RESEARCH ARTICLE

Study on habitat suitability of overwintering cranes based on landscape pattern change—a case study of typical lake wetlands in the middle and lower reaches of the Yangtze River

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Abstract

Shengjin Lake wetland is located in the middle and lower reaches of the Yangtze River in China. It is a typical lake-type wetland and is also an ideal place for rare cranes to overwintering. The changes of wetland landscape are closely related to the habitat quality of wintering cranes. It is of great significance to study the habitat change of wintering cranes in wetland for wetland ecological restoration and restoration. In this paper, we analyze four kinds of winter cranes and wetland landscape pattern types from the years 1986 to 2015. Also, we adopted the Pearson correlation analysis method to analyze the relationship between wetland landscape types and crane population, and the main landscape types of cranes habitat were obtained. We selected disturbance degree, food richness, vegetation cover, and hydrological condition as the main factors affecting wintering habitat of cranes. We established a habitat suitability index model for wintering cranes and generated habitat suitability assessment maps by ArcGIS. The results show that the change of landscape pattern in Shengjin Lake protected area was obvious, the number of wetland patches increased, the fragmentation degree of landscape increased, the landscape patch difference became smaller, and the diversity index and evenness index increased gradually. From 1986 to 2015, the number of wintering cranes decreased and the habitat suitability index of wintering cranes decreased from 0.845 to 0.465, and the habitat suitability of wintering cranes fell from 13,577.11 to 7424.42 ha, which showed the overall habitat deteriorated significantly and had a positive correlation between the crane population and habitat suitability.

Keywords Wetland · Habitat impact factors · Habitat suitability evaluation model · Winter cranes · Landscape

Introduction

Wetland is a unique ecosystem formed by interaction between terrestrial system and water system. It is known as the three major ecosystems of the world with forests and oceans and is widely distributed around the world. The functions of

wetlands are diverse. Its biological species are also relatively rich (Ausseil and Shepherd 2007). Wetland has a strong ecological purification function, plays an important role in ecosystem services and ecosystem function, increases the diversity of vegetation, and provides important habitat for wildlife (Zhou 2014). The loss and degradation of wetlands directly threaten the survival and reproduction of biology (Matchett and Fleskes 2017).

Wetland birds are an important part of wetland ecosystem, which play an important role in maintaining ecosystem stability and are good indicators of environmental change. Birds are one of the most iconic ecological assets of the wetland ecosystem (Mistry et al. 2008) and are very sensitive to changes in surrounding habitats (Devictor and Jiguet 2007). Among them, cranes are typical overwintering waterfowl in wetlands and are also important wild animals in the world. The Shengjin Lake wetland had attracted waterbirds that account for about 10% of the total in the Yangtze River basin to inhabit in winter, and the maximum density of waterbirds in winter was about 160 per square kilometer, which was one of the

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wetland lakes with high waterbird density in the middle and lower reaches of the Yangtze River, which was one of the winter habitats of four species of cranes: hooded crane, Siberian crane, common crane, and white-naped crane. (Liu 2011). There were only 15 species of cranes in the world, 11 of which were marked as endangered species in the IUCN Red List (James and Claire 2013). Because of its low fecundity and high sensitivity to environmental change, it has strict environmental requirements for its habitat and is more vulnerable to the threat of environmental change in wetlands (Devictor and Jiguet 2007). At present, remote sensing technology, aerial photography technology, audio frequency analysis, radar monitoring, and other technologies and methods have been widely used in crane research (Na et al. 2015; Curro et al. 2015; Jones et al. 2010; Li et al. 2014).

In recent years, the population structure of overwintering cranes has changed obviously due to the agricultural development, human activities, and other factors interfering with the natural wetland in Shengjin Lake (Wang and Dong 2015). The study of the relationship between birds and ecological environmental factors was a core issue in evaluating habitat suitability. (Hinojosa et al. 2013). Studies had shown that the surrounding environment of birds was very complex and had many influencing factors, such as land use (Chapman and Reich 2007), landscape structure (Pino et al. 2000), and habitat gradient (Kujawa 2002), road (Peris and Pescador 2007), human disturbance (Cao and Liu 2008; Jiang et al. 2007), and water level (Xu and Cheng 2005). Among them, freshwater resources and anthropogenic disturbance activities were the two main factors to promote the habitat suitability of cranes (Cao and Liu 2008). These studies only focus on the single analysis of the impact of various factors on the habitat of the cranes and lack of discussion on the factors affecting the distribution of the cranes, and on the relationship between the dynamic changes of the habitat-suitable areas and the populations of the cranes. In this paper, the effects of wetland landscape types on the number of four species of overwintering cranes were studied from landscape scale. Based on the comprehensive geographical factors such as vegetation, hydrology, disturbance, and topography, the evaluation model of habitat suitability of cranes was established. The effects of landscape changes on the habitat of overwintering cranes were analyzed quantitatively, and the quantitative relationship between the number and distribution of overwintering cranes and the landscape changes were analyzed, and the response mechanism of overwintering cranes to the landscape pattern of natural wetlands was clarified. Through the research of this project, it is expected to explore the main factors affecting the species, quantity, and distribution of typical wetland cranes in the middle and lower reaches of the Yangtze River and the interaction mechanism between geographical distribution of cranes and land use change was analyzed to provide theoretical basis for the protection and ecological restoration of natural wetland cranes in China.

About the study area

Shengjin Lake National Nature Reserve is located in Chizhou City in the southwestern of Anhui Province near Yangtze River, at east longitude 116° 55′ to 117° 15′, north latitude 30° 15′ to 30° 30′ (Fig. 1). The area of Shengjin Lake was approximately 33,340 hm². It has a subtropical monsoon climate, with four different seasons, abundant sunshine, and good rainfall. The average annual rainfall was 1554.4 mm, and the average annual temperature was 16.4 °C (Li et al. 2014).

The Shengjin Lake National Nature Reserve is located along the migratory routes of migratory birds in the Asia-Pacific region. The beaches are vast and the feed is relatively full. Migratory waterbirds are gradually relocated to Shengjin Lake in early October each year and removed at the end of April of the following year. Every autumn and winter, researchers, experts, and scholars from countries in the United Nations, Europe, and the USA visit the field. According to the survey, there were 142 species of waterfowl, 66 species of which were wintering migratory waterfowl. The five species of waterfowl are first-class national protected animals, such as *Grus monacha*. The 16 species of waterfowl are second-class national protected animals. In 1992, the reserve was listed by the Ministry of Woodland and the World Wide Fund for Nature as one of the nature reserves with world significance in China. In 1995, it joined the network of Chinese and Biosphere Reserves, and in 2002, it joined the Northeast Asia Crane Network Protection Area. In 2005, it joined the East Asian-Australian wading bird conservation area network as a member of the wetland protection network in the middle and lower reaches of the Yangtze River, an important wetland in China and Asia. On December 25, 2015, Shengjin Lake was listed in the "List of Internationally Important Wetlands," being the first nature reserve in Anhui Province to receive the international title.

