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Multi-scale habitat selection by two declining East Asian waterfowl species at their core spring stopover area

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ABSTRACT

Animals respond to their environment at multiple spatial scales that each require different conservation measures. Waterbirds are key bio-indicators for globally threatened wetland ecosystems but their multi-scale habitat selection mechanisms have rarely been studied. Using satellite tracking data and Maximum entropy modeling, we studied habitat selection of two declining waterfowl species, the Greater White-fronted Goose (*Anser Albifrons*) and the Tundra Bean Goose (*A. serrirostris*), at three spatial scales: landscape (30, 40, 50 km), foraging (10, 15, 20 km) and roosting (1, 3, 5 km). We hypothesized that the landscape-scale habitat selection was mainly based on relatively coarse landscape metrics, while more detailed landscape features were taken into account for the foraging- and roosting- scale habitat selection. We found that both waterfowl species preferred areas with a larger percentage of wetland and waterbodies at the landscape scale, aggregated waterbodies surrounded by scattered croplands at the foraging scale, and well-connected wetlands and well-connected middle-sized waterbodies at the roosting scale. The main difference in habitat selection for the two species occurred at the landscape and foraging scale; factors at the roosting scale were similar. We suggest that conservation activities should focus on enhancing the aggregation and connectivity of waterbodies and wetlands, and developing less aggregated cropland in the surroundings. Our approach could guide waterbird conservation practices and wetland management by providing effective measures to improve habitat quality in the face of human-induced environmental change.

1. Introduction

The importance of spatial scale in ecology is increasingly recognized (Levin, 1992; McGarigal et al., 2016; Schneider 2001; Wiens, 1989). Habitat is characterized by a multidimensional structure (Wiens and Kotliar, 1990), in which species perceive and respond to their surroundings across a range of spatial scales (Wiens, 1989). Hence, drawing conclusions from any single-scale at which all observations are measured may result in an overestimation of those observations that drive system behavior (Decesare et al., 2012; Mayor et al., 2009). Multi-scale analysis provides important theoretical insight into ecological patterns and processes, and facilitates effective conservation and management (Chave, 2013; Cunningham et al., 2014; Wiens et al., 1987). Conservation goals also vary at different spatial scales, from dealing with large-scale biodiversity threats to restoring finer-scale habitat, and hence different conservation activities are required at different spatial scales (Cabeza et al., 2010). In recent decades, scale-dependent habitat selection by birds has been increasingly studied (Lemaître et al., 2012; Mayor et al., 2009; McGarigal et al., 2016; Spautz et al., 2006; Wiens, 1989), improving conservation planning at different scales (Benítez-López et al., 2017; Cao et al., 2015; du Toit 2010). While most studies have focused on forest and grassland birds (Doherty et al., 2010; Rae et al., 2014; Timm et al., 2016), multi-scale habitat selection of waterbirds is rarely studied (but see review in McGarigal et al., 2016; Becker and Beissinger, 2003; Bellier et al., 2010; Timm et al., 2016; Benítez-López et al., 2017). Furthermore, wetlands are of economic importance, and in the meantime are eco-sensitive and heavily threatened (Turner et al., 2000). Hence, assessing the multi-scale habitat selection of waterbirds, which are key bio-indicators for wetland ecosystems (Amat and Green, 2010), provides crucial insight for wetland management and conservation.

Species distribution modeling, also known as ecological niche modeling, has been widely applied to quantify the relationship between species distribution and environmental factors and predict potentially

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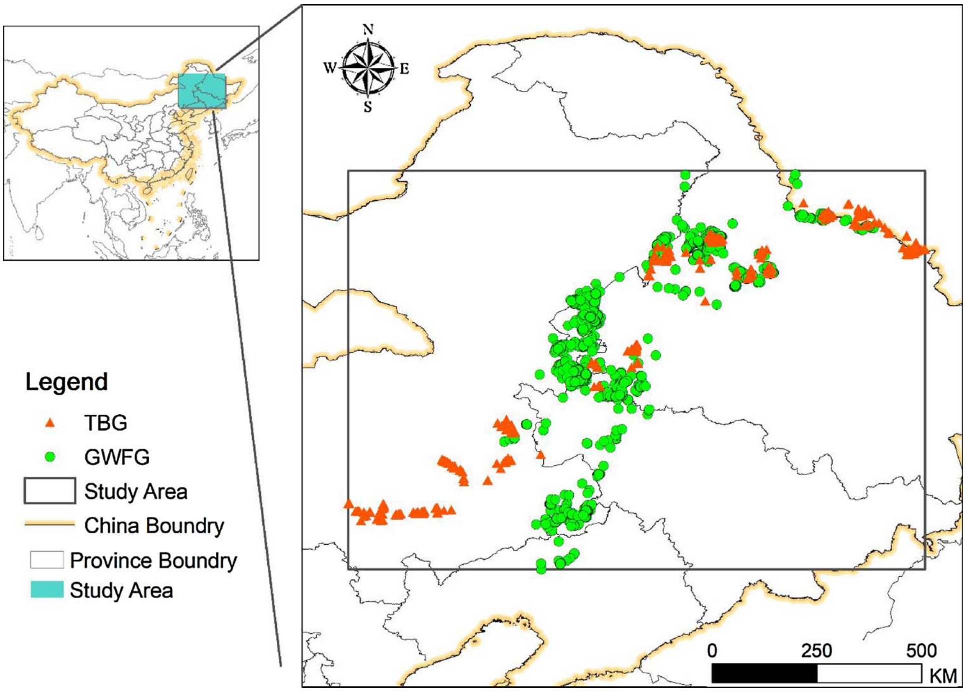

