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Identifying priority sites and gaps for the conservation of migratory waterbirds in China's coastal wetlands

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ABSTRACT

Many waterbird species, in particularly migratory shorebirds, on the East Asian-Australasian Flyway depend on the intertidal areas of coastal China. In recent years, these habitats have suffered severe shrinkage as a result of wetland loss and degradation. Identifying critical areas for waterbirds and assessing conservation status has become an urgent priority for biological conservation. Based on the criteria used to designate Ramsar sites and East Asian-Australasian Flyway Partnership (EAAFP) Flyway Network sites, a general framework is proposed and applied to identify priority sites in China's coastal wetlands using a comprehensive waterbird survey dataset. Sites priority were evaluated by using appearance of globally threatened bird species, and bid species exceeding 1% of their global or flyway population, and population abundance. Sites priorities were ranked using an "irreplaceability index". Totally, 110 sites are proposed as priority sites. Considering the strategic importance of China's coastal wetlands for migratory waterbirds, the conservation status of China's coastal wetlands is inadequate to protect these waterbirds. Currently, 67 of the 110 priority sites lie outside protected areas. Some critical habitats for waterbirds are not included in individual protected areas, especially in Jiangsu, Zhejiang, and Hebei provinces. Improved protection of these areas is urgently needed. However, conservation efforts in China's coastal wetlands face numerous challenges. Many important intertidal areas are increasingly threatened by ongoing and future reclamation plans. There is an urgent need to re-consider and limit the reclamation, particularly at critical sites, and put in place conservation measures to protect migratory waterbirds and their habitats.

1. Introduction

Coastal wetlands, ranked among the most productive ecosystems on earth, are important for biodiversity conservation, especially for the conservation of migratory waterbirds (Airoldi et al., 2008; Davis, 1994; Engle, 2011). Coastal wetlands in China are critical to the survival of many migratory waterbird species using the East Asian-Australasian Flyway (EAAF), by providing staging and over-wintering habitats for more than 200 migratory waterbird species. Over 70% of the globally threatened waterbird species on this flyway depend on China's coastal wetlands (Bai et al., 2015; Bamford et al., 2008; Mackinnon et al., 2012). Among these wetlands, the Yellow Sea intertidal areas are of especially significant importance (Barter, 2002; Battley et al., 2012; Rogers et al., 2010). However, reclamation of coastal wetlands in China has accelerated in the past decades driven by rampant economic development. As a result, a large area of natural coastal wetlands was converted into agricultural and industrial areas (Li et al., 2014; Ke et al., 2011; Jiang et al., 2015). The total area of natural coastal wetland of China decreased by 16% from 1990 to 2000 (Gong et al., 2010) and 23% from 2003 to 2013 [State Forestry Administration of China (SFA), 2003, 2014; http://xzsp.forestry.gov.cn/], resulting in the loss of almost 40% of intertidal habitats since 1990 (Murray et al., 2014; Stroud et al., 2008). Consequently, populations of Great Knot *Calidris tenuirostris*, Red Knot *Calidris canutus*, and Bar-tailed Godwit *Limosa lapponica*, which inhabit on intertidal areas of the Yellow Sea (including Bohai Bay), are decreasing at rates of 5%–9% year^{-1} (Amano et al., 2010; Wilson et al., 2011). Reclamation of intertidal areas in the Yellow Sea is primarily thought to be responsible for the decline of these species

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(Yang et al., 2011; Piersma et al., 2016). The serious plight of China's coastal wetlands has aroused great concern (Larson, 2015; Ma et al., 2014). Taking effective measures to address the loss and degradation of coastal wetland ecosystems in the region and protecting intertidal habitats for migratory waterbirds has been strongly advocated at both national and international levels (IUCN, 2012; Hua et al., 2015). Establishing new protected areas could be one response to this situation. However, protected areas have so far failed to arrest habitat decline (Murray and Fuller, 2015). Identifying priority areas and strengthening the protection and management of critical habitats is essential and gap analysis is an effective tool for this task (Powell et al., 2000; Rodrigues et al., 2004). The criteria for the identification of internationally important wetlands developed by the Ramsar Convention (Ramsar Convention Secretariat, 2010), Birdlife International through the Important Bird and Biodiversity Areas (IBBA; Birdlife International, 2014) and the staging criteria of the East Asian-Australasian Flyway Partnership (EAAFP; http://www.eaaflyway.net) are quantitative and criteria-driven approaches that can be applied on a regional level to plan protected areas for wetland and waterbird conservation (Ambal et al., 2012; Eken et al., 2004; Wells et al., 2005). Building on these developments, a general framework and criteria for identifying and mapping conservation priorities for China's coastal wetland is proposed in this paper. Existing gaps are identified by overlaying current protected areas on coastal wetland habitat maps. This study enhances the understanding of the importance of China's coastal wetlands for waterbirds and provides scientific support to the government, non-governmental organizations, and the general public on strategically strengthening the conservation of the EAAF and coastal wetlands in China.

