terrestrial and inland water areas and 10% of coastal and marine areas, especially areas of particular importance for

biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape'.

China has made great efforts to conserve biodiversity - as of 2013, 2,697 nature reserves have been established, covering 14.8% of the country's land surface (Ministry of Environmental Protection 2014), less than in North America (17.8%) but greater than in Europe (12.4%) and Australia/New Zealand (10.4%) (Chape *et al.* 2005). Other types of protected areas, such as forest parks and wetland parks, have also been established to contribute to biodiversity conservation. However, the continued loss of biodiversity demonstrates that the inability to effectively protect all crucial habitats and taxa, including birds, is partly the result of gaps in the protected area network and especially the national nature reserve system (Quan *et al.* 2009, Wu *et al.* 2011).

In recognition of these problems the Government of China has issued several directives. In order to strengthen ecological protection and establish ecological security pattern, in 2011 the "State Council's Opinions on Priorities of Strengthening Environmental Protection" (GF [2011] No. 35) made it clear that in areas with important ecological function, terrestrial and marine ecologically sensitive areas, fragile areas, and other areas, ecological protection red lines (EPRL) shall be drawn up. "Decisions on Several Major Issues of Comprehensively Deepening Reform" were adopted at the Third Plenary Session of 18th CPC Central Committee and set ecological protection redlining as a key concept. It explicitly requested "to delineate ecological protection red lines", "establish a national spatial development and protection system", "establish a spatial planning system, delineate production, life and ecological space development control limits, and implement use controls". The EPRL is expected to include 35% of China's land, water and coastline and is proposed to include core and buffer zones of existing nature reserves and various additional areas identified by existing administrative programmes such as the National Biodiversity Strategy and Action Plans (China Council for International Cooperation on Environment and Development 2014). By incorporating biodiversity conservation, the EPRL has the potential to protect areas with high biodiversity conservation value, important species, representative ecosystem types and genetic resources. It is proposed that within EPRL areas protected for their biological diversity, most human activities and all major developmental proposals are forbidden or restricted (China Council for International Cooperation on Environment and Development 2014).

The implementation of the EPRL therefore provides the opportunity to greatly enhance waterbird conservation in China within a broader framework. Compared to many terrestrial bird species and other taxa, waterbirds have suffered major declines but have generally been better monitored. This allows for the application of more objective and quantifiable criteria for site designation and more precise definition of site boundaries. In general, areas important for biological conservation are designated based on either species distribution ranges (e.g. Rodrigues *et al.* 2004, Wu *et al.* 2011) or species diversity and abundance at specific sites, such as Ramsar Sites (Wetlands of International Importance; Ramsar Convention Secretariat 2010) and Important Bird and Biodiversity Areas (IBA; BirdLife International 2014b). The specific criteria for the designation of Ramsar Sites for waterbirds consider both the actual number (regularly 20,000 or more individuals) and proportion (regularly 1% or more of the individuals in a population of one species or subspecies) of waterbirds that a designated site should hold. This set of criteria has been widely accepted and (partly) adopted by other criteria for the designation of sites for conservation, such as IBA and EAAFP Flyway Site (East Asian-Australasian Flyway Partnership 2015). In particular, the expert-driven IBA system, adopting a modified set of Ramsar Site Criteria (see Methods for detail), provided boundaries to important areas, based on field surveys of bird species and their habitats. Up to 2009, 512 sites had been identified as IBAs in Mainland China, of which 410 sites had identifiable boundaries (BirdLife International 2014c). Bird surveys in recent years have established the existence of many new sites which fulfil the Ramsar Site Criteria or IBA Criteria (e.g. Cao *et al.* 2008b; China Coastal Waterbird Census Goup *et al.* 2015). The complete set of sites of waterbird conservation significance should include all existing waterbird IBA sites with determined boundaries, as well as identifying spatially defined new sites fulfilling the Ramsar or IBA site criteria.

To formulate a comprehensive suite of sites of waterbird conservation significance for China's EPRL, we combined current waterbird IBA sites with boundaries, determined the boundaries for those IBAs that are currently lacking, and appended new sites that have been shown to fulfil the Ramsar Site criteria/IBA criteria, based on data from bird surveys undertaken in the last decade. We determined the area of these sites and compared their boundaries with current national nature reserves, and identified the gaps within the currently designated conservation areas. These additional sites will form a significant contribution to EPRL, and will provide critical guidance for waterbird conservation in China in the coming years. We also recommend these newly identified sites be assessed as new Ramsar/IBA sites with their associated site boundaries.

Methods

Important Bird and Biodiversity Areas, bird count and survey information

In order to create a comprehensive set of sites of waterbird conservation significance in mainland China, we examined, according to the best existing knowledge, publicly available data sources, starting with the existing suite of IBAs (BirdLife International 2009, 2014c). The IBAs included the most important sites hitherto known for birds, based on information in the literature and expert knowledge up to 2009. The Secretariat of the Partnership for the East Asian-Australasian Flyway provided another major data source for the sites of waterbird conservation significance based on the compilation and integration of survey data, including information collected after 2009 (Jaensch 2013). Together, these two sources of site data covered most known waterbird surveys that have been published in the ornithological and conservation literature (Cao *et al.* 2008a, 2008c, 2009, 2010, China Coastal Waterbird Census Group 2009, 2011, Conklin *et al.* 2014; China Coastal Waterbird Census Group *et al.* 2015, Jia *et al.* 2016).

