DISTANCE AND VEGETATION FACTORS AFFECT LITTLE EGRETS (ARDEA GARZETTA) HABITAT SELECTION IN NATURAL AND CONSTRUCTED WETLANDS

LU, LIN
College of Landscape Architecture, Sichuan Agriculture University, Chengdu 611130, P. R. China
001lulin2003@163.com

XIONG, HAO
College of Landscape Architecture, Sichuan Agriculture University, Chengdu 611130, P. R. China
393008122@qq.com

HU, YAZHU
College of Landscape Architecture, Sichuan Agriculture University, Chengdu 611130, P. R. China
634330605@qq.com

ZHANG, HAIQING
College of Landscape Architecture, Sichuan Agriculture University, Chengdu 611130, P. R. China
471318019@163.com

1 ABSTRACT

In order to unveil main factors which affect habitat selection of little egrets for their perching and foraging, the survey was conducted in three wetland parks, Gouxihe National Wetland Park, Huanhuaxi egret wetland park, and Bailuxi wetland park, in Sichuan province, China. The results showed that:

The guarding and flushing distances of little egrets were longer in natural wetlands than those in constructed or man-made wetlands.

Significant differences (P<0.05) exist between experimental samples and control samples in distance from disturbed area, vegetation density, vegetation coverage, slope, distance from water surface, and distance factor and vegetation factor were two principal components.

Little egrets intended to inhabit in areas with gentle slope, dense vegetation, wide forest belt, short distance from water surface, long distance from disturbed area, and forest near a fork estuary.

There were significantly differences (P<0.05) between natural wetlands and constructed wetlands or man-made wetlands in three habitat factors. Which include distance from disturbed area, ground coverage and vegetation coverage. The distance from disturbed area was the most limiting factor in constructed wetlands.

Little egrets preferred to selected farmlands, fishponds, rivers and shallows as their foraging sites, and likely lived in shoals of artificial rivers and lakes in constructed wetlands,.

In conclusion, great differences existed in egret habitat selection between natural wetland and constructed wetland, and there was a significant correlation between habitat factors in foraging and habitat selection, among which distance and vegetation factors contributed more to this selection.

1.1 Keywords

Natural wetlands, Constructed wetlands, Habitat selection, Egret

2 INTRODUCTION

Due to a lack of research on the ecological habits and habitat selection preferences of wetland aquatic birds, the construction of artificial wetlands in cities does not have technical standards or methods that can be used to study and practice habitat creation (Adama, 1908). Habitats used for wetland animals are an indispensable part of wetlands and are an important factor of the ornamental value of wetlands (Brown 1988; Bergin 1992; Mosnier et al., 2003; Buenestado et al., 2008; Gillies et al., 2010; Chao et al., 2011; Chen, 2011). In artificial wetlands in urban areas, the design and construction of animal landscapes and habitat can not only increase the regional biodiversity, improve the ecological function of the wetland, and make it more similar to natural wetlands but can also make the landscape more dynamic and abundant (Chen, 1998). The destruction and disappearance of large areas of natural wetlands and waterfowls have led to a decrease in biodiversity, and there is an urgent need to protect the habitats and living environments of animals. Therefore, research in this area is also needed to provide the basis for the ecological restoration of wetlands (Emlen 1985; Morris 1987; Apps et al., 2001; Erwin et al., 2004; Farina 2006; Abliz 2009; Dong et al., 2010; Fraser et al., 2010; Dong et al., 2013). In this paper, research on egret habitat selection was conducted in three wetland parks in Sichuan Province, China. The preference in the selection of habitat factors was quantified at multiple scales. Ecological habits and habitat selection between natural wetlands and artificial wetlands were compared. The habitat selection mechanisms of egrets were analyzed to provide data to support and reference for egret immigration, egret habitat and drainage construction, and for the ecological restoration of natural wetlands.

3 METHODS

3.1 Research sites

Three wetlands in Sichuan Province were selected as the research targets, namely, Gouxihe National Wetland Park, Huanhuaxi Egret Wetland Park, and Bailuxi Wetland Park. Of which, the Gouxihe National Wetland Park is located in Langzhong County and is a natural wetland with a total length of 95 km (79 km long in Langzhong County). This research was conducted over approximately 60 km from Qianfu to Miaogao, including many types of wetlands, such as wetlands, river shoals, lake wetlands, aquatic ponds, and irrigation reservoirs. Huanhuaxi Egret Wetland Park is located in Chengdu City and covers an area of 32.32 hm2, including the areas of Wanshushan (mainly tall trees), Changlanghu and Egret Island. The latter two areas are mainly composed of artificial lakes and artificial wetlands in shallow waters. Bailuxi Wetland Park is located in Chengdu and covers an area of 5000 acres that is composed of the three large lakes and six small lakes, which are connected by original and artificial rivers of various widths.