Fig. 1. Map of the study area in the Northeast China Plain (NCP). Red triangles and green circles represent the satellite tracking points. TBG refers to Tundra Bean Goose (*A. serrirostris*). GWFG refers to Greater White-fronted Goose (*Anser Albifrons*). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

suitable area (Guisan and Thuiller 2005; Peterson, 2006). Species distribution models can also be used to estimate the response function and contribution of environment factors (Razgour et al., 2011) and thus can reflect the habitat selection process (Benítez-López et al., 2017). In species distribution models, environmental variables such as food resources, meteorological factors, elevation and human disturbance, have been frequently used to explore bird-environment relationships and predict suitable habitat (Bridge et al., 2015; Osborne et al., 2001; Rosin et al., 2012; Zhang et al., 2016). Moreover, landscape features can influence bird distribution and their habitat selection considerably (Cushman and McGarigal, 2002; Resetarits and Silberbush, 2016). For instance, landscape composition can influence species distribution (McGarigal and McComb, 1995; Sanza et al., 2012) and shifts therein (Brandolin and Blendinger, 2016; Bruun and Smith, 2003). Landscape fragmentation can cause population declines, especially for area-sensitive species (Herkert, 1994). Therefore, the effect of landscape features needs to be considered in analyzing habitat selection mechanisms and developing management measures (Kosicki, 2017).

The process of habitat selection of migratory birds at their stopover area remains poorly understood (Arzel et al., 2006; Drent et al., 2006). The Northeast China Plain (thereafter NCP) is a core spring stopover area for waterbirds wintering in China (Li et al., 2017), where they spent an extended period of time to accumulate energy before traveling to their breeding grounds in Siberia (Li et al., 2017). However, natural wetlands in the NCP have deteriorated drastically since the 1980s (Gong et al., 2010; Niu et al., 2012). This may explain the considerable decline of East Asian waterfowl wintering in China. The landscape and microhabitat in the NCP is highly heterogeneous (Lu et al., 2016; Niu et al., 2012; Wang et al., 2011). This calls for conservation measures considering the effect of landscape features and environmental factors at different spatial scales.

Using satellite tracking data, we investigate the habitat selection of two migratory waterfowl species, the Greater White-fronted Goose (GWFG, *Anser Albifrons*), and the Tundra Bean Goose (TBG, *A. serrirostris*), in the NCP at three spatial scales: landscape, foraging, and roosting. Waterfowl may first select an area to settle at a broad scale, and later gather more precise information at a finer scale (Beatty et al., 2014; Leopold and Hess, 2013). Therefore, we hypothesize that at the landscape scale, habitat selection is mainly based on relatively coarse landscape metrics such as the percentage of relevant land cover types, while at the foraging and roosting scale, more detailed landscape features, such as shape and aggregation indices of relevant land cover type are taken into account.

2. Methods and materials

2.1. Study area

The Northeast China Plain (NCP) is a low elevation plain (< 250 m asl) surrounded by mountains, located in the northeastern part of China, covering the Heilongjiang, Jilin and Liaoning Provinces and Eastern Inner Mongolia (Huang et al., 1998). We define the range of the study area (between 42°02′N – 50°34′N and 118°05′E – 130°27′E) based on the maximum extent of bird tracking data at this core stopover site (Fig. 1). The climate in this region is continental temperate monsoon and is characterized by cold winters, warm summers and abundant rainfall (Zhao et al., 2015a, 2015b). The mean annual temperature is 1.4–4.3 °C, with an average maximal of 21–22 °C and an average minimal −18 °C (Shen et al., 2009). The mean annual precipitation is 400–1000 mm, and 80% of the precipitation is concentrated between May and September (Chen et al., 2012). Although wetlands only account for less than 10% of the area (Lu et al., 2016), it serves as a core stopover area for waterfowl (Li et al., 2017). Besides, the NCP is also an important crop production area (Shen et al., 2009). The main crops in the NCP include rice, corn and soybean, with the sown acreage of soybean being the largest (Liu et al., 2008).

2.2. Bird tracking data

In 2014 and 2015, a total of 24 GWFG and 13 TBG were captured at their wintering ground in Poyang Lake along the Yangtze River Floodplain, Jiangxi Province, China and equipped with GPS-GSM (Global Positioning System – Global System for Mobile Communications), solar-powered loggers (20-necked IBIS series, Ecotone Telemetry, Gdynia, Poland; 15-necked HQNG series, Hunan Global Messenger Technology Co. Ltd., Xiangtan, China; and 2-backed ANIT series, Blueoceanix Technology Co. Ltd., Tianjin, China). The loggers were programmed to record GPS positions every 2 h and send