Methods

Wetland landscape data classification

The landscape pattern data used in this paper were the data of 8 TM images classified in 1986, 1990, 1995, 2000, 2004, 2008, 2011, and 2015 (December to February of the following year) of Shengjin Lake wetland. Referring to the "Technical Specification for Wetland Resources Survey," the "Wetlands Convention," and the data of field surveys, the wetland landscape of Shengjin Lake was divided into eight types: woodland, water area, grassland, mudflat, reed-flat, paddy field, dry land, and construction land. Referring to Professor Huang Jinliang's classification method (Huang 1999) of Dongting Lake wetland, an interpretation and analysis table is generated (Table 1). According to the interpretation and explanation of

Fig. 1 Study area of the National Nature Reserve in Shengjin Lake
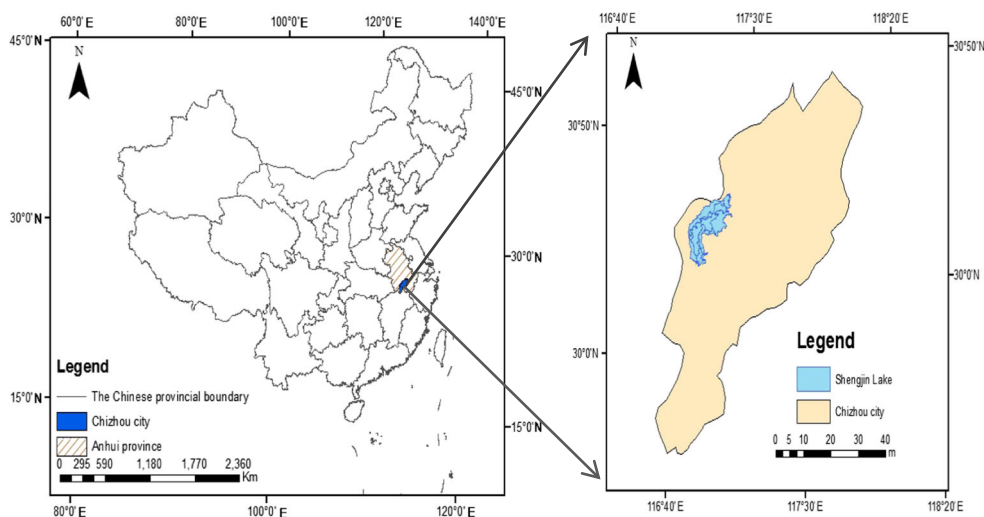
land type in the image, the land use type can be judged and a comparison table of interpretation marks can be established (Table 2). The maximum likelihood method of supervised classification was selected by using ERDAS for band fusion, geometric correction, clipping, image enhancement, and other preprocessing methods, that is, the similarity between other pixels and training samples was calculated according to the mean and variance of the sample data in the training area, so as to determine the maximum probability of wetland landscape belonging to which type.

After classification, 143 data points collected by field GPS were used to test the results, and the Formulas (1) and (2) were used to verify that the kappa coefficient was 0.91. The classification accuracy was high enough to meet the requirements of the research. Kappa coefficient is a way to calculate the classification accuracy, and, when the value is 0.81~1, it means almost perfect. ArcGIS was used to calculate the number and area of patches. Finally, the selected landscape indexes were calculated by using the landscape analysis software FRAGSTATS.

$$k = \frac{P_0 - P_e}{1 - P_e} \tag{1}$$

$$P_0 = \frac{\sum\limits_{i=1}^{n} P_{ii}}{N} \tag{2}$$

where k represents kappa coefficient; P_0 represents classification accuracy of random sample; P_e, n, and N are classification accuracy of samples caused by accidental factors, quantity of land use types, and sample number; and P_{ii} represents the correct classification number of land use variables i, respectively.
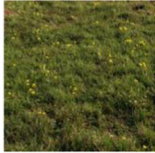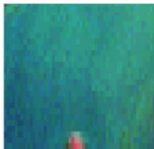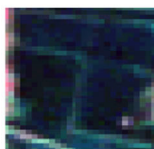
Crane survey method

The cranes' data in this paper is mainly the number of hooded crane, white-naped crane, Siberian crane, and common crane over the years. In the winter of 2011–2015, we visited 14 waterfowl water observation sites in the Lake Shengjin wetland. The observation points are as follows: (1) Tangtian; (2) San Qianmu; (3) Bai Bazhang and Long Kouzui; (4) Xiao luzuiqiao; (5) Chian; (6) Hengzhou; (7) Lianhe Protection station; (8) Dazhou; (9) Shegan; (10) Bai Lianwei; (11) Yang Etou Protection station; (12) Liu Jiach; (13)Yingshan; (14) Tang Tianzha, as shown in (Fig. 2).

Table 1 The table of remote sensing analysis

Land use landscape	Interpretation description
Woodland	Large red, flaky, mainly in mountainous areas, with a small distribution near the site of construction
Water area	Bluish black or light blue, chiefly the lake surface of Lake Shengjin and its tributaries, a small number of lakes with distinct boundaries
Grassland	Shades of red and shades of green, with no obvious boundaries, distributed throughout the protected areas
Mudflat	Varying shades of blue, mainly surrounding the waters, flaky distribution
Reed-flat	Light green, of varying sizes, striped or flaky, with no apparent boundary
Paddy field	Blue-gray, different sizes, grid-like distribution
Dry land	Light green or light red, regular distribution
Construction land	Blue-gray or gray, distributed chiefly along roads and rivers.

Table 2   The table of interpretation signs

Land use landscape	Interpretation marks	Field survey marks
Woodland		
Water area		
Grassland		
Mudfla		
Reed-flat		
Paddy field		
Dry land		
Construction land		

In this study, the distribution of wintering waterbirds was observed by the method of line sampling and fixed-point observation. The specific methods of investigation were as follows: the investigators walked or rode to the established monitoring location, observed with telescopes (monoculars and binoculars) and determined the main distribution of cranes in combination with the identification manual of waterfowl, and recorded the species and number of waterfowl. After the waterfowl left, the land use type of the location was recorded by the combination of GPS and electronic map. The distribution of cranes and other waterfowl sites based on the corresponding data from each observation point is shown in Tables 3 and 4. The cranes' data from 1986 to 2011 were mainly based on statistics from the National Administration of Nature reserves in Shengjin Lake and other researchers' references (Wang 2015; Yang et al. 2015).