3.2 Investigation method

A sampling method was used to investigate the habitat and feeding grounds of egrets. In the habitat and foraging sites of egrets, a 10 * 10 m plot was used as the sample plot, and the same number of plots were randomly selected and used for the control within 300 m of the sample plot. At the habitat selection sites, six habitat factors, namely, slope, vegetation density, vegetation cover, litter cover, distance from artificial interference, and shortest distance to open water, were measured in the sample and control plots. While at the foraging habitat selection sites, cover degree, distance from artificial interference, distance to river, distance to nest, vegetation cover and water depth (Fuller et al., 2005; Huang et al., 2007; Gao et al., 2009; Jinet al., 2011; Huang et al., 2013; Hu et al., 2014) were investigated in the sample and control plots.

3.3 Data processing

All data were processed using the software SPSS 17.0, and a Kolmogorov-Smirnov test was applied to evaluate the normal distribution of the data. Then, the significance of the differences between the habitat factors was evaluated by a T test. A difference was considered significant when the *P* value was greater than 0.05, while the difference was not significant when the *P* value was less than 0.05. When the *P* value was less than 0.01, it was considered to be an extremely significant difference (Lima et al., 1990; Li et al., 1991; Li et al., 1999; Jin et al., 2008).

The principal component analysis method was used to analyze the factors affecting the egret nesting choices, determine the habitat factors that have greater values, and then compare the differences in the habitat selection of egret (Ma et al., 2001; Lu et al., 2003; Li, 2010; Mrriam, 2010; Miguet et al., 2013).

The indexes Wi and Ei from Vanderploeg and Scavia were used to evaluate the foraging habitat preferences (Rosenzweig et al., 1986; Martin, 1998; Ramsay et al., 1999; Heezik et al., 2002; Shu et al., 2009; Wu et al., 2013). The formula is:

$$Wi=(ri/pi)/\sum(ri/pi)$$

$$Ei = (Wi-1/n)(Wi+1/n)$$

(Note, i is the rank of a feature; n is the number of the rank (i=1,2,3... n); pi is the number of samples in the environment with i features accounting for all plots; ri is the number of samples selected by night heron with i features accounting for all selected samples; and the Ei value is from -1 to 1. E>0 represents love, E=1 represents particularly fond of, E<0 represents not loved, E = -1 represents not selected. E=0 represents a random selection, and E close to 0 represents an almost random selection.)

4 RESULTS

4.1 The comparison of average warning distance and average flush distance of egrets

The average warning distances and average flush distances of egrets from the three investigated parks were quite different (Table 1). The two egret indexes from Gouxihe National Wetland Park were higher than those from the other two wetland parks, while Bailuxi Wetland Park had the smallest indexes of all three wetland parks.

Table1. Comparison of egrets Average warning distance and average flush distance in three wetland

	GXH Wetland（m）	HHX Wetland（m）	BLX Wetland（m）
AWD	107.5	49.6	59.9
AFD	56.1	33.5	42.7

(AWD, average warning distance; AFD, average flush distance; GXH, Guixihe; HHX, Huanhuaxi; BLX, Bailuxi.)

4.2 The investigation of egret habitat in Gouxihe National Wetland Park

Three egret habitats were found in this park, namely, the Shitan outfall junction, Banzhulin outfall junction, and Baitangyawan outfall junction. The egret habitats were Cypress-Liquidambar forest and bamboo forest with straight-line distances of 9.9 km and 3.9 km, respectively.

4.2.1 Habitat in the Cypress-Liquidambar forest

The Shitan outfall junction is located upstream of the Gouxihe River and has a width of approximately 60 m; the common species are cypress and Liquidambar. In the habitat, 10 sample plots were used, and three groups of control plots located on the left bank of the upper reaches (first group), the left side of the tributaries (second group), and the left and right banks of the downstream portion of the river (third groups) were chosen. Each group consists of 10 plots. The results are shown in Table 2.

