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Flood exposure for vertebrates in China's terrestrial priority areas for biodiversity conservation: Identifying internal refugia

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ABSTRACT

Extreme weather events are likely to increase in the coming decades which may have severe consequences on biodiversity. As conservation funding is limited, identifying priority areas for conservation of species prone to climatic impacts may improve the benefit of conservation investments. As part of its Biodiversity Action Plan, China is carrying out an initiative to evaluate new threats from climatic impacts by 2030 in Priority Areas for Biodiversity Conservation (PABCs). Focusing on floods, which are exhibiting an increasing trend in recent decades in the country, we generated information for such an initiative. We investigated contemporary flood exposure and species internal refugia for all amphibians, birds, and mammals within the 32 terrestrial PABCs of China. Amphibians comprised the greatest number of species at significant flood exposure followed by mammals and birds (~90%, ~81%, ~52% of the total species richness in the country, respectively). However, availability of flood-free internal refugia > 10% and ≤25% was found for ~15% mammals, ~29% birds and ~1% amphibians. Large areas within PABCs are highly exposed to floods. Species in these areas possessing traits that contribute sensitivity and low adaptability to flood disturbance are the ones expected to face negative delayed effects from past exposure, or to possess less resilience to future impacts, including human activities. In the face of multiple threats we call for implementation of cost-effective strategies that strengthen ongoing conservation actions in flood-prone areas and refugia (e.g., landscape connectivity, habitat restoration, afforestation) to better assist in the allocation of limited resources for protecting vulnerable species.

1. Introduction

Climate change has already altered and will continue shaping the occurrence of extreme weather events in the coming decades (Seneviratne et al., 2012). Substantial progress is being made in projecting changes in climatic conditions and inferring their potential future effects on species conservation (Thomas et al., 2004) and several frameworks are already available for assessing vulnerability (Pacifici et al., 2015). However, less attention has been given to the assessment of extreme weather events (Jentsch et al., 2007; Ameca y Juárez et al., 2013; Royan et al., 2014). This is worrying as such discrete and extreme phenomena (e.g. cold waves, floods, heat waves, hurricanes, snowstorms, typhoons) rather than changes in average climatic conditions can trigger sudden and severe changes in the environment in a short term with devastating consequences on species and populations, and hence posing a great challenge for present-day conservation prioritization and management (Jones et al., 2016).

The occurrence of extreme weather events is naturally bounded in particular regions as a result of physiographic characteristics and climatic conditions becoming a normal environmental feature for resident biota (Parmesan et al., 2000). Recurrent exposure of species to these phenomena is expected to shape behavioural and physiological adaptations over evolutionary time, hence reducing their vulnerability of extinction from this source (Lande et al., 2003). Yet, evidence from field observations revealed that species that have a history of exposure to extreme phenomena can experience severe population declines with increased activity of these phenomena (Sidle et al., 1992; Waite et al., 2007). With the anticipated changes in the frequency and intensity of extreme weather events an increase in current levels of exposure can supersede species' coping strategies acting as buffers against disturbance or allowing fast recovery from population die-offs. This might be especially true for those species' intrinsically vulnerable that are gradually being more weakened by anthropogenic impacts (Laurance and Useche, 2009; Dickinson et al., 2015).

Shaped in part by human-induced climate change, floods are parts of a new pattern of more intense extreme weather across the globe in recent decades (Milly et al., 2002; IPCC, 2012). As with other extreme

Abbreviations: PABCs, Priority areas for biodiversity conservation.

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events, flood formation can have several contributing factors coupled with climatic and hydrological conditions such as terrain slope, soil permeability, and loss of vegetation cover (Bradshaw et al., 2007). In China, the combination of these elements in conjunction with accelerated land transformation is enabling the frequent occurrence of floods causing direct and indirect impacts in both human populations and the environment (Lin et al., 2006; GCRI-BMI, 2009). Flood frequency increased 7-fold in recent decades in China (Ding and Dong, 2005). From the species conservation angle this is alarming because evolutionary adaptation of species to natural variability of extreme events may no longer be sufficient to cope with increased exposure (Guo et al., 1999; Xu et al., 2009).

The stochasticity of floods makes the risk posed on biodiversity difficult to quantify and the readiness for investment in risk reduction and management challenging (IPCC, 2012). As funding in biological conservation is limited it is imperative to take advantage of existing efforts in areas of conservation concern where a sound scientific platform for implementing strategic goals and focus of government commitment may be already in place (Shoo et al., 2011). This in turn can help management interventions more likely to be funded and overall deliver more effective protection for vulnerable species (Hannah et al., 2002). Priority areas for conservation are the focus of government investment to protect biological diversity. Therefore, these areas are valuable for investigating regions where species may be negatively affected by extreme weather events, identifying areas that may act as refugia, and prioritise management options to protect them.

