Quantify Wetland Bird Habitat Selection in Urban Environment

Lin Lu
Sichuan Agricultural University
HAO XIONG
Sichuan Agricultural University
Yan-ting Wang
Sichuan Agricultural University
Gui-ying Lan
Sichuan Agricultural University
Wei-dong Liu
Sichuan Agricultural University
Nian Li (nli@sicau.edu.cn)
Sichuan Agricultural University https://orcid.org/0000-0002-1338-5769

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Abstract

Background: As the importance of wetlands is recognized by society, the awareness of protecting wetlands is gradually awakening. Wetland conservation actions have been taken around the world, which brought the upsurge of urban wetland construction. However, the lack of research on habitat selection of wetland species results in poor construction or restoration of wetlands habitat in cities.

The aims of this work are: (1) to unveil main factors affect habitat selection for the egrets dwelling and foraging. (2) to quantify their preference of habitat factors natural and urban wetland at multi scale.

Methods: Quadrat sampling are used to collect the data of habitat factor selection. Factor analysis and component analysis for the preference and the difference of habitat selection in natural and urban wetland.

Results: Guarding and flushing distances of egret were longer in natural wetland than those in constructed wetland. Difference significance tests of egret perching habitat factors showed that the habitat factors as distance from disturbed area, vegetation density, vegetation coverage, slope, distance from water surface, were striking ($P<0.05$). In natural wetland and constructed wetland, the differences of three habitat factors including distance from disturbed area, ground coverage and vegetation coverage were striking ($P<0.05$). PCA (Principal Component Analysis) extracted two principal components—distance factor and vegetation factor. Vanderloeg and Scavia coefficient analysis results suggested that Egrets intended to inhabit at 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. They preferred to selected farmlands, fishponds, rivers, and shallows as their foraging sites in natural wetland, while in artificial environment the requirement for distance from disturbed area and hiding cover were loosened. The shoals of artificial rivers and lakes in urban wetlands are their choice.

Conclusion: This study suggest that distance and vegetation were two principal components for egrets dwelling habitat selection. The disturbance distance from human was the most limiting factor for egret habitat selection in urban wetlands.

Background

Wetlands play an important role in maintaining ecological security and providing habitat for animals and plants. The rapid development of cities has reduced the area of urban wetlands, degraded urban wetlands and broken habitats, greatly weakened the ecological functions and social benefits of urban wetlands, and brought new challenges to the protection and restoration of urban wetland.

Since joining the Wetland Convention, China has actively carried out wetland protection works, and has established a wetland protection network from wetland protection areas, wetland protection communities to wetland parks. The construction of urban wetland parks is an effective way to protect urban wetlands and is of great significance to the healthy development of cities. Most of the urban wetland now is

secondary wetland or artificial constructed wetland. In construction of urban wetland parks, the functions of sewage treatment and social services have been extensively explored and developed. Although habitat restoration is one of the important contents of the construction of urban wetland parks, the actual design and construction generally follow the principles of ecological patterns and processes, and restore habitats by restoring wetland structures, such as vegetation restoration and water balance. However, as individual organisms respond to the habitat elements and habitat structure in the habitat, they ultimately tend to choose the most suitable area as their habitat, which is more conducive to their survival. Therefore, there is a certain difference between the habitat selection in the urban context and in the natural environment. However, due to the lack of research on the ecological habits and habitat selection preferences of wetland animals, the habitat restoration effect of urban wetlands is unsatisfactory.

Wetlands are habitats for waterbirds to survive (Odum, E. P., 1971). As an important part of the wetland ecosystem, the wetland waterbird community plays an important role in biodiversity protection and ecological balance maintenance, and is also a very sensitive biological indicator for monitoring the wetland water environment quality (Gillies, C. S., & Clair, C. C. S., 2010; Chao, M. C., & Liu, G. H., 2011; Chen, J. L., 2011). Selecting birds as objects to explore the relationship between the wetland habitat and them has a high representative and guiding significance for how to protect and restore the wetland environment.

Habitat selection refers to the process by which an animal or population finds the most suitable habitat among accessible habitats for a certain survival purpose. Ecologist Lack (Lack D,1933)has conducted groundbreaking research on bird habitat selection, pointing out that birds can identify certain features in the environment and actively choose living environments based on these features. The hypotheses and theories proposed for the habitat selection of birds at different stages in the subsequent research mainly focus on two aspects that affect the behavior of animal habitat selection, namely habitat factors (Kluyve, H. N., & L.Tinbergen, 1954; Shobhit Rao & Vijay Kumar Koli, 2017;Regina H Macedo et al, 2018)such as habitat characteristics, predation pressure, and interspecies competition etc., and habitat scale(Bergin. T. M., 1992; Heezik et al, 2002; Jedlikowski J et al, 2016; James W Pearcehiggins et al, 2019).