Wetland landscape indicators selected

The landscape pattern index reflects the landscape pattern information with highly enriched information, and it also reflects static quantitative indicators of landscape composition, landscape pattern, and spatial distribution. Therefore, quantitative analysis of landscape pattern is a core research content of landscape ecology (Cai and Chen 2010). Comprehensive consideration of the habitat characteristics of the study area and the ecological significance of each landscape pattern index, area of a certain type of landscape (CA), proportion of plaque occupied by landscape area (PLAND), density of patches (PD), largest patch index (LPI), Shannon's diversity index (SHDI), Shannon's evenness index (SHEI), and aggregation index (AI) were selected to study the cranes' habitats. Among them, CA refers to the sum of the areas of all patches in a patch type. PLAND refers to the relative proportion of a

patch type to the total landscape area. PD refers to the number of patch in an area of 100 ha. LPI refers to the percentage of the largest patch area in a patch type and the total landscape area. SHDI refers to the area of each patch type multiplied by the natural logarithm of its value, showing the number of landscape and the proportion of each landscape element change. SHEI is the largest possible diversity of the Shannon diversity index divided by the given landscape abundance. AI refers to a value of 100 when landscape patches aggregate into a single or compact patch; when the same type of patch is discretely distributed, the degree of aggregation was 0 (Wei and Liu 2014; Shao et al. 2008).

Pearson's correlation analysis model

Pearson's correlation coefficient is widely used to measure the correlation between two variables which is a direct reflection of the linear relationship between two continuous variables (Rodgers and Nicewander 1988). Pearson's correlation coefficient is between −1 and 1. When the correlation coefficient is close to 1 or −1, there is a strong linear correlation between the two variables. When the correlation coefficient is greater than 0, the two variables increase simultaneously, which indicates positive correlation, and when the correlation coefficient is less than 0, one variable increases while the other variable decreases, which means that they are negatively correlated. When the correlation coefficient is equal to 0, there is no correlation or unclear correlation between variables.

$$r = \frac{\sum_{i=1}^{n} \left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)}{\sqrt{\sum_{i=1}^{n} \left(X_i - \overline{X}\right)^2} \sqrt{\sum_{i=1}^{n} \left(Y_i - \overline{Y}\right)^2}} \tag{3}$$

r can be estimated by the standard fractional mean of the (X_i, Y_i) sample points. Therefore, the upper formula is also equivalent to

$$r = \frac{1}{n} \sum_{i=1}^{n} \left(\frac{X_i - \overline{X}}{\sigma X}\right)\left(\frac{Y_i - \overline{Y}}{\sigma Y}\right) \tag{4}$$

where r denotes Pearson's correlation coefficient, $\frac{X_i - \overline{X}}{\sigma X}$ represents the standard score for the sample, $\overline{X}$ represents sample average, and σX represents sample standard deviation.

Habitat suitability evaluation model for wintering cranes

The HSI model adopts the weight evaluation method, with certain fuzziness, thus being more suitable for field crane habitat investigation and evaluation (Yu 2010). The HSI (habitat suitability index) expression of overwintering crane habitat evaluation index is:
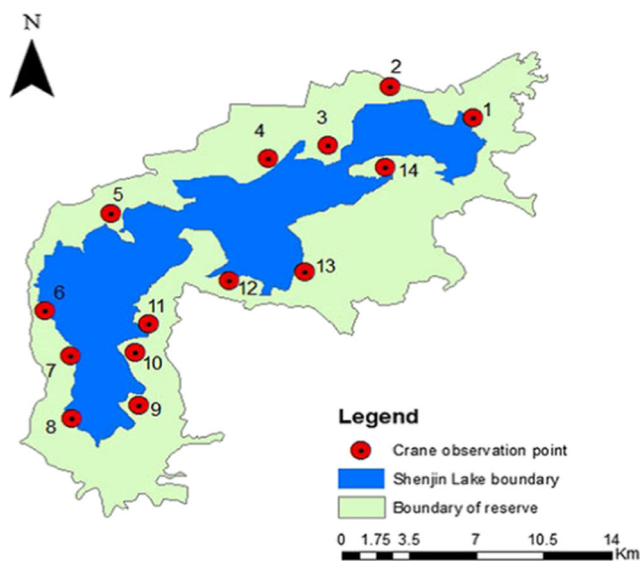

Fig. 2 The observation points distribution of wetland birds

Table 3 The distribution of cranes in different observation points

No.	Observation sites	Crane species
1	Tangtian	Hooded crane
3	Bai Bazhang and Long Kouzui	Hooded crane, white-naped crane, Siberian crane
5	Chian	Hooded crane
6	Hengzhou	Hooded crane
7	Lianhe	Hooded crane, white-naped crane, Siberian crane, Gray Crane
8	Dazhou	Hooded crane, white-naped crane, Siberian crane
9	Shegan	Hooded crane
10	Bai Lianwei	Hooded crane, Siberian crane, Gray crane
11	Yang Etou	Hooded crane, Siberian crane

$$HSI = \sum_{i=1}^{n} h_i w_i \qquad (5)$$

where HSI is the index of habitat suitability of overwintering cranes in Shengjin Lake. h_i is the habitat factor indicator value of the i-th indicator. w_i is the weight of the i-th environment factor, and n represents the total number of factors affecting the quality of wintering crane habitats (Shao et al. 2008).

Results

Effect of landscape pattern change on habitat types of overwintering cranes

The landscape type and area change of Shengjin Lake wetland between 1986 and 2015 are shown in Table 5. In the past 30 years, the landscape types of Shengjin Lake wetland changed significantly. In 1986, dry land, woodland, and water area were the main landscape types in Shengjin Lake, with a total area of 65.14%. By 2015, mudflat, grassland, water area, and dry land had become the main landscape types. From 1986 to 2000, the total area of waters fluctuates slightly but

the overall trend was flat. The total area of paddy field was gradually increasing. The area of woodland and reed-flat had decreased significantly. The area of mudflat and grassland had increased in a fluctuated manner. By 2015, the proportion of patch number has reached over 30%. The largest degree of disturbance to crane habitats was construction land, which gradually increased from 1986 to 2015. In 2015, its patch area accounted for 10%.

In general, in the wetland landscape types of Shengjin Lake, the natural wetland type (reed-flat, woodland, water area) decreased overall trend and the landscape types dry land and construction land, which were greatly disturbed by human activities, gradually rose.

