Over-Wintering Waterbirds Species Diversity Pattern and Its Habitat Suitability Evaluation of Poyang Lake Basin, China

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Abstract: Poyang Lake in Jiangxi Province is the largest freshwater lake in China and is the most important wintering site for the East Asian and Australian Flyway. This area is a biodiversity hotspot hosting various types of waterbirds, mainly endangered Cranes, Storks, and Shorebirds. At a wider landscape scale, the Poyang Lake basin is located in the middle and lower reaches of the Yangtze River and regionally is an essential economic belt ecological pillar for Jiangxi Province to build an ecologically more robust province. Despite Jiangxi Province carrying out a series of management and protection works, such as Bird Award Lake, International Bird Watching Festival, community co-management and so on, the population number and spatial-temporal distribution of some waterbirds still has large fluctuations, as seen elsewhere around the world. In this case, the research results on bird community diversity, spatial-temporal pattern, landscape effect and habitat suitability can provide targeted scientific reference for scientific monitoring, ecological protection and economic development of bird resources and their habitats in Jiangxi Province, and will provide the most significant ecological suggestions for the harmony between human and nature.

From 2016-2020, a survey of wintering waterbirds was carried out in 42 sub-lakes located in two national nature reserves (Poyang Lake National Nature Reserve and Nanji National Nature Reserve, PNNR and NNNR respectively) and one provincial nature reserve (Duchang provincial nature reserve, DPNR) in the Poyang Lake Basin. The wintering waterbird survey was conducted for five winter seasons, Jan 17–31 in 2016, Jan 09–26 in 2017, Jan 19–31 in 2018, Jan 09–26, 2019 and Jan 05–15 in 2020 in each sub lakes of the study area when the population of birds was relatively stable. We used binoculars, monocular and a spotting scope to observe and count the birds, recording species number and location. The survey routes and observation points were located with GPS receiver in all the vantage points in each sub lake. Then, Hill numbers (species richness index, exponential of Shannon's diversity index, inverse Simpson’s diversity index) was computed using the iNEXT package to quantify biodiversity measures of bird communities in the Poyang Lake. In addition to field survey data, Remote Sensing and Geographic information system was used to evaluate the habitat suitability of bird communities through Analytical Hierarchical Process method, using various indicators namely land cover type, Normalized Difference Moisture Index (NDMI), Normalized Difference Vegetation Index (NDVI) slope and road density. The land cover type was obtained through a multi-date classification of Landsat OLIR TIRS satellite images in 2016 to 2020. All the data analysis was operated in various software. The Environment for Visualizing Images was used to preprocess and classify Landsat image. Vegetation indices (NDVI and NDMI) were computed from spectral bands of Landsat images, Red and near infra-red band for NDVI and infra-red bands for NDMI. The slope was calculated from Digital Elevation Model. Google Earth Engine (GEE) cloud platform were used to calculate (NDVI) and (NDMI) from Landsat 8 image. Geographic Information System were used to overlay indicators for the evaluation of habitat suitability. Methods of Land Use Change Evaluation (MOLUSCE) were used to analysis the habitat suitability change during the study period. Spatial pattern analysis program for quantifying landscape structure were used to

calculate landscape metrics. The data analysis and graphing software were used to analysis the correlation between landscape metrics and waterbird abundance.

The overall research content of this study includes community structure (including basic community composition, community similarity, spatial-temporal difference), spatial-temporal patterns of large-size wintering waterbirds, effects of landscape characteristics on species abundance (taking large-size wintering waterbirds as the research object) and habitat suitability (taking wild geese as the research object), lake-island effect. Accordingly, the research results showed that:

(1) Community structure of wintering waterbirds

During the study period, 58 wintering waterbirds species of 9 orders and 13 families were observed, and most of them were ANSERIFORMES (29.31%) and CHARADRIIFORMES (22.41%). The documented avifauna were dominated by Palearctic species (72.41%), followed by Oriental species (17.24%). The residency type was dominated by winter migratory birds (81.03%), followed by resident birds (18.97). Critically Endangered and Vulnerable species account about 1.72% and 8.62%, respectively. The similarity of avian communities in NNNR and PNNR was high (88%), Similarly, species composition of NNNR and PNNR was more similar. Hence, the study showed that among the recorded orders, ANSERIFORMES and CHARADRIFORMES (~86%), CORACIIFORMES and PODICIPEDFORMES (~85.00%) formed a small cluster, which suggests that they were more similar in species composition numbers.

Secondly, temporal difference of wintering waterbirds species diversity was observed in the entire study area and period. Accordingly, the highest and lowest species diversity was observed in 2019 and 2018, respectively. Spatial differences in species richness and species diversity were also observed, whereby in NNNR had the highest diversity and DPNR had the lowest diversity. In different research years, there were also spatial differences on species diversity in the three different nature reserves. Spatial differences of species diversity were also observed among the sub lakes during the survey years. For example, the highest species diversity was observed in Da Hu Chi lake of PNNR, followed by Bai Sha lake of NNNR.