As early as the late 1970 s and early 1980s, the US "Fish and Wildlife Service" carried out research on wetland bird habitat selection. They studied 150 kinds of fish and other wildlife habitat elements and habitat suitability model Habitat Suitability Index, which includes the study of 5 waterfowl habitat types, the determined habitat elements include food condition elements (water depth factors, water area and interference) and reproduction conditions (vegetation cover type, area, interference factors). Scholars have conducted a lot of research on the selection of waterbird habitats on a small scale. Studies have shown that the habitat factors that affect the selection of waterbirds habitats on a small scale include food factors, vegetation structure, concealed conditions, water depth factors, human disturbance factors, and natural enemy influences. In different regions, due to the different environmental conditions and landscape types and the intensity of human activity interference, the conditions of waterbirds habitat requirements show great differences (Wershkui, D. F., & Mcmahon E, 1977; Thompson, D. H., 1979).

The egret (*Ardea garzetta)* is the most common species of heron. It is distributed in southern Europe to Japan and Africa, South Asia, East Asia, Southeast Asia, and is widely distributed in lakes, rivers, ponds in southern China, which is also the dominant species of wetland birds. A lot of investigations have conducted on their habitat preferences including vegetation, food, water and other factors Chaney, A. H., 1978, Zhu, X., & Chen, Q. J., 2000; Huang, H. M. et al, 2013). However few studies have refined and quantified a series of habitat factors, such as density and distance from the open water, which have an important influence on the habitat selection of egrets. According to the current situation of wetland habitat selection research, the quantification of habitat factors is the focus and difficulty of the current habitat selection research, and it is also of great significance to the ecological restoration of specific species of wetlands and waterfowl attraction.

Therefore, this study takes the Sichuan Wetland Park in Sichuan Province as an example to conduct a quantitative method to study on the habitat selection preferences of the major waterbird type in Sichuan wetland, egret. The research mainly focuses on two habitat types: dwelling habitat and foraging habitat. the preference for specific habitat factors at multiple scales of egret are quantified and the habitat selection differences in natural wetlands and constructed wetlands differences in urban area are compared in this study. With a view to supporting urban wetland park construction and urban wetland habitat creation and restoration, we (1) investigated the egret's survival status, habitat and foraging habitat in study area; (2) discussed the dwelling habitat selection for egrets, and micro-niche habitat selection preferences both in natural and urban wetland by using sample methods to analyze differences in the selection of six habitat factors for egrets (namely, vegetation coverage, vegetation density, ground cover, distance from artificial disturbance, distance from open water, and slope; (3) understand egret foraging habitat selection by analyzing the selection preference of six habitat factors (sheltering, distance to artificial interference, distance to river, distance to nest, vegetation coverage, and water depth), and comparing the choice of foraging habitat behavior differences between natural wetlands and urban wetlands.

Methods

Study Area

Three wetlands in Sichuan Province were selected as the research targets, namely, Gouxi River National Wetland Park (GNP), Huanhuaxi wetland park (HWP), and Bailuxi wetland park (BWP). Among them, Gouxi River National Wetland Park (GNP) is in Langzhong City, Nanchong, Sichuan Province. It is a natural wetland with a total length of 95km. The area of this study is from Qianfo to Miaogao with wide water surface and good water quality. The complex terrain, abundant vegetation and high coverage forest around the water provides a suitable habitat for wild animals. HWP is in the southwest of Chengdu, which is an urban artificial wetland park, covering an area of 32.32hm2. It consists of three areas: Wanshu Mountain, Canglang Lake and Bailuzhou. Shoal waters of constructed wetlands. Wanshu Mountain is mainly a tall tree planting area, and Canglang Lake and Egret are artificial lakes and artificial wetland

shoals. BWP is in Chengdu, covering an area of 5000 acres, composed of three large lakes and six small lakes, which are connected by original and artificial rivers with various width.

Method and Data Processing

Field Investigate

The number of egrets, daily activities and working hours, the distribution of foraging sites, the types of vegetation in the habitats are recorded to understand the egret habits and behavior in three wetland parks. The distribution sites of egrets' dwelling habitats and foraging sites are marked by GPS in wetland park maps. Guarding and flushing distances are measured.

Sampling and data collection

Sampling method was used to investigate the egret habitat selection. The dwelling and foraging sites were used as the sample plot, and the same number of plots were randomly selected as control plot within 300m of the sample plot, each plot was 10 * 10m.