From 1986 to 2015 (Table 6), landscape density (PD) increased first, and after 2011, patch density decreased, human activities decreased, and conservation actions in protected areas were strengthened. From 1986 to 1990, the value of the Shannon diversity index (SHDI) rose slightly, and the landscape changed little. From 1990 to 1995, the SHDI value decreased and the landscape difference decreased. From 1995 to 2004, the value of the Shannon diversity index (SHDI) and the Shannon evenness index (SHEI) values increased, and the landscape difference became larger. From 2004 to 2011, the

Table 4 The description of bird distribution

Land use types	Description	Waterbird distribution description
Woodland	Trees, shrubs, etc.	Mainly the habitat of herons
Water area	Shengjin Lake and surrounding artificial ponds, etc.	The habitat of major waterbirds, including herons, cranes, ducks
Grassland	Surface vegetation cover	Wild ducks, cranes, waterfowl gathering places
Mudflat	There are fewer foods in the dry season, and there are a lot of aquatic organisms at the boundary with the river.	Crane, heron, duck waterfowl habitat
Reed-flat	Grass vegetation, providing concealment for bird habitat	Have some concealment, some waterfowl
Paddy field	Paddy field, rice scattered in winter rice fields become one of the food sources of waterfowl	Mainly the foraging ground of cranes
Dry land	Mainly oilseeds such as rapeseed	Very few distributed birds
Construction land	Human activity area, transportation and construction land	Almost no waterfowl distribution

Table 5 Landscape type statistics of Shengjin Lake natural wetland

| Landscape type | Year 1986 | | Year 1990 | | Year 1995 | | Year 2000 | |
	CA (hm²)	PLAN (%)	CA (hm²)	PLAND (%)	CA (hm²)	PLAND (%)	CA (hm²)	PLAND (%)
Water area	5356.21	16.07	6493.95	19.48	7797.78	23.39	8454.5325	25.36
Paddy field	1519.02	4.56	3610.35	10.83	2896.74	8.69	2915.505	8.74
Woodland	6163.64	18.49	6615.63	19.84	4085.10	12.25	5688.7425	17.06
Reed-flat	3310.70	9.93	1299.24	3.90	1163.79	3.49	1958.4	5.87
Dry land	10,195.74	30.58	10,002.70	30.00	12,863.79	38.58	7836.795	23.51
Mudflat	2668.95	8.01	2184.06	6.55	1008.99	3.03	699.5475	2.10
Grassland	2983.78	8.95	1950.03	5.85	2243.16	6.73	4118.58	12.35
Construction land	1141.96	3.43	1184.04	3.55	1280.65	3.84	1667.8975	5.00
Landscape type	Year 2004		Year 2008		Year 2011		Year 2015	
	CA (hm²)	PLAND (%)	CA (hm²)	PLAND (%)	CA (hm²)	PLAND (%)	CA (hm²)	PLAND (%)
Water area	7216.65	21.65	8592.26	24.77	9202.16	27.60	5946.17	17.83
Paddy field	3547.62	10.64	3525.23	10.57	2003.85	6.01	3186	9.56
Woodland	2231.37	6.69	3338.37	10.01	4286.52	12.86	3089.88	9.27
Reed-flat	1213.47	3.64	1073.97	3.22	1753.53	5.26	415.08	1.24
Dry land	5506.92	16.52	5932.40	17.79	5875.92	17.62	4782.9	14.35
Mudflat	5102.91	15.31	1990.89	5.97	2075.58	6.23	6585.48	19.75
Grassland	6223.41	18.67	5872.68	17.61	5531.85	16.59	5825.07	17.47
Construction land	2297.65	6.89	3014.20	9.04	2610.59	7.83	3509.42	10.53

CA indicates the area of a certain type of landscape; PLAND indicates the proportion of the area occupied by the plaque

SHDI value and SHEI value decreased, and in 2015, the SHDI value increased again. The main land type of cultivated land was the construction of protected area. In 1995, the area of cultivated land was the most and the landscape had the largest difference. With the transformation of cultivated land, the uniformity of protected areas increased and the differences between patch areas became smaller. With SHDI value and SHEI value increasing, the area of water areas will decrease, the area of mudflat will increase, the area of dry land will decrease, and the area of construction land will increase. The

diversity of landscape patches in protected areas will be small, and the diversity index and evenness index will increase. The aggregation index (AI) value was the highest from 1995 to 2000, and the value was above 80. It was a relatively complete landscape during the study period. After 2000, the degree of fragmentation of the bird habitat landscape was intensified, the degree of patch agglomeration was reduced, and the extent of aggregation in 2008 was 74.227. The types of patches in Shengjin Lake wetland landscape were more diversified. In 2011, the AI value increased, the wetland landscape improved, and the AI value decreased in 2015. The change of AI value indicates that each patch type in Shengjin Lake wetland landscape was not uniform and the wetland landscape was in an unstable state.

Table 6 Landscape indices of the Shengjin Lake natural wetland in 1986 to 2015

| Index year	PD	LPI	SHDI	SHEI	AI
1986	0.520	15.652	0.810	0.925	77.215
1990	0.662	16.334	0.816	0.932	77.247
1995	0.487	24.857	0.750	0.857	84.971
2000	0.653	11.013	0.809	0.924	81.527
2004	0.606	9.100	0.838	0.958	75.334
2008	0.693	19.816	0.829	0.948	74.227
2011	0.647	23.055	0.812	0.928	77.208
2015	0.601	13.830	0.848	0.969	76.361

PD indicates the plaque density index; LPI indicates the proportion of the largest plaque in the landscape area; SHDI indicates the Shannon diversity index; SHEI indicates the Shannon uniformity index; AI indicates the aggregation index

Correlation analysis of wintering cranes and habitat types

Combined with the patch area of landscape pattern types and the number of cranes (Fig. 3), Pearson's correlation analysis was carried out with spss software. The results of the analysis are shown in Table 7. From the four species of cranes, there was a significant positive correlation between hooded crane and reed-flat and paddy field ($P < 0.01$), and the correlation coefficients were 0.871 and 0.863 respectively. There was a significant positive correlation between hooded crane and mudflat, grassland, water area, and woodland ($P < 0.05$), and the correlation coefficients were 0.768, 0.743, 0.695,