Extensive consultation with all major conservation agencies and groups working in China, including the International Crane Foundation, BirdLife International, Wetlands International, Hong Kong Bird Watching Society and China Coastal Waterbird Census Group contributed additional sites for assessment based on recent survey reports and unpublished information collected in recent years (Table 1). Correspondence with and information from these conservation agencies and individual experts has enabled us to compile data on a network of key sites for waterbirds in China.

Criteria for designation of potential important sites

In order to determine important sites based on standardised and widely accepted criteria, we adopted the Ramsar Site Criteria (Ramsar Convention Secretariat 2010). In brief, the Ramsar Site Criteira contain two groups of criteria, which focus on wetland protection (Group A) and biological/species conservation (Group B) respectively (Ramsar Convention Secretariat 2010). We applied the Group B criteria to identify avian sites of conservation significance. The specific Ramsar Site Criteria we used include:

> Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
> Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
> Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
> Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

Table 1. Sources of data used to justify the listing of 422 sites of waterbird conservation significance and major species (taxonomic groups) concerned.

Data source	Number of sites of waterbird conservation significance	Major regions	Major species
BirdLife International, 2014c	286	Mainland China	All waterbird groups
Jaensch, 2013	79	Mainland China	Migrating, wintering and breeding waterbirds
Martinez, unpublished data[1]	29	South China Coast	Migrating and wintering shorebirds
China Coastal Waterbird Census unpublished data[2]	12	Fujian Coast	Breeding seabirds
International Crane Foundation, unpublished data[3]	10	Northeast China	Migrating and breeding waterbirds
Cao unpublished data[4]	3	Northeast China and South China Sea	Migrating anatidae and seabirds
Melville unpublished data[4]	2	Inland China	Migrating shorebirds
China Coastal Waterbird Census Group *et al.* 2015	1[5]	Eastern China Coast	Migrating, wintering and breeding waterbirds

[1]sites of waterbird conservation significance were judged to meet the BirdLife IBA Criteria based on regular Spoon-billed Sandpiper *Calidris pygmaea* counts in Guangdong Province from 2011, conducted by Jonathan Martinez.

[2]sites of waterbird conservation significance were judged to meet the BirdLife IBA Criteria based on the survey data of China Coastal Waterbird Census program led by China Coastal Waterbird Census Team, supported by Hong Kong Bird Watching Society, Xiamen Bird Watching Society, Fujian Bird Watching Society, Shenzhen Bird Watching Society, Yellow River Delta National Nature Reserve, etc.

[3]sites of waterbird conservation significance were judged to meet the IBA Criteria (BirdLife International 2014b) based on crane surveys in eastern China conducted by International Crane Foundation for more than ten years.

[4]sites of waterbird conservation significance were judged to meet the BirdLife IBA Criteria based on other survey data from Lei Cao and David Melville, respectively.

[5]this data source also updated the species list of 25 sites from the above data sources (Supplementary Material Table S1).

The existing IBA sites in China that we incorporated in this study are designated based on the global IBA Criteria (see http://www.birdlife.org/datazone/info/ibacritglob for detail), which adopted (1) Ramsar Site Criteria relating to total numbers and populations (criteria 5 and 6, corresponding to IBA criteria A4iii and A4i+A4ii) (2) modified Ramsar Site criterion 2 (corresponding to IBA criterion A1, which emphasises the regular utilisation of the sites by species or populations), (3) modified Ramsar Site criterion 4 (corresponding to IBA criteria A4iv, which emphasizes the migration stages of migratory species), and (4) two additional criteria, A2 and A3, for restricted-range and biome-restricted species (but none of the existing Chinese IBA sites fulfilled these criteria). We have adopted the definition of waterbirds used by Wetlands International (2012).

Determining site boundaries

For most IBAs defined to date, boundaries have already been determined based on field surveys and expert knowledge (Jaensch 2013). We determined boundaries for the remaining IBAs and newly identified sites based on the discrete divide between habitats used by birds and those that they do not, for instance, using sea walls, river banks, lake or wetland edges, etc. These readily identifiable boundary features were used to delineate the site in biological terms by defining the likely extent of the land and water body that is of direct importance for the waterbird species present. In addition, because many inland wetlands are subject to major seasonal or annual variation in extent due to rainfall recharge or flooding, boundaries for these wetlands were carefully delineated to include the largest extent of waterbird habitat area whenever possible, based on visual inspection of a series of false color Landsat satellite images from different representative periods of the year.

Assessing the conservation significance of the sites

We compared the extent of sites of waterbird conservation significance with the currently identified IBA boundaries and the national nature reserve boundaries, at both the national and provincial scale. We identified the bird conservation gaps based on each conservation regime, i.e. the area of sites of waterbird conservation significance outside the current IBAs and national nature reserves for each province. In addition, we compared the species in the current IBAs with the newly identified sites. We digitized the boundaries of all latest national nature reserves for analyses (Ministry of Environmental Protection 2014). All analyses were done in ArcGIS 10.2 (ESRI 2013).

Results

In total, we identified 422 sites of waterbird conservation significance in mainland China (Figure 1, Table 1; Table S1 in the online supplementary material), including the existing 286 IBAs which formed the foundation for the entire suite of sites. These sites support 126 waterbird species (Table S2). Guangdong, Xinjiang, Inner Mongolia and Heilongjiang Provinces hold more than 30 sites, and Fujian, Zhejiang and Liaoning more than 20 sites of waterbird conservation significance respectively (Table 2).