(2) Spatial-temporal pattern and landscape impacts on large-size wintering waterbirds

Large-size waterbirds are the flagship species of avian communities and their habitats. Consequently, the dominant large-size wintering waterbirds in the study area were chosen as the research objects to study their respective spatial-temporal patterns and the effects of landscape metrics on wintering waterbird abundances. The large-size wintering waterbirds in this study include Geese (Tundra Swan, Swan Goose, Greater White-fronted Goose, Bean Goose, Greylag Goose and Lesser White-fronted Goose), Cranes (Siberian Crane, White-naped Crane, Common Crane and Hooded Crane), Storks (Oriental Stork and Black Stork) and Eurasian Spoonbill. According to the results of this study, these large-size wintering waterbirds show differences in temporal and spatial distribution. Temporally, there were annual differences in the entire study area scale, nature reserve, sub-lake. Similarly, there were spatial differences in large-size wintering waterbirds at the nature reserve and sub-lake scales. Focusing on these spatial-temporal differences, this study conducted landscape impact analysis through landscape metrics, such as the landscape habitat connectivity index (DIVISION, COHESION), Contagion index (CONTAG), Shannon Diversity index (SHDI), and Simpson Diversity index (SIDI) in order to analyses the correlation of landscape metrics with the large-size wintering waterbirds abundances. The results of the study showed that COHESION, CONTAG, SHDI, and SIDI index were positively correlated with the spatial-temporal distribution of large-size wintering waterbirds. DIVISION index was negatively correlated with the spatial-temporal distribution of large-size wintering waterbirds. These landscape characteristics evidently can promote spatial-temporal distribution of

large-size wintering waterbirds and needs further investigation.

(3) Habitat suitability analysis of wintering waterbirds (specifically, common geese)

Sympatric species have similar niche selection, and knowledge of habitat suitability is essential to design a good conservation strategy for wintering waterbirds in Poyang Lake. Therefore, in this study, common geese, which are both the large-sized flagship wintering waterbirds and may well represent the wider waterbird communities, were chosen as the focus of habitat suitability analysis in the study area. Landsat images with a resolution of 30 m downloaded from the United States Geological Survey, and other ancillary data were used for the study, and different software was used for preprocessing, classifying the satellite imagery, and mapping habitat suitability. Consequently, land cover types were divided into vegetation, mudflats, water, and sand. Common geese surveyed from the forty-two sub lakes in three nature reserves were chosen as training areas for wintering habitat of common geese to validate the results of the study on habitat suitability of wintering waterbirds in the whole Poyang Lake basin. The level of habitat suitability was divided into four classes: best suitable habitat, suitable habitat, fair habitat and unsuitable habitat.

Among the four levels of habitat suitability classes, the best suitable (optimum) habitat had little change among different research years, showed a slight annual increase trend, ranging from 1589-1607 km2, and accounted for about 42.00% of the entire Poyang Lake basin, mainly distributed in the middle and south of the basin. The suitable habitat showed slight annual decreasing, ranging between 580-600 km2, accounting for about 15.00% of the entire Poyang Lake basin, mainly mosaic distributed among the best suitable habitat. The fair habitat area was relatively stable, between 1110-1120 km2, accounting for about 30.00% of the entire Poyang Lake basin, mainly distributed in the northern edge area and eastern area of Poyang Lake basin. The area of unsuitable habitat was less, about 490 km2, less than 13.00% of the entire Poyang Lake basin.

(4) Lake-island effect of wintering waterbirds in Poyang Lake

Wintering waterbirds in Poyang lake had obvious lake-island effect. The bird species richness was significantly correlated with the sub lake area ($r = 67.55$, $P < 0.01$), and the sub lake area was significantly correlated with the habitat types richness ($r = 64.25$, $P < 0.01$). Similarly, there is a significant nesting pattern distribution of waterbirds in Poyang Lake. The diversity turnover components of waterbirds in Poyang Lake ($\beta sim = 0.464$) greater than nested components ($\beta nes = 0.364$), and the bird species composition in each sub lake is different. Sub lake area, the habitat types richness was significantly correlated with nesting rank ($r = -0.644$, $P < 0.01$ and $r = -0.646$, $P < 0.01$), and conformed to the selective extinction hypothesis and habitat nestedness hypothesis. Maying lake has the highest local beta diversity contribution (0.062) whereas Dacha lake has the lowest local beta diversity contribution (0.007).

Based on the research results, collectively, suggestions for the management and conservation of wintering waterbirds and their habitat in Poyang Lake basin are put forward as follows: (1) Geese (Tundra Swan, Swan Goose, Greater White-fronted Goose, Bean Goose, Grey Goose and Lesser White-fronted Goose), Cranes (Siberian Crane, White-naped Crane, Common Crane and Hooded Crane) and Storks should be routinely monitored; (2) Many sub lakes need to pay more attention, for example the Da hu chi, Bai Sha Hu lake and Xin Miao. These sub lakes were the most winter sites that harbor many species of birds species including endangered birds; (3) DPNR needs more attention to improve the level of protection status; (4) The vegetation and water environment of the middle and south should be the priority of management, and public awareness and education should be enhanced; (5) The northern edge area and eastern area of Poyang Lake Basin can carry out more wetland restoration projects for wintering waterbirds.

These research results provide information on the community structure characteristics of wintering waterbirds

in Poyang Lake, spatial-temporal patterns of large size wintering waterbirds and their relationships with landscape metrics, and an assessment of habitat suitability and spatial distribution of common geese, lake-island effect which can provide the latest scientific reference for the species management and conservation of large-size waterbirds in Poyang Lake. This work will be helpful to formulate more specific management actions and long-term plans in the future management and conservation of Poyang Lake basin and other nature reserves, and will provide theoretical support for the protection of waterbirds around the world, especially large-size endangered birds. Similarly, following the research results it is suggested that in the future, more research is needed in the following areas: (1) the relationship between the water level of all sub lakes and wintering waterbirds; (2) investigation on the distribution of various wintering waterbirds over long time scales; (3) build a distribution and population number change model of wintering waterbirds in order to predict the future situation of wintering waterbirds.

Key words: Over-wintering waterbirds; Waterbirds community structure; Spatial-temporal pattern; Landscape effect; Habitat suitability; Lake-island effect; Poyang Lake.