Fig. 3 The map of winter cranes' quantity change from 1986 to 2015
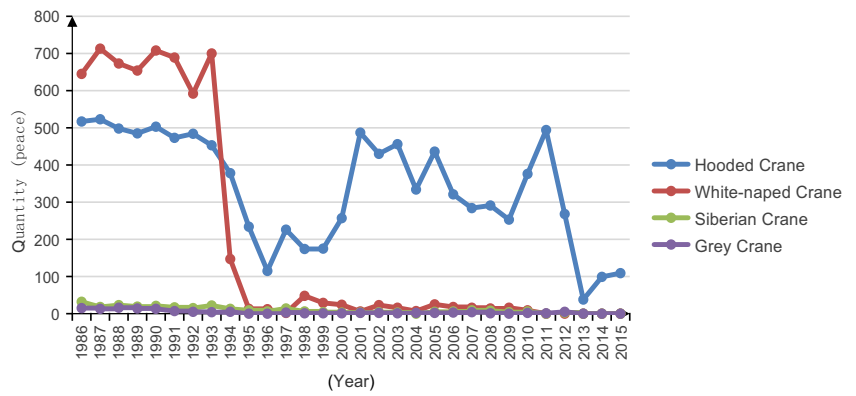
and 0.692 respectively. There was a significant negative correlation between hooded crane and construction land ($P < 0.01$), and the correlation coefficient was -0.894 ($P < 0.01$). There was a significant positive correlation between Siberian crane and reed-flat and paddy field ($P < 0.01$); significant positive correlation with grassland, water area, and grassland ($P < 0.05$); and negative correlation with construction land ($P < 0.01$). There was a significant negative correlation with mudflat. There was a very significant positive correlation ($P < 0.01$) between white-naped crane and grassland and mudflat; and a significant positive correlation between white-naped crane and reed-flat, paddy field, and dry land ($P < 0.05$); and a very significant negative correlation with construction land ($P < 0.01$). There was a significant positive correlation between common crane and water area and reed-flat ($P < 0.01$); significant positive correlation with grassland, mudflat, and paddy field ($P < 0.05$); and very significant negative correlation with construction land ($P < 0.01$), but no significant correlation with dry land.

From the view of crane population, there was a significant positive correlation between crane population and reed-flat, paddy field, water area, and mudflat ($P < 0.01$), and between crane population and grassland land ($P < 0.05$). There was a significant negative correlation between crane population and construction land ($P < 0.01$).

It can be seen from Table 7 that there was a significant negative correlation between the Siberian crane and the mudflat, and a significant negative correlation between the white-naped crane and the grassland, which was closely related to the hunting competition and foraging preference of wild animals in the Shengjin Lake wetland. There were many winter migratory birds in Shengjin Lake. The predatory competition between cranes and other waterfowl and their preference for certain plants lead to the deviation of the correlation between mudflat and grasslands in particular periods.

Analysis of habitat factors of wintering cranes

The living conditions of wild animals determine that the habitat factors were generally the factors that satisfy survival, such as light, humidity, temperature, vegetation type, and food quantity (Zhang 2008). The choice of crane habitat should mainly meet the two conditions of easy foraging and concealment (Wu et al. 2013). They generally choose to inhabit in reed marshes with shallow water, which not only provide them with abundant food resources but also provide a good shelter for cranes (Yang et al. 2015). In Shengjinhu wetland reserve, cranes (hooded crane, etc.) were taken as target species, with reference to the relevant literature and the experts' scores to carry out model studies. The habitat elements for these references were selected including the degree of

Table 7 The Pearson correlation analysis on the habitat of cranes in Shengjin Lake wetland

	Hooded crane	Siberian crane	White-naped crane	Common crane
Paddy field	0.863**	0.834**	0.627*	0.591*
Dry land	0.457	0.682	0.437*	−0.363
Woodland	0.692	0.603*	0.712	0.618
Grassland	0.743*	0.821*	0.812**	0.767*
Mudflat	0.768*	−0.754*	0.829**	0.712*
Reed-flat	0.871*	0.819**	0.659*	0.683**
Water	0.695*	0.713*	0.784*	0.818**
Construction land	−0.894*	−0.845**	−0.902**	−0.813**

Double-tail test: *$P < 0.05$, **$P < 0.01$

disturbance and food abundance, and plant cover suitability, hydrological conditions, spatial patterns, optimal areas for breeding, and types of land use provide relevant information for the assessment and management of habitat suitability in protected areas (Yu 2010). According to the field survey data of Shengjin Lake Nature Reserve and the related literatures, four factors including human interference degree, food richness, vegetation cover, and hydrological conditions were selected as the study to influence the wintering crane habitat model main factors.

Human interference factor

With the development of the economy, the increase in the population and the increasing scope of human activities have intensified the impact on wetlands and human activities have become the mainly influencing factors for habitat degradation and fragmentation in the Shengjin Lake wetland reserve. Overwintering cranes often choose habitats away from densely populated towns as far away as possible from residential areas and roads. Due to the complex feeding habits, cranes could survive in a variety of habitat types and farmland was also an important feeding ground for cranes. However, human production and living activities in farmland and construction land had a great impact on the foraging and habitat of cranes; therefore, it was not suitable as a crane habitat. Through on-the-spot observations, it was found that the location of habitat choices for overwintering cranes was more than 300 to 500 m above the human activity area. Therefore, according to the behavioral habits of the wintering cranes, the disturbance level of Shengjin Lake wetland was divided into five degrees (Table 8).

Food conditions

Food resources had an important impact on the number of wintering crane populations. The richness and the distribution of food resources will have an impact on crane populations. In Shengjin Lake wetland, the hooded cranes mainly feed on plant rhizomes, residual grains such as rice, wheat, and some mollusks and insects, while Siberian cranes, white-naped cranes, and common cranes mainly feed on plant rhizomes

and some mollusks. The food resources of the four wintering cranes are mainly distributed in grassland, paddy field, reed-flat, and mudflat, of which grassland had the most abundant food resources. Due to the tides and the erosion and deposition of the water, a large amount of nutrients and plant fruits were retained in the mudflat, which provided sufficient food for the survival of cranes. According to experimental observations, the main foraging sites of the winter cranes and waterfowls in Shengjin Lake were found in shallow water areas and reed swamps. Therefore, according to the foraging area of wintering cranes, the food conditions in the habitats of the winter cranes were divided into five grades: abundant, medium-abundant, generally abundant, medium-poor, and poor (Table 9).

Vegetation cover

The main plant types of grassland in Shengjin Lake are *Phalaris arundinacea*, *Polygonum jucundum*, et al. (Xu et al. 2008; Liu et al. 2016). These plants were widely distributed around the Shengjinhu Lake area, whose height was about 60–150 cm, meeting the hidden and foraging needs of cranes. The concealed conditions of grassland were good, but the lack of crane food resources was not suitable as the main habitat of cranes. The type of vegetation cover provided cranes with food and rest areas, thus playing a crucial role in the survival of cranes in the winter. According to the type of vegetation coverage, the height and density of the habitat will be suitable for habitat adaptation; vegetation cover type was divided into five grades: more appropriate, appropriate, generally appropriate, less suitable, not suitable (Table 10).