Of the existing IBAs, 263 had boundaries defined by BirdLife International. We designated boundaries for the remaining 23 IBAs and 136 newly identified sites. By combining these, we generated a map of all sites of waterbird conservation significance (Figure 1). The total area of sites of waterbird conservation significance covers 7.28×10^5 km^2, c.7.6% of China's land surface. Because all IBAs were included in the process, the total area of existing IBAs (6.89×10^5 km^2) made up 94.7% of the total area of sites of waterbird conservation significance.

Despite the relatively large areas designated as national nature reserves prior to 2008 (c.9.52×10^5 km^2), they contribute less than half of the total area of sites of waterbird conservation significance (Figure 2). Provinces in western and northern China, including Qinghai, Xinjiang, Gansu,

https://doi.org/10.1017/S095927091700003X Published online by Cambridge University Press

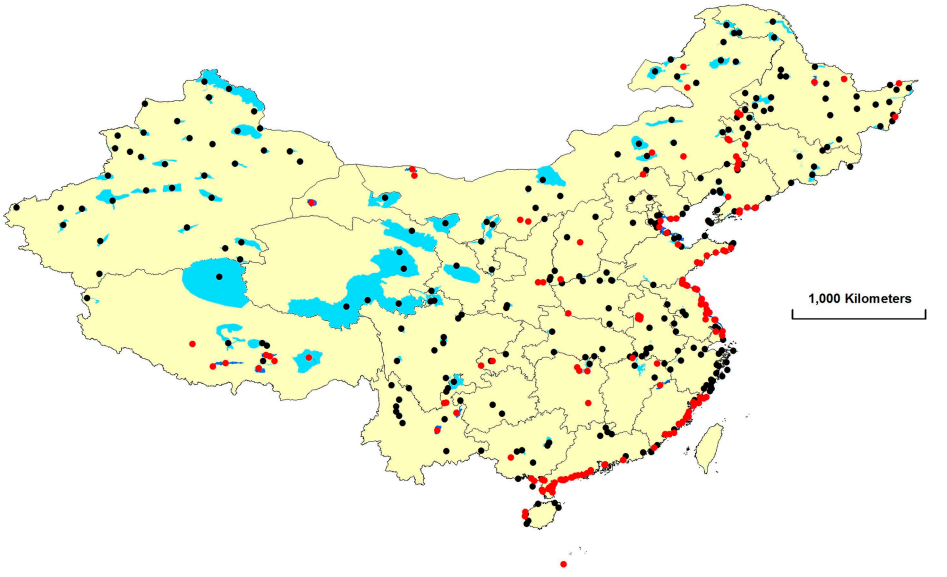

Figure 1. Map showing the full set of sites of waterbird conservation significance in mainland China. Black dots represent existing IBA sites which were previously identified by BirdLife, and red dots are new sites that reach IBA Criteria supplemented in this study. Light blue areas are IBA areas that were previously designated, and dark blue areas are new areas identified in this study. Note that a few supplemented sites (red dots) mask IBA sites (black dots).

Inner Mongolia and Tibet, contain the largest areas of sites of waterbird conservation significance outside existing national nature reserves (Table 2).

The newly identified sites cover a wide range of threatened species including three 'Critically Endangered', six 'Endangered', seven 'Vulnerable', 10 'Near Threatened' and 60 species of 'Least Concern' (Table 3, Table S2). In addition, the newly identified sites cover five species that are not included in current IBAs, including two 'Near Threatened' and seven 'Least Concern' species (Table 4).

Discussion

Based on various novel and recent sources of data, we have been able to develop a comprehensive list of sites of waterbird conservation significance for China, providing the most up-to-date overview of areas of high waterbird conservation significance based upon the best available knowledge. This study benefited from the well-established knowledge and survey data that exist for waterbirds, compared to other groups, perhaps because it is easier to comprehensively find, identify and count waterbirds in open wetland habitats compared to other bird groups, such as passerines in dense forest. The existence of generally robust population estimates for most waterbird populations (Wetlands International 2012) also permits the more effective establishment of global and regional population size and status, as well as the identification of internationally important waterbird areas in the context of these, based on the A4 (congregations) global IBA criteria (BirdLife International 2014b). In addition, much effort has been put in waterbird conservation in China in recent years, as a result of the long-term decline of waterbird populations (e.g. Cao *et al.* 2011, Wang *et al.* 2012a). Once these areas of sites of waterbird conservation significance are incorporated into the final EPRL with top protection priority, we also foresee that the recent research and survey efforts in waterbirds in China will greatly enhance their effective conservation and management by influencing policy. This impact will be critical, especially with regard to the unprecedented stress created by China's rapid

https://doi.org/10.1017/S095927091700003X Published online by Cambridge University Press

Table 2. Provincial statistics of sites of waterbird conservation significance in mainland China. In brackets of 'Total sites' are the numbers of newly identified sites in this study, and therefore the difference between the two numbers in this column represents the number of currently recognized IBA sites in each province. 'Total area of sites of waterbird conservation significance' is the area of sites of waterbird conservation significance in each province. Bracketed values indicate the new areas identified in this study, so the difference between the two numbers in this column represents the area of currently recognized IBA sites in each province. 'Within-NNR area' is the area of national nature reserves in each province. 'Outside-NNR area' is the area of sites of waterbird conservation significance that currently lies outside of national nature reserves in each province.