Table2. Comparison of the indexes between sample and control plots in Shitan outfall junction

	Indexes	Sample plots	Control plots	t-test	
				t value	*P* value
The first group	Slope	0.14±0.08	0.32±0.11	-4.038	0.001
	DAI	70.30±11.51	74.50±15.96	-0.675	0.508
	DCWS	10.00±10.54	9.00+9.66	0.221	0.827
	vegetation coverage	0.46±0.04	0.60±0.05	-5.588	0.000
	vegetation density	0.26±0.03	0.25±0.03	0.391	0.701
	GCC	0.60±0.66	0.90±0.09	-8.216	0.000
The second group	Slope	0.14±0.08	0.10±0.04	1.118	0.278
	DAI	70.30±11.51	3.30±3.02	\	\
	DCWS	10.00±10.54	5.90+2.76	1.190	0.250
	vegetation coverage	0.46±0.04	0.60±0.23	-7.684	0.000
	vegetation density	0.26±0.03	0.28± 0.01	-1.704	0.106
	GCC	0.60±0.66	0.80±0.10	-5.071	0.000
	Slope	0.14±0.08	0.19±0.09	-1.394	0.180
	DAI	70.30±11.51	23.60±20.50	2.035	0.000

	DCWS	10.00±10.54	5.80+7.23	1.039	0.313
The third group	vegetation coverage	0.46±0.04	0.27±0.10	\	\
	vegetation density	0.26±0.03	0.16±0.12	2.384	0.028
	GCC	0.60±0.66	0.35±0.09	6.708	0.000

(DAI, distance from artificial interference; DCWS, distance from the clear water surface; GCC, ground cover coverage.)

There were no significant differences between the sample and the first control group in terms of the distance from artificial interference, the distance from the clear water surface and the vegetation density, while there were significant differences in the slope, vegetation coverage and the coverage of the ground cover. There were no significant differences between the second groups in terms of the slope, the distance from the clear water surface and the vegetation density, while the distance from artificial interference, the vegetation coverage and the coverage of the ground cover were significantly different. In the third group, there were no significant differences between the slope, the distance from artificial interference and the distance from the water surface, while the vegetation density was significantly different, and the degrees of vegetation coverage and ground cover were extremely significantly different. However, this result showed no practical significance because the tree crown was obviously destroyed by egret nibbling and the ground cover plants were destroyed by egret manure, which led to lower degrees of vegetation coverage and ground cover in the sample plot than in the control.

Based on the analysis of the results of three groups and the control plots, it can be deduced that slope, human disturbance, and vegetation density are highly related to egret habitat selection.

4.2.2 The habitat in bamboo forest

There were two bamboo forest egret habitats in our survey, namely, bamboo forest outfall junction and Baitangyawan outfall junction. Ten sample plots were set up in the south area of the first outfall junction, while 10 control plots were set up randomly on the north shore area. At the same time, 10 sample plots and 10 control plots were set up in the Baitangyawan outfall junction, and the control plots were set up randomly around the sample plots within a range of 200 m. The results are shown in Table 3.

Table 3. Comparison of the indexes between sample and control plots in bamboo forest.

	Indexes	Sample plots	Control plots	t-test	
				t value	*P* value
bamboo forest outfall junction	Slope	0.19±0.02	0.21±0.05	-0.756	0.471
	DAI	20.60±5.12	92.20±6.18	-19.935	0.000
	DCWS	0.00±0.00	4.00+4.18	\	\
	vegetation coverage	0.68±0.05	0.53±0.05	4.376	0.002
	vegetation density	3.72±0.28	0.28±0.04	\	\
	GCC	0.20±0.07	0.94±0.08	-14.513	0.000
Baitangyawan outfall junction	Slope	0.09±0.05	0.08±0.07	0.239	0.817
	DAI	113.00±7.77	91.80±17.7	2.441	0.054
	DCWS	35.80±2.77	25.80+21.76	1.019	0.338
	vegetation coverage	0.75±0.06	0.58±0.02	5.354	0.001
	vegetation density	2.90±0.30	0.28±0.02	18.968	0.000
	GCC	0.88±0.10	0.08±0.07	0.239	0.817

(DAI, distance from artificial interference; DCWS, distance from the clear water surface; GCC, ground cover coverage.)