Hydrological conditions

Water resources were an important part of the overwintering crane breeding habitat. A study of waterfowl in FL, USA, showed that the effective foraging depth of waterfowl was no more than 40 cm (Xia et al. 2010). Although the water level was lower in the dry season of Shengjin Lake in winter and spring, most of the waters had a water level of more than 50 cm and the hidden conditions in the lake area were poor. It was not suitable as the main habitat of cranes. The nest of overwintering cranes was usually 10–30 cm deep, and the

Table 8 Degree of interference of human activities on wintering cranes habitat

ID	Degree	Feature description
1	No interference	No human activity
2	Mild interference	Less human activity
3	Intermediate interference	Little human activity
4	Little strong interference	Intensive agricultural production area
5	Strong interference	Human activity intensive areas

Table 9 Degree of food for wintering cranes' habitat

ID	Grades	Landscape type
1	Abundant	Shallow water, reed-flat
2	Medium-abundant	Mudflat, grassland
3	Generally abundant	Dry land, paddy field
4	Medium-poor	Deep water
5	Extremely poor	Construction land

Table 10 Degree of vegetation cover on wintering cranes' habitat

ID	Degree	Feature description
1	Suitable	Reed land, arbor forest
2	Medium suitable	Shrub forest, arable land
3	Commonly suitable	High-covered grassland
4	Little suitable	Low-covered grassland
5	Unsuitable	Bare land

surface area was between 1 and 25 cm^2 and shallow water with an area less than 25m^2. Therefore, the water conditions of Shengjin Lake wetland were divided into five levels: shallow water, deep water, wet, relatively wet, and dry (Table 11).

Evaluation of habitat suitability of wintering cranes

The research refers to Jia Jiuman's assessment of wetland biodiversity indicators and Wu Xi's selection of habitat suitability models for Dongting Lake wetland ecosystem characteristics and waterbird habitat suitability evaluation (Jia and Hao 2010; Wu 2010; Wang 2015), and the habitat suitability model was established according to the habits of wintering cranes conditions.

The choice of habitat for wintering cranes was mainly affected by four major factors: artificial disturbance level, food condition, vegetation cover, and hydrologic condition. However, each factor has a different influence on the selection of crane habitat and the cranes were inhabited according to each factor. The contribution value of the habitat was used to determine the weight, and the importance of each factor to the choice of crane habitat was measured (Table 12).

The remote sensing images used in this study are mainly Landsat TM images with a resolution of 30 m. Therefore, in order to quantitatively evaluate the comprehensive suitability of overwintering cranes, the size of the evaluation unit was determined to be 30 cm × 30 cm. Then, the study took road, hydrology, vegetation coverage, and landscape pattern data as a buffer analysis and overlay analysis by the ArcGIS software. The potential habitat suitability of each evaluation unit was calculated by Formula (5). The habitat quality of overwintering cranes was divided into suitability area ($0.9 < \text{HSI} < 1$), medium-suitability area ($0.7 < \text{HSI} < 0.9$),

commonly suitability area ($0.5 < \text{HSI} < 0.7$), less-suitability area ($0.3 < \text{HSI} < 0.5$), and unsuitability area ($0 < \text{HSI} < 0.3$). The results of habitat suitability evaluation are shown in Fig. 4. The area and proportion of each grade were calculated by statistical analysis tools.

It was calculated that the habitat suitability evaluation indices for cranes in Shengjin Lake wetland reserve have been 0.845, 0.83, 0.77, 0.63, 0.77, 0.63, 0.51, and 0.465 from 1986 to 2015. According to Fig. 5, the habitat suitability of cranes in Shengjin Lake wetland gradually decreased from 12.72% in 1986 to 1.26% in 2015. In 2004, there was a slight increase. The medium-suitability area fell from 29.47% in 1986 to 21.8% in 2015. The area of the commonly suitability area fluctuates slightly and is stable around 30%. The less-suitability area rose from 22.65% in 1986 to 31.95% in 2015. The unsuitability region rose from 7.74% in 1986 to 14.29% in 2015. In general, the suitability regions of overwintering cranes gradually changed to unsuitable regions. The habitat quality of cranes was getting worse. The effect of human activities on the habitat adaptation of cranes was increasing.

Response of the number of wintering cranes to habitat suitability

According to investigations, there are 66 kinds of winter waterfowls in Shengjin Lake, of which there are four types of wintering cranes: *Grus monacha*, *Grus leucogeranus*, *Grus vipio*, and *Grus grus*. Among them, *Grus monacha* and *Grus leucogeranus* were national first-class protected animals and *Grus vipio* was a national second-class protected animal. From the number of three cranes, *Grus leucogeranus*, *Grus vipio* cranes were the main cranes in Shengjin Lake. The total amount of cranes for wintering had gradually declined from 1986 to 2015 (Fig. 3), and no traces of *Grus leucogeranus*, *Grus vipio*, and *Grus grus* had been observed from 2013 to 2015. The changes in the suitability of habitats in wetlands in protected areas had affected the number of overwintering cranes. Overall, the degree of habitat suitability had gradually declined and the total amount of cranes had gradually declined.

By means of Pearson's correlation analysis method of spass software, the correlation between the number change of

Table 11 Degree of water on wintering cranes' habitat

ID	Degree	Feature description
1	Shallow water	The depth of water less than10 m
2	Deep water	Perennial water, the depth of water more than 10 m
3	Humid area	Moist perennial, but no obvious hydronephrosis
4	Less humid area	Paddy field, intermittent hydronephrosis
5	Dry area	the surface is dry and the water content of the surface less than 10%

Table 12 Weight factor and crane habitat selection

Factors	1	0.8	0.6	0.3	0
Artificial disturbance	No interference	Mild interference	Intermediate interference	Llittle strong interference	Strong interference
Food condition	Abundant	Medium-abundant	Generally abundant	Medium-poor	Extremely poor
Vegetation cover	Suitable	Medium suitable	Commonly suitable	Little suitable	Unsuitable
Hydrologic condition	Shallow water	Deep water	Humid area	Less humid area	Dry area

overwintering cranes and the regional change of habitat suitability was studied. It was concluded that the *Grus monacha*, *Grus leucogeranus*, *Grus vipio*, and *Grus grus* and areas of suitability area and medium-suitability area were positive correlations, and the correlation coefficients were 0.566, 0839, 0.838, 0.842, and 0.647, 0.836, 0.607, and 0.834 respectively. That is, when the area of suitability and medium-suitability area changes, the number of four cranes will also change accordingly. The four cranes were negatively correlated with the commonly suitability area, less-suitability area, and the unsuitability area. The correlation coefficients were -0.514, -0.893, -0.598, and -0.845; -0.524, -0.844, -0.798, and -0.634; and -0.588, -0.663, -0.624, -0.799 respectively. That is, when the areas of commonly suitability area, less-suitability area, and the unsuitability area had changed, the numbers of the four species of cranes had changed in reverse.

Discussion

Analysis on the change of landscape pattern of wintering crane habitat

Based on the landscape pattern results of the Shengjin Lake wetland and the analysis of crane habitats, it was found that the number of wetland patches increased, the fragmentation degree of the landscape increased, and the habitat of the overwintering cranes was greatly affected. The habitat suitability of winter cranes decreased from 13,577.11 hm^2 in 1986 to 7244.42 hm^2 in 2015, which supported the conclusion that the habitat of overwintering cranes deteriorated.

