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Changing land use and its impact on the habitat suitability for wintering Anseriformes in China's Poyang Lake region

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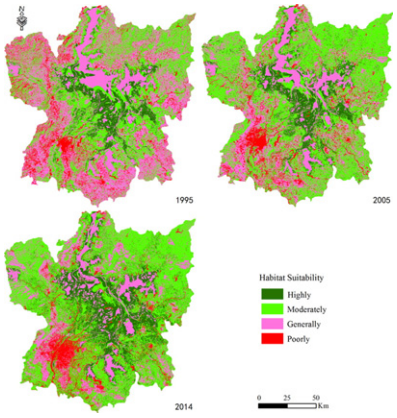
HIGHLIGHTS

- Remote sensing and GIS are integrated to assess the impact of land-use changes.
- Lake shrinkage leads to the expansion of well-suited wetland.
- The good habitat for wintering Anseriformes increased consistently.
- Dam constructions altered the hydrological regimes of Poyang Lake.

GRAPHICAL ABSTRACT



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ABSTRACT

As an internationally important wetland for migratory waterbirds, China's Poyang Lake region has experienced substantial changes in land use during the past two decades owing to climate change and anthropogenic disturbances. Recent dam constructions on the Yangtze River and its tributaries for agriculture and hydroelectric power exert strong effects on the hydrological regimes of this lake. However, few studies have investigated how the land-use changes through time affect the habitat suitability for wintering Anseriformes—the largest community in this region. Thus, it is necessary to timely monitor changes in the habitat quality and understand the potential factors that alter it. In this study, three periods (1995, 2005 and 2014) of typical environmental indicators that have direct impacts on foraging and resting for the Anserformes, including proximity to water (density of lakes, rivers and ponds), human disturbances (density of residences and various road networks), preferred land cover types and food availability (NDVI), are integrated to develop a habitat suitability index model for habitat mapping. The results indicate that long-term lake shrinkage in low-water periods led to greatly expanded wetlands in these years, which provided more suitable habitat for migratory waterfowl. The amount of highly suitable habitat in 2014 was nearly twice as much as in 1995. Recent survey data from 1997 to 2013 also revealed an increase in the population size, and confirmed the improvement of habitat suitability in the Poyang Lake region. Spatial analysis revealed that land use changes contributed most to the improved habitat coverage between 1995 and 2014. However, the relative significances of these transformations for highly suitable and moderately suitable habitats are strikingly different. Increases in wetland and paddy field area are the main reasons for

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explaining these improvements, respectively. The framework model proposed in this study will help governments to evaluate habitat conservation and restoration for protecting waterbirds in a spatially explicit way.

1. Introduction

Habitat suitability is the capacity of the environment to provide appropriate conditions for wildlife. However, owing to the disturbances from global climate change and intensive human activities, multiple changes in ecosystem properties and functions have exerted severe impacts on the wildlife habitat and biodiversity in recent years (Brook et al., 2008; Naeem et al., 2012; Cardador et al., 2015). In particular, changes in land use and land cover are considered as one of the most important factors that threaten the habitat quality (Seoane et al., 2006; Torres et al., 2014). In response to such changes, many efforts have been deployed to make conservation policies and management strategies (Olsson and Rogers, 2009; Reza et al., 2013). A lot of natural reserves with strict regulations have been set up to protect various wildlife around the world (Zheng et al., 2012; Thomas et al., 2012; Mascia et al., 2014). The European Commission 2020 Biodiversity Strategy and Convention on Biological Diversity has also made strong commitments, but they are still partially unable to monitor their progress towards meeting the goals (Zlinszky et al., 2015). Therefore, quick and effective assessment of the habitat suitability for species through time is a decisive step in habitat conservation and restoration.