In 1994 the first National Biodiversity Conservation Strategy and Action Plan was issued by the Chinese government to fulfil China's obligations under the Convention on Biological Diversity. The strategic plan has been expanded and updated to address emergent pressures and challenges for ensuring biodiversity conservation by 2030 (NBSAP, 2010). In this ambitious guiding framework, 32 terrestrial and 3 areas for coastal and marine conservation were defined as “Priority Areas for Biodiversity Conservation” (hereafter PABCs) aiming to effectively protect ecosystem integrity and species from anthropogenic impacts, as well as to improve capacities to cope with climate change by 2030. In April 2015, after preliminary evaluation and field investigation led by the Ministry of Environmental Protection, boundaries of PABCs were defined considering various factors such as regional representativeness of ecosystems, richness, level of rarity and endangerment, threats, scientific value of species, and the inclusion of national and most provincial-level natural reserves (MEP and CAS, 2015).

The network of PABCs accounts for nearly a quarter of the land territory (24.47%) (MEP and CAS, 2015). Yet, it is unknown the extent to which PABCs contain areas of species' geographical distributions exposed to any type of extreme weather event. Likewise it is unknown whether PABCs contain internal refugia for potentially vulnerable species: identifying these areas will be paramount in guiding for monitoring of risks and management interventions of species in circumstances when available refugia outside PABCs are limited or inexistent.

In this study, we investigated species risk status data and patterns of contemporary flood exposure for all extant amphibians, birds and terrestrial mammals (hereafter “mammals”) in China, as well as within the country's 32 terrestrial PABCs to answer: (i) what is the number of threatened, non-threatened and data-deficient species currently exposed to floods in China; ii) to what extent the PABC network captures species found at significant exposure at the country level; iii) how well does the PABC network capture flood-free internal refugia for significantly exposed species?; and iv) which species may be at greatest risk to flood disturbance? In answering these questions we used geospatial information on flood incidence in China over the last three decades, the current coverage of terrestrial PABCs, and updated species' geographic distribution and risk assessments from the National Red List of China. PABCs were designated with the main goal of conserving key ecosystems and species from human pressures rather than specifically tackle risks posed by extreme weather events. Therefore, we predict that the coverage of the geographical ranges of the majority of species identified at significant flood exposure by PABCs will be high whereas the coverage of species' internal refugia from floods within PABCs, will be low.

2. Materials and methods

2.1. Study area and datasets

For all geospatial and statistical analyses we used ArcMap software (Version 10.0; ESRI, 2010) and R software (Version 3.2.0; R Core Development Team, 2015). We used updated species distribution maps of amphibians, birds and mammals (in shapefile format) and risk categories extracted from the Assessment Report on Threatened Status of Terrestrial Vertebrates in China (Accessed January 2015) (MEP and CAS, 2015), with the primary data being the species extent of occurrences and the national risk assessment of species. Global initiatives for amphibians, mammals (IUCN, 2014) and birds (Birdlife International and Nature Serve, 2014) were the basis of the national risk assessments which now include updated distribution records (collected from atlases, nature reserve biodiversity survey reports, museum collections, and field survey records) and reassessments of species following the IUCN guidelines and criteria version 3.1 (IUCN, 2012a) in conjunction with the IUCN guidelines for application of the criteria at regional and national level version 4.0 (IUCN, 2012b). Species geographical ranges have been widely used as indicator to investigate signals of species decline and exposure to extinction risk factors (Collen et al., 2011; Venter et al., 2014). However, species are not distributed evenly throughout their range. Red List expert distribution maps are drawn as range polygons linking known areas where polygons are associated with a particular level of confidence from 1 “Extant” to 6 “Presence Uncertain”. In our study, we used range polygons for which presence is labelled as “Extant” as these reflect areas of the species range where occurrence is most likely (IUCN, 2012a). By focusing on extant areas (rather than the entire species geographical range) we aimed to avoid overestimating the current degree of exposure to floods. For the three taxa we excluded polygons of species ranges where the species was coded as extinct, introduced, vagrant or of uncertain origin. For birds we used native breeding geographic ranges excluding non-breeding ranges or where a species was recorded as passage migrant.

Following the IUCN Red List guidelines and criteria, we grouped species as “Threatened” (Critically Endangered, Endangered, and Vulnerable) and “Non-Threatened” (Near Threatened and Least Concern). Data-Deficient species were incorporated in the analysis provided that these have polygons coded as extant and their risk status was fully assessed.

Frequency and geographic distribution of flood extents, available as shapefiles, were extracted from the Darmouth Flood Observatory (Accessed January 2015) (Brakenridge and Kettner, 2014). This database is dedicated to floods only, rather than focused on floods and humanitarian aspects (e.g., Emergency events database) or floods and the estimation of economic losses (e.g., NatCatSERVICE). The observatory uses orbital remote sensing to detect floods supplemented by news reports, and satellite imagery to measure and draw bounding polygons per flood event. For floods in China the observatory provides records from 1984 to the present. Hence this study makes use of individual flood events for a 31-year time interval (1984–2014), for which records are available. Polygons of the 32 terrestrial PABCs of China were obtained as individual shapefiles from the report on boundary adjustment of priority areas of biodiversity conservation in China (MEP, 2015, Accessed May 2015).

2.2. Quantifying species exposure to floods in China

In the assessment of species vulnerability to climatic impacts knowledge on species-level traits contributing vulnerability to extreme weather events is limited (Ameca y Juárez et al., 2014; Royan et al., 2014) compared with what we know about traits associated with