In the outfall junction habitat in the bamboo forest, there were no significant differences between the sample and control plots in terms of slope and distance to open water, while there were extremely significant differences in terms of the distance from artificial interference, vegetation coverage, vegetation density and ground cover. In the Baitangywan outfall junction habitat, there were no significant differences between the sample and control plots in terms of slope, distance to open water, and ground cover, while there were extremely significant differences in vegetation coverage and vegetation density. When there were no differences in slope or distance to open water, the egrets likely selected habitats near regions with

artificial interference. For vegetation selection, the egrets were inclined to select bamboo forests with greater degrees of vegetation coverage and coverage density rather than cypress-Liquidambar forests. This tendency reduced their reliance on the distance of artificial interference.

4.2.3 Principal component analysis

The three habitats were analyzed by using the principal component analysis method, and the results are shown in Table 4.

Table 4 Factor analysis of egrets habitat selection in Gouxihe wetland.

Component	Initial eigenvalue			Quadratic sum extraction and load		
	Total	Variance %	Up to %	Total	Variance %	Up to %
1	2.994	49.893	49.893	2.994	49.893	49.893
2	1.952	32.529	82.423	1.952	32.529	82.423
3	0.674	11.237	93.659			
4	0.261	4.355	98.015			
5	0.062	1.038	99.053			
6	0.057	0.947	100.00			

There are two principal components with eigenvalues greater than 1, and their cumulative contribution rate was 82.423%; these components can be considered the main factors that influenced the habitat selection of the egret, and the factor rotation matrix table is shown in Table 5. The first principal component mainly consisted of the distance from artificial interference (0.918), distance from the water surface (0.870) and ground coverage (0.939), and can be considered as the distance factor that affected egret habitat selection. On the other hand, the second principal component mainly consisted of vegetation coverage (0.956) and vegetation density (0.970) and was considered the vegetation factor that affected egret habitat selection (Table 5).

Table 5 Rotated component matrix.

	Component	
	1	2
Slope	-0.656	-0.061
DAI	0.918	-0.098
DCWS	0.870	0.267
vegetation coverage	0.210	0.956
vegetation density	-0.171	0.970
GCC	0.939	-0.140

4.3 Comparison of egret habitat selection in constructed wetlands and natural wetlands

4.3.1 Egret habitat selection in constructed wetlands

To study the egret habitat selection in Huanhuaxi Egret Wetland Park, 9 sample plots and 9 control plots were set up randomly, while in Bailuxi Wetland Park, 6 sample plots and 12 control plots were also set up randomly. Then, the significant differences in the habitat factor variables were analyzed, and the results are shown in Table 6.

The results showed that there were no significant differences between the sample and control plots in terms of slope, vegetation coverage, vegetation density, or degree of ground coverage, while there were significant differences in the distance from artificial interference and distance to open water in

Huanhuaxi Egret Wetland Park. In contrast, there were no significant differences in vegetation coverage and vegetation density, but there were significant differences in the slope, distance from artificial interference, degree of ground coverage, and distance to open water in Bailuxi Wetland Park.

Table 6. Comparison of the indexes between sample and control plots in wetland egrets habitat.

	Indexes	Sample plots	Control plots	t-test	
				t value	*P* value
Huanhuaxi wet land park	Slope	0.11±0.11	0.21±0.27	-1.053	0.308
	DAI	50.33±4.94	31.33±6.83	6.753	0.000
	DCWS	12.77+4.81	8.77+8.13	5.269	0.003
	vegetation coverage	0.61±0.04	0.65±0.08	-1.187	0.253
	vegetation density	0.28±0.01	0.28±0.02	-0.099	0.922
	GCC	0.68±0.09	0.67±0.13	0.199	0.845
Bailuxi wetland park	Slope	0.00±0.00	0.08±0.05	\	\
	DAI	61.33±3.44	38.66±23.78	3.235	0.007
	DCWS	0.00+0.00	34.66+15.02	\	\
	vegetation coverage	0.43±0.01	0.44±0.10	\	\
	vegetation density	0.21±0.01	0.21±0.42	0.365	0.720
	GCC	0.00±0.00	0.50±0.21	\	\

(DAI, distance from artificial interference; DCWS, distance from the clear water surface; GCC, ground cover coverage.)