By Pearson's correlation analysis, it was found that there was a significant positive correlation between the population of crane and reed-flat, paddy field ($P < 0.01$), water area, and mudflat in Shengjin Lake, and the land types of landscape pattern and cranes were related to the quantity of cranes in Shengjin Lake ($P < 0.01$). There was a significant positive correlation between crane population and grassland ($P < 0.05$), and a significant negative correlation between crane population and construction land ($P < 0.01$). It was verified that the main landscape pattern types of crane habitats were reed-flat land, paddy field, water areas and mudflat, and grassland. The main factors of habitat destruction were the increase in construction land and the increase in human disturbance.

Response of wintering crane population to landscape pattern change

Overall, the number of overwintering cranes (Fig. 2) declined sharply between 1986 and 2015, while the natural wetland in Shengjin Lake remained relatively stable during 1986–1993. Between 1994 and 1999, the number of cranes decreased sharply, and the number of cranes increased slightly from 2000 to 2011, but it was far from the initial state of the area. From 2012 to 2015, no traces of white-naped cranes, Siberian cranes, and common cranes were observed, and the largest number of hooded cranes was only 40. It can be seen from Table 5 that the area of reed-flat in Shengjin Lake had decreased overall, the area of construction land and paddy field had increased, and the area of water area and beach land had changed greatly. A comparative analysis of Table 5 showed that, in 1995, the waters of Shengjin Lake increased, which overflowed the mudflat, resulting in a large decrease in the area of mudflat. At the same time, reed-flat was reclaimed and used to form dry land and paddy field, which resulted in the decrease of reed-flat area, the decrease of habitat area suitable for cranes survival, the decrease of rare cranes food, and the decrease of crane population, and Fig. 2 changes in cranes population can be verified. In 2000, the area of reed-flat, grassland, and paddy field increased, the corresponding habitats suitable for cranes increased, and the number of cranes increased. In 2004, the increase of human activity, the increase of traffic land, the increase of construction land, the decrease of reed-flat area in Shengjin Lake, and the increase of grassland, but not the increase of grassland area, were mostly for abandoned dry land that do not provide too much food for cranes. The main habitat area of rare cranes still decreased, and the number of cranes decreased accordingly. In 2011, the area of reed-flat increased, cranes' food increased, and cranes increased slightly. In 2015, the area of water area decreased significantly, the aquatic plants died in large numbers, and the area of reed-flat decreased, the suitable food for cranes decreased, the corresponding habitat for the survival of cranes decreased, and the number of cranes decreased significantly. On the other hand, the development of agriculture, overplanting, grazing, building reservoirs, reclaiming fields in lakes, and applying pesticides and chemical fertilizers may all caused the decrease of cranes. The evaluation index of habitat suitability of crane habitat was calculated by HSI

Fig. 4 Habitat suitability evaluation map for cranes wintering in Shengjin Lake from1986 to 2015 (from left to right)
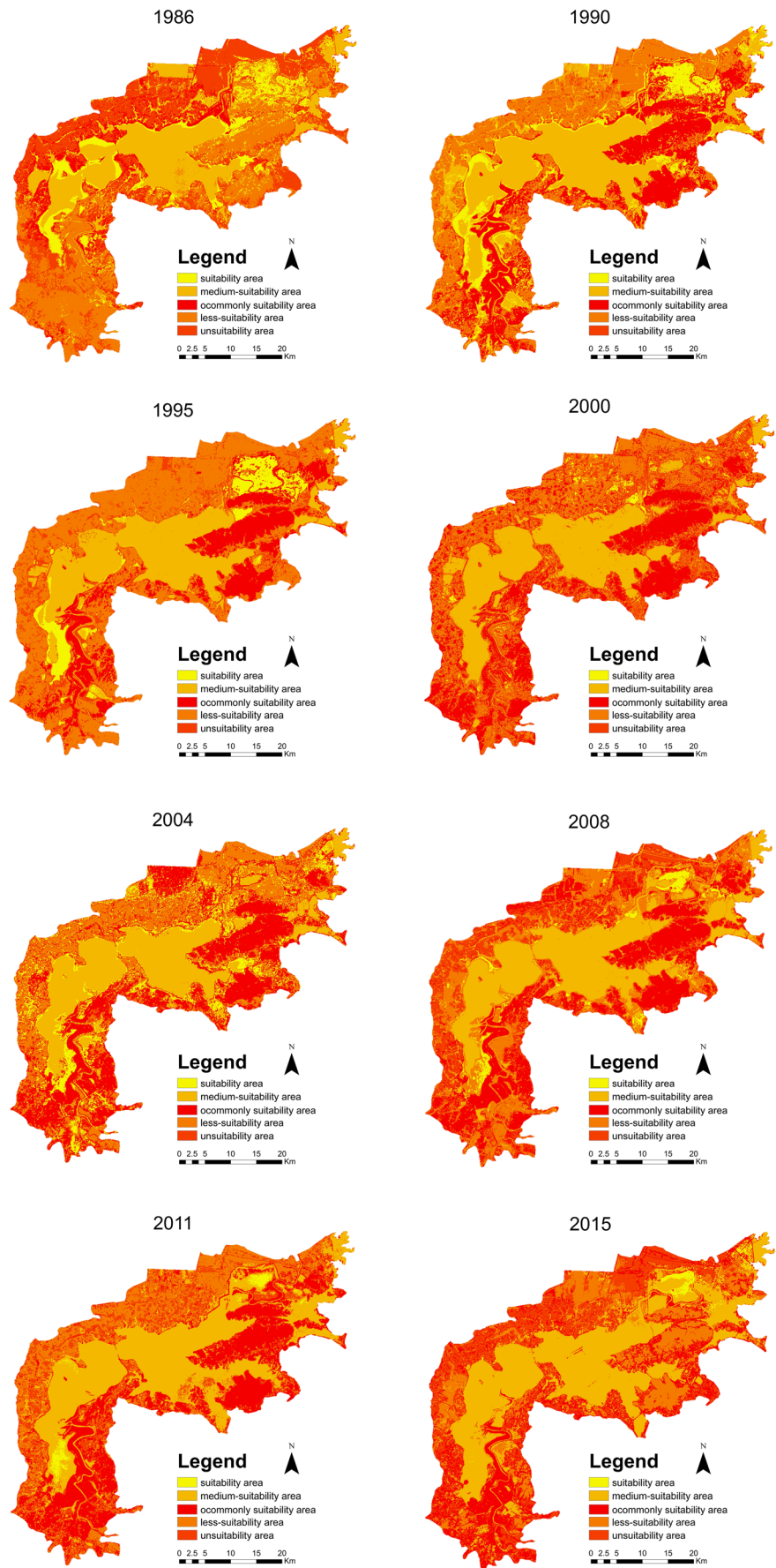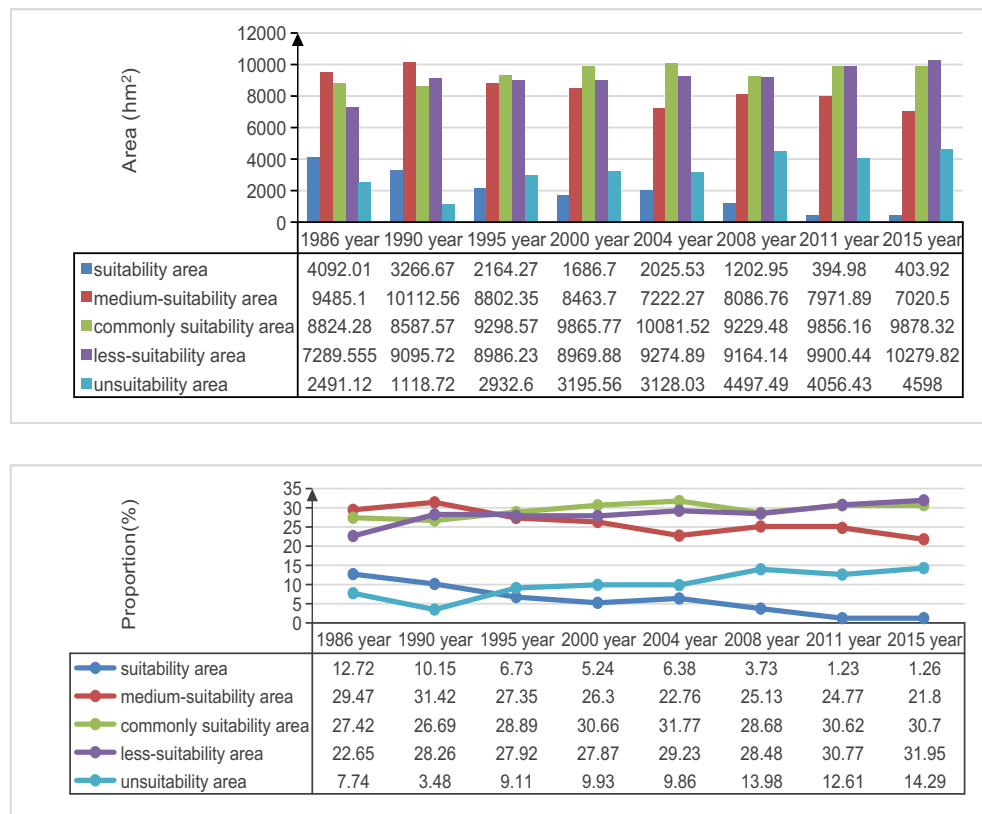
Fig. 5 Habitat suitability evaluation for cranes wintering in Shengjin Lake