Province	Total sites (newly identified sites)	Total area of sites of waterbird conservation significance ($\times 10^2$ km^2)	Within-NNR area ($\times 10^2$ km^2)	Outside-NNR area ($\times 10^2$ km^2)
Anhui	9(4)	11.44	1.74	9.70
Beijing	2(0)	1.99	0.00	1.99
Chongqing	3(1)	1.91	0.05	1.86
Fujian	27(22)	18.67	5.06	13.62
Gansu	7(0)	727.53	182.31	545.22
Guangdong	37(30)	9.61	1.75	7.86
Guangxi	11(1)	34.38	5.03	29.35
Guizhou	3(0)	2.12	0.40	1.72
Hainan	9(3)	5.22	1.18	4.03
Hebei	9(5)	30.04	0.16	29.89
Henan	10(2)	19.51	5.79	13.71
Heilongjiang	33(0)	208.55	76.25	132.29
Hubei	6(0)	21.82	10.61	11.20
Hunan	5(3)	40.65	16.85	23.80
Jilin	18(5)	83.71	45.50	38.21
Jiangsu	18(11)	75.28	24.51	50.77
Jiangxi	10(2)	55.59	8.20	47.40
Liaoning	22(8)	65.96	19.78	46.18
Inner Mongolia	34(10)	627.50	154.11	473.39
Ningxia	4(0)	80.64	15.85	64.79
Qinghai	4(1)	2016.23	823.75	1192.49
Shandong	17(9)	80.28	14.62	65.66
Shanxi	4(1)	9.29	1.78	7.51
Shaanxi	8(3)	14.14	3.47	10.67
Shanghai	5(1)	14.70	4.42	10.28
Sichuan	11(1)	168.55	107.89	60.66
Tianjin	7(3)	22.30	1.04	21.26
Tibet	14(6)	1648.09	1300.46	347.63
Xinjiang	36(0)	1031.23	176.92	854.31
Yunnan	17(3)	124.88	6.15	118.73
Zhejiang	22(1)	23.41	1.60	21.80
Total	422(136)	7275.21	3017.24	4257.96

economic development that has impacted upon these waterbirds and their habitats (Zhang *et al.* 2011, MacKinnon *et al.* 2012, Ma *et al.* 2014, Murray *et al.* 2014).

IBA sites form the cornerstone of the sites of waterbird conservation significance by contributing 67.1% total sites and 94.7% of their area. However, the 140 new sites (3.90×10^4 km^2 area) confirm the gaps in the current suite of identified IBAs in China. The main reason for this difference is that the IBA process, updated in 2009, did not include sites or areas that have been identified and surveyed in more recent years, which contribute the majority of the supplementary sites. Geographically, the most significant gaps are along the eastern coast of China. These areas are key staging or wintering sites for shorebirds, identified by recent surveys (e.g., Ma *et al.* 2013, China Coastal Waterbird Census Group *et al.* 2015). Meanwhile, conservation gaps in the site safeguard

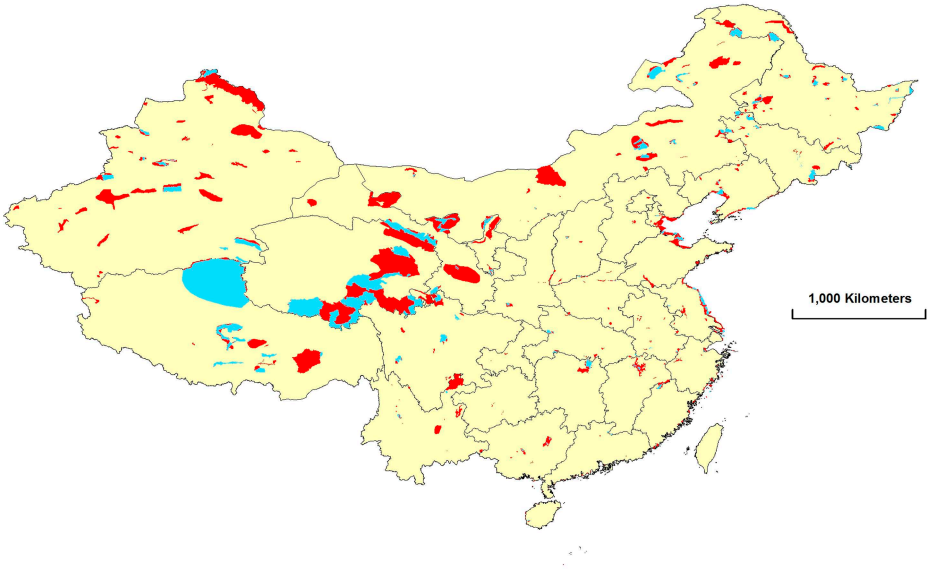

Figure 2. Map showing the extent of the areas of sites of waterbird conservation significance in mainland China that fall outside the current national nature reserve coverage, updated as of 2008. Areas in light blue represent the sites of waterbird conservation significance that fall under the protection of national nature reserves and those areas marked in red represent the area of sites of waterbird conservation significance outside of existing national nature reserves.

network for waterbirds in western China are also considerable since a larger number of sites of conservation significance were identified in western provinces than in eastern provinces (Table 2). Although the area of newly identified sites is small (constituting 5.3% of the total area of all sites of waterbird conservation significance), these new sites constitute almost a third of the number of all sites. We believe that the benefit from improved survey efforts and enhanced knowledge of habitats has been more effective in delineating site boundaries and will better focus future conservation efforts.