4.3.2 Comparison of egret habitats in constructed and natural wetlands

A significant difference test was employed to compare the egret habitats in Huanhuaxi Egret Wetland Park and Bailuxi Wetland Park to those in the Gouxihe outfall conjunction area. In the comparison of the habitats in Huanhuaxi Egret Wetland Park with the natural wetland control, there were significant differences in the distance from artificial interference, degree of vegetation cover and degree of ground cover, while there were no differences in slope, distance to open water surface and vegetation density (Table 7). In contrast, there were no significant differences in the distance from artificial interference and degree of vegetation cover in Bailuxi Wetland Park or the natural wetland control comparison group, while there were extremely significant differences in the slope, distance to open water surface, degree of ground cover and vegetation density.

Table 7. Comparison of the indexes of egrets habitat between constructed wetland and Shitan outfall junction.

	Indexes	Sample plots	Control plots	t-test	
				t value	*P* value
Huanhuaxi wet land park	Slope	0.14±0.08	0.11±0.11	0.630	0.537
	DAI	70.30±11.51	50.33±4.94	\	\
	DCWS	10.00±10.54	12.77+4.81	-0.724	0.479
	vegetation coverage	0.46±0.04	0.61±0.04	-6.813	0.000
	vegetation density	0.26±0.03	0.28±0.01	-2.035	0.058
	GCC	0.60±0.66	0.68±0.09	-2.417	0.027
Bailuxi	Slope	0.14±0.08	0.00±0.00	\	\
	DAI	70.30±11.51	61.33±3.44	\	\
	DCWS	10.00±10.54	0.00+0.00	\	\

wet land park	vegetation coverage	0.46±0.04	0.43±0.01	1.653	0.121
	vegetation density	0.26±0.03	0.21±0.01	3.003	0.009
	GCC	0.60±0.66	0.00±0.00	21.737	0.000

The results of the two groups showed that there were some similarities between the natural wetlands and the artificial wetlands in terms of habitat selection, and there were some differences, such as the distance from artificial interference, between the two groups.

4.4 The investigation of egret foraging habitat selection

4.4.1 Egret foraging habitat selection in Gouxihe National Wetland Park

At the beach 200 m away from the lower part of the Chenjiatan hydropower station, we found an egret foraging location, and four samples were collected from the area with white feathers and feces. Egrets were also observed to be foraging in the riparian area, five times in the paddy field, four times in the fish pond, and four times in the river bank. The nearest egret foraging sample plot was 238 m from the river, and the furthest was 4827 m from the river. Fifteen samples were randomly sampled around the sample plots as control plots. The Vanderploeg and Scavia selection coefficients were analyzed, and the results are shown in Table 8.

Table 8. Egrets habitat selection preference in Gouxihe wetland.

Habitat factor	i	r_i	pi	E_i	Preference degree
Water depth（cm）	0	0.00	0.21	-1	NS
	0-30	0.88	0.53	0.405	P
	〉30	0.12	0.25	-0.200	NS
Distance from artificial interference（m）	〈50	0.05	0.28	-0.592	NP
	50-100	0.83	0.54	0.320	P
	〉100	0.12	0.18	-0.117	NP
Distance from river（m）	〈20	0.47	0.40	0.080	AR
	20-200	0.35	0.28	0.120	P
	〉200	0.17	0.31	-0.260	NP
Distance from nests（m）	〈1000	0.47	0.31	0.190	P
	1000-2000	0.23	0.38	-0.240	NP
	〉2000	0.30	0.31	-0.040	AR
Cover degree	〈0.33	0.30	0.35	-0.070	AR
	0.33-0.66	0.23	0.25	-0.010	AR
	〈0.66	0.47	0.40	0.080	AR
Vegetation coverage	〈0.33	0.71	0.56	0.175	P
	0.33-0.66	0.12	0.16	-0.081	AR
	〈0.66	0.17	0.28	-0.178	NP

i, ri, pi and Ei, as described in data processing section; P, favourite; NP, unfavourite; R, randomly select; AR, almost randomly select; NS, no select.

4.4.2 Egret foraging habitat selection in Huanhuaxi Egret and Bailuxi Wetland Parks

Egrets were found foraging 14 times in Huanhuaxi Egret Park, including 8 times in the artificial river and 6 times in the shoal area, and they were found foraging 12 times in Bailuxi Wetland Park, including 3 times on the bank of the artificial river and 9 times in the shoal area of the artificial lake. The mean value of all the plots was analyzed, and the results are shown in Table 9.