	1986 year	1990 year	1995 year	2000 year	2004 year	2008 year	2011 year	2015 year
suitability area	4092.01	3266.67	2164.27	1686.7	2025.53	1202.95	394.98	403.92
medium-suitability area	9485.1	10112.56	8802.35	8463.7	7222.27	8086.76	7971.89	7020.5
commonly suitability area	8824.28	8587.57	9298.57	9865.77	10081.52	9229.48	9856.16	9878.32
less-suitability area	7289.555	9095.72	8986.23	8969.88	9274.89	9164.14	9900.44	10279.82
unsuitability area	2491.12	1118.72	2932.6	3195.56	3128.03	4497.49	4056.43	4598

	1986 year	1990 year	1995 year	2000 year	2004 year	2008 year	2011 year	2015 year
suitability area	12.72	10.15	6.73	5.24	6.38	3.73	1.23	1.26
medium-suitability area	29.47	31.42	27.35	26.3	22.76	25.13	24.77	21.8
commonly suitability area	27.42	26.69	28.89	30.66	31.77	28.68	30.62	30.7
less-suitability area	22.65	28.26	27.92	27.87	29.23	28.48	30.77	31.95
unsuitability area	7.74	3.48	9.11	9.93	9.86	13.98	12.61	14.29

model, and the deterioration of crane habitat quality was obtained. Combined with Pearson's correlation analysis, it was proved that crane population had a strong correlation with the change of landscape pattern.

The crane population was closely related to the population and the amount of pesticides and fertilizers, which could control the migration of the population, the scientific planting in the agricultural process, the misuse of fertilizers and pesticides and so on. Therefore, wetland conservation units all over the world should arrange reasonable labor and agricultural production activities in order to reduce the disturbance to the foraging habitat of wintering waterbirds. In order to attract more overwintering cranes, Shengjin Lake Reserve needs to improve the living environment of cranes, reduce the disturbance of human activities, control the water level reasonably, and improve the integrity of landscape patches. At the same time, it is necessary to strengthen the residents around the protection of wild animals such as overwintering waterfowl.

Conclusion

In this paper, the dynamic changes of wetland were studied by selecting the corresponding landscape pattern index. The results showed that the number of wetland patches in Shengjin Lake increased, the degree of landscape fragmentation increased, and the fragmentation of wetland ecology was serious. According to the present situation of Shengjin Lake wetland research area, the distribution of crane data, and the landscape pattern change of Shengjin Lake wetland, Pearson's correlation analysis method was used to analyze the correlation. It was concluded that the three landscape types of reed-flat, mudflat, and grassland have the greatest influence on the suitability of cranes. Four influencing factors were selected to measure the habitat suitability of overwintering cranes. The habitat suitability index of cranes was calculated by HIS model. Finally, the relationship between the number of cranes and suitability regions and sub-suitability regions were obtained by Pearson's correlation analysis. The results showed that the comprehensive index of habitat suitability of overwintering cranes fell from 0.845 to 0.465, which showed that the overall habitat of cranes had deteriorated obviously. Among them, the number of cranes was positively correlated with the suitability region and sub-suitability region, while the cranes were negatively correlated with the general suitability region, the sub-suitability region, and the unsuitability region. Through the above analysis and conclusion, the protection of wetland not only can effectively improve the habitat suitability of wintering waterfowl, but also can restore the natural landscape of wetland and improve species diversity.

Based on the classification of wetland, this paper classifies Shengjin Lake wetland to obtain the information of land landscape pattern and then analyzes the relationship between cranes and changes of land landscape pattern, and puts forward some suggestions for the protection of cranes. However,

the habitat selection of cranes is related not only to the distribution of wetland land types but also to rainfall, temperature, and other factors (Mihorski et al. 2016). However, due to the geographical location limitation of Shengjin Lake, the selection of suitable index factors for evaluating habitat was less, which to some extent affects the breadth of this study.

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