Comparing sites of waterbird conservation significance with areas currently protected as national nature reserves shows conservation gaps and shortfalls in the current site safeguard network for waterbird conservation in China. Since many national nature reserves are not explicitly established for avian conservation, it is not surprising that some important sites and areas are not currently included in China's large nature reserve network. Provincial and county level nature reserves may cover some of the remaining gaps in the national protected area system, but the conservation effectiveness of these nature reserves cannot be expected to match the management actions and provisions of national nature reserves (Quan *et al.* 2009). This confirms the importance of incorporating these areas within the EPRL framework to provide a greatly enhanced site safeguard network for the effective conservation of China's avifauna.

The suite of sites of waterbird conservation significance could be further improved in several ways. First, because of the lack of systematic waterbird surveys in China, the current list of sites is biased towards specific groups and species (for instance, Spoon-billed Sandpiper *Calidris pygmaea*, Zöckler *et al.* 2016) and certain regions (eastern China, eastern coasts and the East Asian-Australasian Flyway). This highlights the need for more systematic and long-term waterbird surveys throughout China. Second, we should not lose sight of the probability that some previously designated sites of waterbird conservation significance may have lost some or all of their significance due to habitat degradation or loss (Zhang *et al.* 2011). Protection of such areas will not

https://doi.org/10.1017/S095927091700003X Published online by Cambridge University Press

Table 3. Inclusion of threatened and Near Threatened waterbird species in newly identified sites of waterbird conservation significance.

Species	IUCN status	Inclusion in the newly identified sites (number of sites)	Inclusion in the current IBAs (number of sites)
Spoon-billed Sandpiper *Calidris pygmaea*	Critically Endangered	34	3
Baer's Pochard *Aythya baeri*	Critically Endangered	10	83
Siberian Crane *Grus leucogeranus*	Critically Endangered	7	28
Red-crowned Crane *Grus japonensis*	Endangered	11	63
Black-faced Spoonbill *Platalea minor*	Endangered	6	27
Far Eastern Curlew *Numenius madagascariensis*	Endangered	8	7
Great Knot *Calidris tenuirostris*	Endangered	8	8
Nordmann's Greenshank *Tringa guttifer*	Endangered	7	8
Oriental Stork *Ciconia boyciana*	Endangered	7	77
Saunders's Gull *Larus saundersi*	Vulnerable	15	26
Swan Goose *Anser cygnoides*	Vulnerable	9	87
Relict Gull *Larus relictus*	Vulnerable	7	13
White-naped Crane *Grus vipio*	Vulnerable	8	45
Hooded Crane *Grus monacha*	Vulnerable	5	41
Chinese Egret *Egretta eulophotes*	Vulnerable	3	22
Dalmatian Pelican *Pelecanus crispus*	Vulnerable	4	20
Falcated Duck *Anas falcata*	Near Threatened	5	7
Eurasian Curlew *Numenius arquata*	Near Threatened	12	10
Northern Lapwing *Vanellus vanellus*	Near Threatened	2	7
Eurasian Oystercatcher *Haematopus ostralegus*	Near Threatened	6	4
Bar-tailed Godwit *Limosa lapponica*	Near Threatened	7	5
Black-tailed Godwit *Limosa limosa*	Near Threatened	6	7
Red Knot *Calidris canutus*	Near Threatened	7	5
Red-necked Stint *Calidris ruficollis*	Near Threatened	4	7
Curlew Sandpiper *Calidris ferruginea*	Near Threatened	6	2
Asian Dowitcher *Limnodromus semipalmatus*	Near Threatened	5	2

https://doi.org/10.1017/S095927091700003X Published online by Cambridge University Press

Table 4. Inclusion of new waterbird species in newly identified sites of waterbird conservation significance that were absent from current IBAs.

Species	IUCN status	Inclusion in the newly identified sites (number of sites)
Little Grebe *Tachybaptus ruficollis*	Least Concern	1
Red-footed Booby *Sula sula*	Least Concern	1
Brent Goose *Branta bernicla*	Least Concern	1
Grey-headed Lapwing *Vanellus cinereus*	Least Concern	3
Long-billed Plover *Charadrius placidus*	Least Concern	1

necessarily contribute to the conservation of the waterbird species for which they were originally identified without targeted management actions. Moreover, continuous revision of waterbird population estimates (e.g. Delany and Scott 2002, 2006, Wetlands International 2012) can also change the importance of a site as knowledge improves about flyway population sizes and the relative contributions made by sites. It is therefore important that studies continue to assess their relative importance and conservation status, which, where necessary, may include the addition and removal of sites from the list. The essential and critical step of achieving this goal is, again, to conduct more systematic surveys for both waterbirds and habitats, especially in areas where habitats and waterbirds have undergone dramatic changes, such as the Yellow Sea coast and the Yangtze River floodplain. Thirdly, because of the lack of detailed habitat information, waterbird distribution and counts, most site boundaries have been determined based on expert knowledge and desk studies. Obtaining better information will greatly promote the objective determination of site boundaries, which will help better partitioning of conservation efforts and resources.

Since the EPRL is expected to undergo regular revision (China Council for International Cooperation on Environment and Development 2014), the possible improvements to the process listed above are feasible. We believe the interactive revision and updating of the EPRL as knowledge improves will benefit waterbird and biodiversity conservation in many respects. For instance, environmental changes and habitat loss can cause redistribution of birds and systematic surveys can identify new sites of conservation significance as these become apparent.

