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Drivers of waterbird communities and their declines on Yangtze River floodplain lakes

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ABSTRACT

The seasonally flooded Yangtze Valley Floodplain wetlands of China are globally important for wintering waterbirds in the East Asian-Australasian Flyway. These birds have declined in the last 60 years, so understanding factors shaping waterbird distribution and abundance patterns is critical for their conservation. We applied linear mixed models to investigate the effects of climate, winter water area and inundation area (the difference between maximum flooded and winter dry season water area) on waterbird abundance and diversity at 72 lakes in 2005 and 2016. Neither winter water area nor climate featured in the best models, rather inundation area was the key determinant of waterbird abundance and diversity. Future water abstraction and land claim will therefore have greater impacts on waterbird abundance and diversity than likely climate change effects. Significant declines in waterbird abundance and diversity between 2005 and 2016 were not explained by modelled variables and there was no reduction in wetland inundation areas to explain these declines, confirming other factors were responsible. These potentially include declining wetland quality affecting carrying capacity (*e.g.* flooding phenology, disturbance, habitat loss and degradation, declining water quality caused by eutrophication and pollution) and/or factors limiting migratory waterbird populations at other stages in their life cycle elsewhere. The studied Yangtze lakes are amongst the best for wintering waterbirds and many are protected for their biodiversity, suggesting such protection cannot fully safeguard these internationally shared populations when threatened by other, currently unknown factors. This confirms the urgent need for more research to safeguard these ephemeral lake systems for their global biodiversity significance.

1. Introduction

River flow patterns modified by human activities and climate change are amongst the most profound and widespread of global changes affecting biodiversity throughout the world. The Yangtze (the longest river in Asia and third longest in the world Chen et al., 2002) is unique for its extensive ephemeral basin wetlands, recharged by summer monsoonal rainfall, bringing water laden with nutrients and sediment, followed by subsequent autumn and winter water level recession (Yang et al., 2002; Fang et al., 2006). Some 100 such wetlands larger than 10 km^2 cover *c*.10,600 km^2 in middle and lower reaches of the Yangtze River Floodplain (henceforth, Yangtze Floodplain Cui et al., 2013), the largest concentration of shallow and seasonal flooded lakes in the world (Yang et al., 2008). These provide ecosystem services (*e.g.* flood alleviation, water supply and storage, fisheries, aquaculture, transport, aggregate and other mineral resources) to tens of millions of people (Pang et al., 2006; Nakayama and Watanabe, 2008; Cao and Fox, 2009; De Leeuw et al., 2010). They are also of global importance for over one million wintering waterbirds (Fang et al., 2006; Cao et al., 2008a, 2008b, 2008c, 2010), recent rapid declines in the abundance of which have underlined the urgent need to understand the causes of changes in Yangtze Floodplain waterbird communities (Jia et al., 2016). Fang et al. (2006) documented the serious loss and reduction in area of these wetlands and their role in the loss of biodiversity in the region, so it is natural to look for causes of waterbird declines in relation to these two factors since their review.

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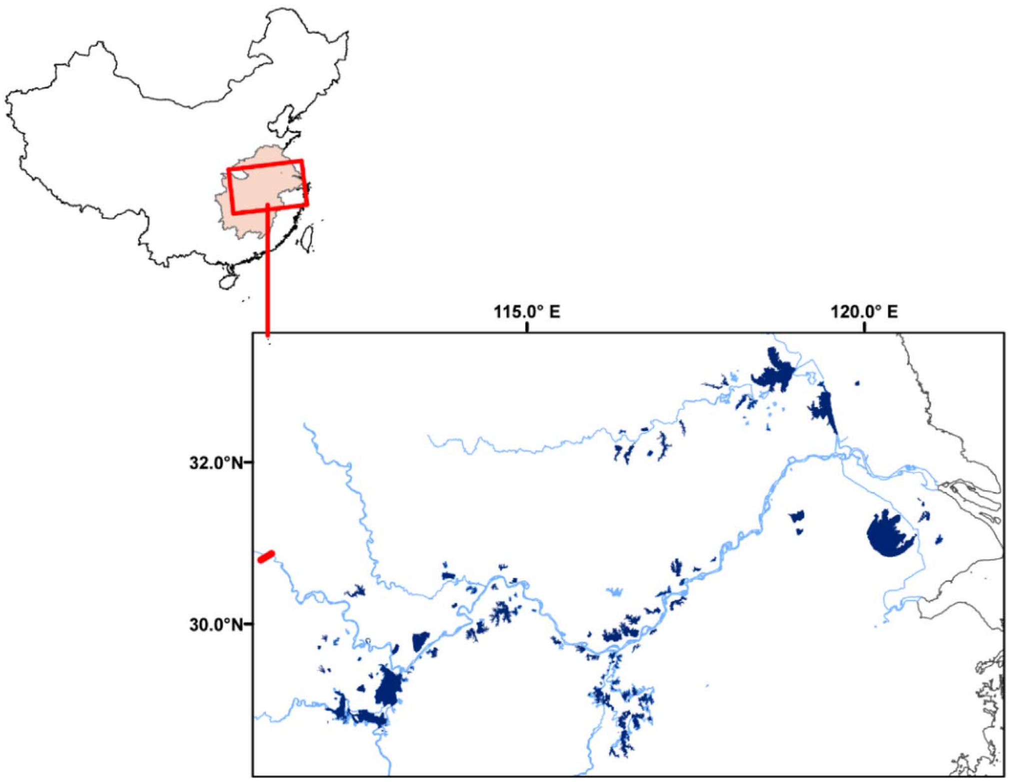