5 DISCUSSION

Multiple scales of wetland waterfowl factors influence the selection of egret habitat. This study focuses on the habitat factors at the microhabitat scale and discusses the influence of habitat factors on the habitat selection of egrets.

5.1 Large-scale habitat

There are five outfall junctions located in the middle and downstream portions of the Gouxi River, and three of these junctions were found to be close to egret habitats. However, there is no literature that reports the influence of river outfall junctions on the selection of egret habitat in river wetlands. Our results may explain the relations between river outfall junctions and egret habitat selection.

To take the Shitan outfall junction as an example, the egrets that were foraging outside and homing back moved in the directions of the three rivers; therefore, the river can be seen as a traffic guidance signal. Choosing river outfall junctions can help homing egrets gather along the riverside.

It has been reported that waterfowls prefer to select their living habitats in regions with large open water areas (Yang et al., 2000; Zhang et al., 2003; Zhang et al., 2005; Yan, 2006; Yan et al., 2007; Wu, 2012; Yan et al., 2014). Usually, the open water surface areas are larger in outfall junctions than in junctions without outfalls. Therefore, egrets are more inclined to select habitats in the river wetlands at the junctions of river mainstreams and tributaries. It can also be deduced that outfall junctions provide guidance and signals for egret foraging and homing flights, and a larger proportion of open water surfaces attract egret nesting.

5.2 Microhabitat

The analysis of the data from all sample plots showed that there was a strong correlation between the slope and the habitat selection of egrets. However, there is no evidence that there is a causal relationship between the slope and the habitat selection of egrets.

By comparing the differences between bamboo forests and cypress-liquidambar forests, it was found that the bamboo forest canopy was smoother than the cypress-liquidambar forest canopy, which had a relative slope less than 0.1. Furthermore, egrets prefer to select bamboo forests as its habitat. Therefore, it could be that the slope determines the smoothness of the tree canopy within the area. On the other hand, the vegetation coverage in the bamboo forest was relatively higher, and its canopy foliage was extremely rich, which leads to a preference for egrets to nest. Therefore, the smoothness and richness of the canopy foliage will possibly affect egret habitat selection, and the effect of slope on the egret habitat selection is achieved by these two elements.

The vegetation in some sample plots was also found to be destroyed by egrets in our research. In these plots, there were no differences between the sample plots and the control plots in terms of vegetation type, vegetation density, vegetation height and vegetation age. However, the degrees of ground cover and vegetation coverage were lower in these sample plots than in the control plots. The reason may result from the nibbling of egrets on vegetation canopy, the changes of soil properties and the damage to the ground cover and shrubs by egret feces (Zhu et al., 1988; Zhou et al., 1998; Zhu et al., 1998; Zhu et al., 2000; Zhu et al., 2001; Zhou et al., 2010; Zhou, 2011).

5.3 Construction of egret habitat

For city wetland parks in Sichuan Province, coniferous and broad-leaved mixed forest composed of evergreen trees or bamboo forests, which are suitable for the nesting and resting of egrets, should be planted in disturbed areas and areas less than 20 m from open water. The vegetation density in these areas should be greater than 0.3 plants/m2, and the vegetation density in bamboo forests should be great than 30 trees/m2, while the belt width should be greater than 30 m and the belt length should be longer than 100 m. If there is no need for other egrets to utilize shrubs as their habitats, the shrub and ground cover should be as sparse as possible to reduce the destruction of vegetation by egrets. Waters with depths greater than 0.3 m should be increased in the park, and the distances of these waters from artificial interference should be greater than 60 m. At the same time, the design of the waterfront should be emphasized, and the number of inlets with better shelter should be increased.

6 CONCLUSION

In natural wetlands, the activity of egrets is frequent, their behavior is active, foraging and resting are regular, the daily flight distance is far, the flight time is long, the foraging area radius is wide, and the foraging areas are mostly farmlands, fish ponds, rivers and shoals. The distance factors (including the distance from artificial interference, distance to open water and ground cover degree) and the vegetation factors (vegetation density and vegetation coverage) are two key factors for egret habitat selection in natural wetlands.

In the constructed wetlands, there are only two kinds of egret habitat, namely, the shoals of artificial rivers and artificial lakes. In artificial wetlands, due to long-term human interference, egrets have gradually formed a tolerance to human interference, and the alert and flush distances have increased.

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