The sites of waterbird conservation significance will be included in the final EPRL of China, after coordination, consultation and negotiations between legislators, local governments, stakeholders and experts/scientists (China Council for International Cooperation on Environment and Development 2014). Inclusion of the proposed sites in the final EPRL will greatly benefit waterbird conservation, but also contribute to broader environmental protection, given that waterbirds can be effective indicators of environmental health and the state of biodiversity (e.g. Amat and Green 2010) as well as providing ecosystem services (Green and Elmberg 2014). The EPRL aims to provide scope for a far more comprehensive framework for the extensive protection of biodiversity and ecosystem services than simply protecting waterbirds. However, this necessitates further extensive systematic survey and acquisition of data and knowledge, especially relating to other taxa and the provision of ecosystem services.

For this reason, we see three major means of improving environmental protection and biological conservation under the current EPRL framework. First, we suggest that it is necessary to conduct systematic surveys of other taxa and provision of ecosystem services, and to make more survey data publicly available, to fill the knowledge and conservation gaps in the scope and coverage of the current EPRL. Our practice of establishing the sites of waterbird conservation significance could hopefully set an example for conservation of other taxa, for instance, terrestrial birds and mammals

in the EPRL. There have been a growing number of surveys of waterbirds and other taxa, for instance, the national wetland surveys conducted by State Forestry Administration during 2009–2013. The survey results, if publicly available, will greatly enhance our understanding of waterbird status and trends. Second, it is essential to harmonise environmental protection and biological conservation with social and economic development at a higher level of governments and at larger spatial scales. Although the EPRL establishes a rigorous set of mechanisms to protect biodiversity, its effectiveness will be questionable without support from agencies, stakeholders and actors operating outside of the EPRL and without a strengthened set of laws (He *et al.* 2013, China Council for International Cooperation on Environment and Development 2014). For instance, many waterbirds that winter in the Yangtze River floodplain rely on the annual water level fluctuations in seasonally flooded lakes, which have been severely impacted by flood control, hydroelectric developments, water abstraction, agricultural and industrial projects upstream (Wang *et al.* 2013). It is therefore critical to evaluate the effects of such activities and projects within and outside of the EPRL, if the site protection elements afforded by site designation are to be effective in delivering effective biodiversity conservation and ecological protection. Finally, "site protection" in itself is only the beginning of a process that delivers biodiversity conservation and the maintenance of ecosystem services. Having established the existence and the extent of interest in a site that contributes to the EPRL, it is essential that resources are applied to understanding the mechanisms that deliver these values to society in a way that ensures their effectiveness in perpetuity.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S095927091700003X

Acknowledgements

We thank Spike Millington, Taej Mundkur, David Melville, Zhengwang Zhang, Xiubo Yu, Jing Li, Qingquan Bai, Nicholas Murray, Richard Fuller, Jim Harris, Fengshan Li, Vivian Fu, Bena Smith, and Chris Hassell for sharing information, knowledge and data, for inspiring discussion and for constructive comments. We are grateful to the six anonymous referees for comments on an earlier draft. The study was supported by the National Natural Science Foundation of China (Grant No. 31500315 and 31370416), the National Basic Research Program of China (973 Program, Grant No. 2012CB956104), State Key Laboratory of Urban and Regional Ecology, Chinese Academy of Sciences (No. SKLURE2014-2-3), China Biodiversity Observation Networks (Sino BON) and Science and Technology Service Network Initiative Project of the Chinese Academy of Sciences (KFJ-EW-ZY-004-6).

References

Amat, J. A. and Green, A. J. (2010) Waterbirds as bioindicators of environmental conditions. Pp. 45–52 in C. Hurford, M. Schneider and I. Cowx eds. *Conservation monitoring in freshwater habitats: A practical guide and case studies*. Dordrecht, The Netherlands: Springer.

BirdLife International (2009) *Directory of Important Bird Areas in China: key sites for conservation*. Cambridge, UK: BirdLife International. Also available from: http://www.chinabirdnet.org/iba_inventory.html.

BirdLife International (2014a) Country profile: China (mainland). Available from: http://www.birdlife.org/datazone/country/china. Checked: 2014-08-22.

BirdLife International (2014b) Important Bird and Biodiveristy Areas. Available from: http://www.birdlife.org/worldwide/programme-additional-info/important-bird-and-biodiversity-areas. Checked: 2014-08-22.

BirdLife International (2014c) Important Bird and Biodviersity Areas factsheets.