Traditional field survey methods have been demonstrated extremely time-consuming, whereas remote sensing techniques exhibit great potential in monitoring various ecosystem properties, while also allowing rigorous checking of accuracy and supporting standardized processing (Poschlod et al., 2005; Lengyel et al., 2008; Dong et al., 2013). Many studies have used this technique for habitat mapping and quantification of habitat quality parameters, as well as multiparameter modeling of the environmental quality (Hui et al., 2008; Spanhove et al., 2012; Dai et al., 2013). Several methods have been developed to assess habitat suitability, including generalized linear models (Osborne et al., 2001; Vasconcelos et al., 2013), ecological niche variable analysis (Strubbe et al., 2013), resource-based models (Cardador et al., 2014, 2015) and habitat suitability index (Reza et al., 2013; Liang et al., 2015), which are generally based on the relationship between species community and habitat characteristics. Multidimensional environmental factors must be taken into account such as land use and landscape structure, topographic and hydrological conditions, as well as anthropogenic activities that affect foraging and nesting of different species (Brotons et al., 2004; King et al., 2010; Monsarrat et al., 2013). These ecosystem properties need to be integrated into analyses to evaluate habitat quality (Porzig et al., 2014; Zlinszky et al., 2015). Meanwhile, repeated satellite remote sensing data provide us an opportunity to objectively assess the effects of long-term land use changes on landscape-scale habitat owing to various natural and human disturbances (Yuan et al., 2014; Senapathi et al., 2015). Traditional pixel-based classification method solely based on spectral information can result in “salt and pepper” effects in the classification results owing to high spectral variance within the objects of interest (Benz et al., 2004; Ke et al., 2010). To improve the classification accuracy, object-based image analysis by features of different remote sensing spectral values, textures and shapes was used to classify land use types. Initially, high-resolution remote sensing images are interpreted using this method (Yu et al., 2006; de Laet et al., 2007; Myint et al., 2011). But it has also proved to be efficient for the medium-resolution Landsat data for large-scale studies (Walker et al., 2010; Vieira et al., 2012; Jia et al., 2015).

Poyang Lake is the largest freshwater lake in China and is of global importance for conserving migratory waterfowls of the East Asian–Australasian Flyway (Wang et al., 2013). >400,000 waterbirds make Poyang Lake their wintering home (Ji et al., 2007; Li et al., 2012). A major reason that hundreds of thousands of migratory waterbirds travel to this region for winter is the rich food resources provided by emergent and submerged aquatic plant diversity of this wetland (Dronova et al., 2011; Jia et al., 2013). The natural hydrological fluctuations, usually floods and drying, govern the distribution and abundance of biota and ecological processes in freshwater ecosystems (Kingsford et al., 2004; Bellio et al., 2009; Wang et al., 2013). However, anthropogenic disturbances imposed on rivers by building dams, weirs, levees and sand mining can severely alter the hydrological variability, land cover types as well as the habitat coverage. Recent dam construction on the Yangtze River and the tributaries for agriculture and hydroelectric power has greatly affected the hydrological regimes of Poyang Lake (Feng et al., 2012; Guo et al., 2012). The major hydrological consequence of the Three Gorges Dam is to weaken the forcing of the Yangtze River on the connected Poyang Lake, allowing more water to flow from the lake to the river during the dry season between October and March (Wang et al., 2013). Despite the potential adverse impacts of large dams on the downstream lakes and the critical role of Poyang Lake in global biodiversity conservation, few studies have focused on the effects of the sequent land use changes on the habitat for wintering waterbirds in this region.

Thus, it is necessary to monitor the changes in habitat quality and make clear the reasons that alter it. This study focuses on the habitat suitability for the representative migratory waterfowl—Anseriformes in China's Poyang Lake region, and examines how changing land use have affected the habitat during the past two decades. The aim of this study is to develop an effective framework for tracking the changes in habitat quality based on remote sensing and GIS techniques, and to assist in the conservation of biodiversity and ecosystem services in a spatially explicit way.

2. Description of the study area

Poyang Lake, one of the largest freshwater lakes in China, lies at the southern bank of the middle reach of the Yangtze River and the northern part of Jiangxi province (Fig.1). Its seasonal variations in inundation regimes along with water level fluctuations generate a unique landscape of marshlands in winter and flood plains in summer, which are dominantly controlled by the water balance between the Yangtze River and five major tributaries (Gan River, Fu River, Xin River, Rao River and Xiu River) (Shankman et al., 2006; Hui et al., 2008). These hydrological conditions also affect the surrounding land cover types and soil moisture by forming a mosaic of aquatic and wetland ecosystems (Dronova et al., 2011). During the wet seasons from late spring throughout the summertime, water recharges from Jiangxi basin and the Yangtze River increase the lake coverage to the peak of approximately 4000 km^2, whereas during the low-water dry months (November to early March), the lake becomes a complex assembly of hydrological distinct rivers and shallow waters interspersed with meadows (Shankman et al., 2012; Jia et al., 2013). Such variations in turn govern the availability of food and habitat for wildlife (Liu et al., 2011). Moreover, it is during the dry period that migratory waterbirds occupy as the habitat.

The area of the Poyang Lake watershed is 16.2×10^4 km^2. This study analyzes the core region surrounding the lake with about 1.96×10^4 km^2. Rapid economic development during the past two decades has greatly changed regional land use and land cover (Hui et al., 2008; Jiang et al., 2008). However, the associated effects on the habitat suitability for migratory waterbirds remains unclear. Every year, over 400,000 waterfowls use these wetlands as their wintering area (Ji