2. Data and methods

2.1. Study area

China's coastal wetlands cover 11 provinces/municipalities: Fujian, Guangdong, Guangxi, Hainan, Hebei, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin and Zhejiang. They encompass an area of 5.80 million ha, accounting for 10.85% of the total area of wetlands in China (Taiwan is not included because of limitations on data collection, SFA, 2014). The primary type of coastal wetland in China consists of permanent shallow marine waters (less than 6 m deep at low tide) according to the Ramsar Convention. These wetlands account for 59.22% of China's total coastal wetland, followed by intertidal areas and estuarine waters, which account for 18.73% and 15.10%, respectively (SFA, 2014). China's coastal wetlands provide critical habitat for millions of individual waterbirds, especially for shorebirds, gulls and terns on the EAAF, which are often highly dependent on coastal wetlands (Barter, 2002; Mackinnon et al., 2012). Seven nature reserves with coastal wetland in China (Chongming Dongtan Nature Reserve, Liaohe Estuary National Nature Reserve, Maipo Nature Reserve, Nandagang Wetland Nature Reserve, Yalujiang Estuary National Nature Reserve, Yancheng National Nature Reserve, and Yellow River Delta National Nature Reserve) are included in the Flyway Site Network of the EAAFP (Fig. 1; http://www.eaaflyway.net/).

2.2. Data collection and processing

Regular surveys of bird numbers and distribution have long provided a basic data source to inform bird research and conservation. However the coverage of China's coastal wetlands by such surveys is limited, making it difficult to apply survey findings at a national scale. Elsewhere in the world citizen-based bird watching data such as Breeding Bird Surveys and Christmas Bird Counts have been used successfully as a data source in such large scale studies (Snäll et al., 2011; Valiela and Martinetto, 2007). Accordingly, in this study both published literature and citizen-based bird records were used as data sources. In detail, the data sources include the China Coastal Waterbird Census (2005–2013; Bai et al., 2015), Status of Waterbirds in Asia 1987–2007 (Li et al., 2009), the Hong Kong Bird Report (2001–2011), Mai Po Inner Deep Bay Ramsar site waterbird monitoring programme (2001–2015) (Hong Kong Bird Watching Society, 2001–2015; www.hkbws.org.hk), and the annual China Bird Report (2003–2007) and bird survey records from the China Bird Watching Network website (2008–2013; http://www.chinabirdnet.org/). The data were reformatted and integrated into a dataset after quality control. The information of dataset includes waterbird species, site name, site location (latitude and longitude), number of individuals and survey date. Earlier surveys may overestimate current numbers because of recent changes of habitat and declines in waterbird populations. For this reason, only post-2000 data were used in this study. The dataset contains records on 99 species from 2989 surveys at 201 sites, including 63 shorebirds, 12 terns, 16 gulls, four sea birds (Christmas Island Frigatebird *Fregata andrewsi*, Marbled Murrelet *Brachyramphus marmoratus*, Black-throated Loon *Gavia arctica* and Red-throated Loon *Gavia stellata*) and four other species (Red-crowned Crane *Grus japonensis*, Black-faced Spoonbill *Platalea minor*, Chinese Egret *Egretta eulophotes* and Dalmatian Pelican *Pelecanus crispus*) that are dependent on coastal wetlands. Waterbird survey sites were located by latitude and longitude using ArcGIS 10.0 and then mapped. The protection status of China's coastal wetland was collected from the State Oceanic Administration of the People's Republic of China (http://www.gov.cn/gzdt) and the Ministry of Environmental Protection of the People's Republic of China (http://sts.mep.gov.cn/zrbhq/zrbhq).

2.3. Ranking survey sites

Table 1 lists proposed criteria and thresholds used to identify the priority areas of China's coastal wetlands for waterbird conservation. Areas supporting globally threatened species, a significant proportion of the population of specific species or exhibiting high population abundance are considered to have high conservation priority (Margules & Pressey, 2000; Pressey & Taffs, 2001; Langhammer, 2007; Ramsar Convention Secretariat, 2010). Three criteria and their provisional thresholds are proposed in Table 1 to identify priority sites. The irreplaceability index (I) indicates the priority of a site (see Formula (1)):

$$I = \sum_{i=1}^{s} {}^{n_i}/_{N} \times 100, \quad (1)$$

where n_i denotes the population of ith species of waterbirds at the survey site, N denotes the population of ith species globally or flyway-wide, according to Waterbird Population Estimates Fifth Edition (WPE5; Wetlands International, 2015; http://wpe.wetlands.org/) and s denotes the number of species at the survey points. A higher value of I represents a higher priority of a site for conservation.

2.4. Procedures for priority setting and gap analysis

The population of each species and the total waterbird population at each site are indicated by the highest number recorded in a single survey. The WPE5 was used to assess the proportion of each species on the flyway (the minimum population was used in the study). Threatened species were identified according to the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of birds (http://www.iucnredlist.org/). Site priorities were ranked using the value of the irreplaceability index (I), which was determined followed Formula (1). The sites were overlain with the map of distribution of National Nature Reserves and checked individually using the list and locations of other protected areas (excluding National Nature Reserves). Sites locate beyond the protected areas were recognized as gap areas.

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