Fig. 1. Distribution of 72 lakes surveyed in 2005 and 2016 within the Yangtze River floodplain (shaded light pink on map top left). The location of the Three Gorges Dam (red stripe lower map) is also shown on the inset map. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

China has a highly effective network of national, provincial and local nature reserves to protect the most important sites for wintering waterbirds, although more protection is needed to be fully effective in conserving the freshwater biodiversity of the Yangtze Floodplain (Liu et al., 2003; Zheng et al., 2012; Zhang et al., 2015). The effectiveness of such site-protection network programmes for aquatic systems, especially those subject to periodic fluvial inundation, is entirely dependent on factors upstream in the catchment. Reductions in specific waterbird species and guilds reflect key hydrological and trophic changes in Yangtze Floodplain wetlands upon which these birds depend (Fox et al., 2011; Zhang et al., 2011, 2015; Yu et al., 2017). Changes in timing of inundation have been shown to affect the extent of seasonally flooded grassland used by Lesser White-fronted Geese *Anser erythropus* (Wang et al., 2012, 2013), *Carex* sedge meadows used by Greater White-fronted Geese *Anser albifrons* (Zhao et al., 2012) and submerged macrophyte tuber resources used during water table recession by Swan Geese *Anser cygnoides,* Tundra Swan *Cygnus columbianus* and Hooded Cranes *Grus monacha* (Fox et al., 2011; Zhang et al., 2011). To understand composite community effects, we needed to assess how the waterbird communities of individual water bodies responded to changes in water regime.

Total wetland size affects waterbird abundance and diversity (Suter, 1994), including those of semi-arid systems (Froneman et al., 2001), as do annual fluctuation in water levels (Colwell and Taft, 2000; Taft et al., 2002). Yangtze Floodplain wetlands are characterised by high summer water tables followed by autumn and winter drawdown of water levels. These progressively create large areas of shallow water and exposed lake sediments, which are temporarily most attractive to feeding waterbirds (excepting diving waterbirds species). Based on classic species-area relationships, we hypothesise that inundation area (the difference in water area at maximum flooding extent compared to the minimum during the dry season) should be a predictor of waterbird abundance and diversity equally important as, or perhaps even more important than total winter lake water area. Local precipitation (Canepuccia et al., 2007) and ambient temperature (Ridgill and Fox, 1990; Lehikoinen et al., 2013; Pavón-Jordán et al., 2015) affect waterbird distributions and abundance through their effects on food availability and abundance, ice cover and thermoregulatory demands (Meehan et al., 2004; White, 2008; Zuckerberg et al., 2011). Hence, we also expect cumulative precipitation in January and average temperature in January to affect waterbird abundance and diversity.

Understanding factors that shape wintering waterbird distribution and abundance patterns is crucial for their effective conservation. Here, we applied a linear mixed modelling approach to show the effects of total wetland area, wetland inundation area, local midwinter precipitation and temperature on wintering waterbird abundance, species richness, diversity, and number of functional groups to determine the key drivers of Yangtze Floodplain waterbird abundance and diversity. To test for temporal changes in waterbird abundance and diversity, we also included the effect of year in the models to detect the changes of waterbird abundance and diversity between 2005 and 2016 when intensive waterbird surveys were repeated at 72 Yangtze Floodplain discrete lake basins (hereafter 'lakes').

2. Materials and methods

2.1. Waterbird survey data

Survey data were collected from c. 970,000 km^2 of the middle and lower Yangtze Floodplain in 2005 (Barter et al., 2006) and in January 2016 using the same techniques (see Fig. 1 and online Appendix A1). All of the 72 most important wintering waterbird areas (Cao et al., 2008a, 2010) were counted using experienced observers and the 'look–see' counting method (Bibby et al., 2000). All species encountered were identified and their abundance recorded, covering as much of each wetland unit as possible in the shortest time (usually within one day, always less than five days for the two largest lakes) to derive total numbers present at each lake. For the details of lake selection, survey techniques and duration see online Appendix A1.