Available from http://www.birdlife.org on 2014-08-22.
Cao, L., Barter, M. and Lei, G. (2008a) New Anatidae population estimates for eastern China: Implications for current flyway estimates. *Biol. Conserv.* 141: 2301–2309.
Cao, L., Barter, M. and Wang, X. (2008b) Saunders's Gull: a new population estimate. *Bird Conserv. Internatn.* 18: 301–306.
Cao, L., Barter, M., Zhao, M., Meng, H. and Zhang, Y. (2011) A systematic scheme for monitoring waterbird populations at Shengjin Lake, China: methodology and preliminary results. *Chinese Birds* 2: 1–17.
Cao, L., Pan, Y. and Liu, N. (2007) Waterbirds of the Xisha Archipelago, South China Sea. *Waterbirds* 30: 296–300.
Cao, L., Tang, S., Wang, X. and Barter, M. (2009) The importance of eastern China for shorebirds during the non-breeding season. *Emu* 109: 170–178.
Cao, L., Wang, X., Wang, Q. and Barter, M. (2008c) Wintering anatidae in China: a preliminary analysis. *Casarca* 11: 161–180.
Cao, L., Zhang, Y., Barter, M. and Lei, G. (2010) Anatidae in eastern China during the non-breeding season: geographical distributions and protection status. *Biol. Conserv.* 143: 650–659.
Chape, S., Harrison, J., Spalding, M. and Lysenko, I. (2005) Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. *Phil. Trans. R. Soc. B-Biol. Sci.* 360: 443–455.
China Coastal Waterbird Census Group. (2009) *China Coastal Waterbird Census Report (9.2005-12.2007)*. Hong Kong: Hong Kong Bird Watching Society.
China Coastal Waterbird Census Group. (2011) *China Coastal Waterbird Census Report (1.2008-12.2009)*. Hong Kong: Hong Kong Bird Watching Society.
China Coastal Waterbird Census Group, Bai, Q., Chen, J., Chen, Z., Dong, G., Dong, J., Dong, W., Fu, V. W. K., Han, Y., Lu, G., Li, J., Liu, Y., Lin, Z., Meng, D., Martinez, J., Ni, G., Shan, K., Sun, R., Tian, S., Wang, F., Xu, Z., Yu, Y., Yang, J., Yang, Z., Zhang, L., Zhang, M. and Zeng, X. (2015) Identification of coastal wetlands of international importance for waterbirds: a review of China Coastal Waterbird Surveys 2005–2013. *Avian Res.* 6: 1–16.
China Council for International Cooperation on Environment and Development. (2014) Institutional Innovation of Eco-Environmental Redlining (CCICED Special Policy Study Report). Available from http://goo.gl/OGTNNN.
Conklin, J. R., Verkuil, Y. I. and Smith, B. R. (2014) *Prioritizing migratory shorebirds for conservation action on the East Asian-Australasian Flyway*. Hong Kong: WWF-Hong Kong.
de Boer, W., Cao, L., Barter, M., Wang, X., Sun, M., van Oeveren, H., de Leeuw, J., Barzen, J. and Prins, H. H. T. (2010) Comparing the community composition of European and eastern Chinese waterbirds and the influence of human factors on the China waterbird community. *Ambio* 40: 68–77.
Delany, S. and Scott, D. (2002) *Waterbird population estimates (3rd edition)*. Wageningen, The Netherlands: Wetlands International.
Delany, S. and Scott, D. (2006) *Waterbird population estimates (4th edition)*. Wageningen, The Netherlands: Wetlands International.
East Asian-Australasian Flyway Partnership. (2015) Criteria for inclusion in the Flyway Site Network. Available from http://www.eaaflyway.net/about/the-flyway/flyway-site-network/become-a-site/#criteria.
ESRI (2013) ArcGIS Desktop: Release 10.2. Redlands, CA: Environmental Systems Research Institute.
Fox, A. D., Cao, L., Zhang, Y., Barter, M., Zhao, M., Meng, F. and Wang, S. (2011) Declines in the tuber-feeding waterbird guild at Shengjin Lake National Nature Reserve, China – a barometer of submerged macrophyte collapse? *Aquatic Conserv: Mar. Freshw. Ecosyst.* 21: 82–91.
Green, A. J. and Elmberg, J. (2014) Ecosystem services provided by waterbirds. *Biol. Rev.* 89: 105–122
He, G., Zhang, L., Mol, A., Lu, Y. and Liu, J. (2013) Revising China's environmental law. *Science* 341: 133.
Jaensch, R. (2013) New tools for development of the Flyway Site Network: An integrated and updated list of candidate sites and guidance on prioritisation. Report to Partnership for the East Asian - Australasian Flyway.
Jia, Q., Koyama, K., Choi, C.-Y., Kim, H.-J., Cao, L., Gao, D., Liu, G. and Fox, A. D. (2016)

Population estimates and geographical distributions of swans and geese in East Asia based on counts during the non-breeding season. *Bird Conserv. Internat.* 26: 397–417.

Liu, J., Ouyang, Z., Pimm, S., Raven, P., Wang, X., Miao, H. and Han, N. (2003) Protecting China's biodiversity. *Science* 300: 1240–1241.

Liu, J., Zang, C., Tian, S., Liu, J, Yang, H. Jia, S., You, L., Liu, B. and Zhang, M. (2013) Water conservancy projects in China: Achievements, challenges and way forward. *Glob. Environ. Chang.* 23: 633–643.

Liu, W., Zhang, Q. and Liu, G. (2010) Lake eutrophication associated with geographic location, lake morphology and climate in China. *Hydrobiologia* 644: 289–299.

Ma, Z., Hua, N., Peng, H., Choi, C., Battley, P., Zhou, Q., Chen, Y., Ma, Q., Jia, N., Xue, W., Bai, Q., Wu, W., Feng, X. and Tang, C. (2013) Differentiating between stopover and staging sites: functions of the southern and northern Yellow Sea for long-distance migratory shorebirds. *J. Avian Biol.* 44: 504–512.

Ma, Z., Melville, D. S., Liu, J., Chen, Y., Yang, H., Ren, W., Zhang, Z., Piersma, T. and Li, B. (2014) Rethinking China's new great wall. *Science* 346: 912–914.

MacKinnon, J., Verkuil, Y. I. and Murray, N. (2012) *IUCN situation analysis on East and Southeast Asian intertidal habitats, with particular reference to the Yellow Sea (including the Bohai Sea)*. Gland, Switzerland and Cambridge, UK: IUCN. (Occasional Paper of the IUCN Species Survival Commission No. 47).

MaMing, R., Zhang, T., Blank, D., Ding, P. and Zhao, X. (2012) Geese and ducks killed by poison and analysis of poaching cases in China. *Goose Bulletin* 15: 2–11.

Ministry of Environmental Protection (2014) *Report on the state of environment in China 2013*. Beijing: Ministry of Environmental Protection.

Murray, N. J., Clemens, R. S., Phinn, S. R., Possingham, H. P. and Fuller, R. A. (2014) Tracking the rapid loss of tidal wetlands in the Yellow Sea. *Front. Ecol. Environ.* 12: 267–272.

Quan, J., Ouyang, Z., Xu, W. and Miao, H. (2009) Management effectiveness of China nature reserves: status quo assessment and countermeasures. *Chin. J. Appl. Ecol.* 20: 1739–1746. (In Chinese with English abstract).

Ramsar Convention Secretariat (2010) *Designating Ramsar Sites: Strategic framework and guidelines for the future development of the list of Wetlands of International Importance, Ramsar handbooks for the Wise Use of Wetlands, 4th edition, vol. 17*. Gland, Switzerland: Ramsar Convention Secretariat.

Rodrigues, A. S. L., Andelman, S. J., Bakarr, M. I., Boitani, L., Brooks, T. M., Cowling, R. M., Fishpool, L. D. C., da Fonseca, G. A. B., Gaston, K. J., Hoffmann, M., Long, J. S., Marquet, P. A., Pilgrim, J. D., Pressey, R. L., Schipper, J., Sechrest, W., Stuart, S. N., Underhill, L. G., Waller, R. W., Watts, M. E. J. and Yan, X. (2004) Effectiveness of the global protected area network in representing species diversity. *Nature* 428: 640–643.

State Forestry Administration (2002) *China National Wetland Conservation Action Plan*. Beijing: State Forestry Administration.

Nations, United. (1992) *Convention on biological diversity*. Available from https://www.cbd.int/doc/legal/cbd-en.pdf.

Wang, X., Barter, M., Cao, L., Lei, J. and Fox, A. D. (2012a) Serious contractions in wintering distribution and decline in abundance of Baer's Pochard *Aythya baeri*. *Bird Conserv. Internatn.* 22: 121–127.

Wang, X., Fox, A. D., Cong, P., Barter, M. and Cao, L. (2012b) Changes in the distribution and abundance of wintering Lesser White-fronted Geese *Anser erythropus* in eastern China. *Bird Conserv. Internatn.* 22: 128–134.

Wang, Y., Jia, Y., Guan, L., Lu, C., Lei, G., Wen, L. and Liu, G. (2013). Optimising hydrological conditions to sustain wintering waterbird populations in Poyang Lake National Natural Reserve: implications for dam operations. *Freshwat. Biol.* 58: 2366–2379.

Wetlands International (2012) *Waterbird population estimates, fifth Edition. Summary report*. Wageningen, The Netherlands: Wetlands International.

Wu, R., Zhang, S., Yu, D., Zhao, P., Li, X., Wang, L., Yu, Q., Ma, J., Chen, A. and Long, Y. (2011) Effectiveness of China's nature reserves in representing ecological diversity. *Front. Ecol. Environ.* 9: 383–389.

Yang, H., Chen, B., Barter, M., Piersma, T., Zhou, C., Li, F. and Zhang, Z. (2011) Impacts of tidal land reclamation in Bohai Bay, China: ongoing losses of critical Yellow

Sea waterbird staging and wintering sites. *Bird Conserv. Internatn.* 21: 241–259.

Zhang, Y., Cao, L., Barter, M., Fox, A. D., Zhao, M., Meng, F., Shi, H., Jiang, Y. and Zhu, W. (2011) Changing distribution and abundance of Swan Geese *Anser cygnoides* in the Yangtze River floodplain: the likely loss of a very important wintering site. *Bird Conserv. Internatn.* 21: 36–48.

Zöckler, C., Beresford, A. E., Bunting, G., Chowdhury, S. U., Clark, N. A., Fu, V. W. K., Htin Hla, T., Morozov, V. V., Syroechkovskiy, E. E., Kashiwagi, M., Lappo, E. G., Tong, M., Long, T. L., Yu, Y.-T., Huettmann, F., Akasofu, H. K., Tomida, H. and Buchanan, G. M. (2016) The winter distribution of the Spoon-billed Sandpiper *Calidris pygmaeus*. *Bird Conserv. Internat.* 26: 476–489.

LU ZHANG†, XIN WANG†, JUNJIAN ZHANG, ZHIYUN OUYANG, LEI CAO*
State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China.

SIMBA CHAN
BirdLife International Asia Regional Office, Tokyo, Japan.

MIKE CROSBY
BirdLife International, Cambridge, UK.

DOUG WATKINS
99 MacKellar Cr, Cook, 2614, Canberra ACT, Australia.

JONATHAN MARTINEZ
14, bis rue des Temples, 45240 La Ferté Saint Aubin, France.

LIYING SU
International Crane Foundation, World Center for the Study and Preservation of Cranes, Baraboo, WI 53913, Wisconsin, USA.

YAT-TUNG YU
The Hong Kong Bird Watching Society, 7C, V Ga Building, 532 Castle Peak Road, Lai Chi Kok, Kowloon, Hong Kong.

JUDIT SZABO
Research Institute for the Environment and Livelihoods, Charles Darwin University, Darwin, Northern Territory 0909, Australia.

ANTHONY D. FOX
Department of Bioscience, Aarhus University, Kalø, Grenåvej 14, DK-8410 Rønde, Denmark.

**Author for correspondence; e-mail: leicao@rcees.ac.cn*

†These authors contributed equally to this work.

Received 12 November 2014; revision accepted 10 March 2016;
Published online 7 March 2017