(1) Egret dwelling habitat sampling

Based on the result of method 1, there were three egret habitats were found in the natural wetland GNP, namely Baitangya Bay Estuary (BBE), Bamboo Forest Estuary (BFE), and Shitan Mouth Estuary (SME). Therefore, the three habitats sites were setting as sample plot (Fig. 1.). These three habitats can be considered as two types of habitat. The SME is a patch of cypress- liquidambars forest, while the BBE and BFE is a patch of bamboo forest. We set 10 sample plots in the habitat sites in SME, and took 10 control plots on the left bank of the upstream as the control group 1, 10 control plots on the left bank of the tributary as the control group 2, and 10 control plot from the left and right banks as the control group 3(Fig. 1a). Sampling in the BBE and BFE see Fig. 1b and 1c. While sampling in the urban wetland parks see Fig. 2a and 2b.10 sample plots were set up in the south area of the BFE, while 10 control plots were set up randomly on the north shore area. At same time, in BBE, 10 sample plots and 10 control plots were set up respectively, and the control plots were set up randomly around the sample plots with the range of 200m.

Our visit to the Chenjiatan Hydropower Station in natural wetland GNP revealed that a large number of egrets came for food every day in the shoal 200m below the hydropower station, so we random selected 4 samples plot with white feathers and feces in the area.In two urban wetlands parks, samples were set where egrets were found foraging.

10 sample plots were set up in the south area of the BFE, while 10 control plots were set up randomly on the north shore area; 10 sample plots and 10 control plots were set up respectively in SME, and the control plots were set up randomly around the sample plots with the range of 200m.

Field data collection

Quantify the dwelling and foraging habitat selection preference by measuring the data of habitat factors of both sample and control plots.

(1) Dwelling habitat factor measurement

Slope

Calculate the average value of the heights of the 10 lowest points and 10 highest points in the sampling site, and divide the difference by 100.

Vegetation coverage

The proportion of covered points in the sample plot. 100 points at equal distances in the sampling site, using a rangefinder to measure the distance vertically upwards at each point, if the distance is displayed, the mark is 1, indicating that this point is covered; If the distance is not displayed, the mark is 2, indicating that this point is not obscured.

Vegetation density

Proportion of trees with a height greater than 8m in the sample.

Ground cover degree

Proportion of all ground cover and small shrubs.

Distance from artificial disturbance

The distance of the nearest artificial interference from the center of the sample plot (including roads, frequently used buildings, farmland under cultivation).

Distance from the open water

The distance from the center of the sample plot to the nearest open water (all open water surfaces are rivers).

(2) Foraging habitat factor measurement

Water depth

The average water depth value of 9 points from every 1m in four directions with the center of the sample plot as the center point. The depth is recorded as 0 when the standing point of egret is a waterless area.

Distance from artificial disturbance

same as mentioned above.

Distance from the river

The perpendicular distance of the center points of the sample plot from the nearest river.

Distance from preaching habitat

The distance from the center of the sample plot to the nearest egret dwelling habitat.

Vegetation coverage

The proportion of covered points in the sample plot. 25 points at equal distances in the sampling site, using a rangefinder to measure the distance vertically upwards at each point, if the distance is displayed, the mark is 1, indicating that this point is covered; If the distance is not displayed, the mark is 2, indicating that this point is not obscured.

Coverage degree

The proportion of points in four directions of the sample center at the equal angles with distances less than 30m.

(3) Others

Guarding distance

The distance between the observation point and the egret, when they stop moving and raises its head to stand still by approaching slowly.

Flushing distance

The distance between the egret's take-off point and the observer. The take-off point is the point where the egret frightened away after its guarding by approaching unceasingly.

Data Processing

(1) Dwelling habitat selection for egret

All data was processed by use of the software SPSS17.0, Kolmogorov-Smirnov Test was applied to evaluate the normal distribution of the data. Then the significance differences of habitat factors were evaluated by T test. There is considered significant difference when the P value is greater than 0.05, while the difference was not significant in case of P value less than 0.05. When the P value is less than 0.01, the extremely significant difference was considered exist (Lima et al., 1990; Li et al., 1991; Li et al., 1999; Jin et al., 2008).

Using the principal component analysis method, to analyze the factors affecting the choice of egret nesting, determine the habitat factors with greater contribution value, and then to compare differences of the habitat selection of egret (Ma et al., 2001; Lu et al., 2003; Li, 2010; Mrriam, 2010; Miguet et al., 2013)

(2) Foraging habitat preference for egret

The indexes W_i and E_i from *Vanderloeg* and *Scavia* were used to evaluate the preference of foraging habitat (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:

$$W_i = (r_i / p_i) / \sum (r_i / p_i)$$

$$E_i = (Wi-1/n)\ (Wi + 1/n)$$

where *i* is the rank of a feature, *n* is the number of the rank ($i = 1,2,3... n$); p_i is the number of samples in the environment with *i* features accounted for all plots; r_i is the number of samples night heron selected with *i* features accounted for all selected samples; E_i value is from − 1 to 1. If E > 0, represents like, E = 1 extremely like; E < 0 dislike, E = -1 not selected; E = 0 a random selection, close to 0 represents almost a random selection.)

Results

The average warning distance and flush distance of egrets

The average warning distance and average flush distance of egrets from the investigated three parks were quite different (Table 1). The two indexes of the egret from GNP were higher than the other two wetland parks, while BWP is the smallest of all the three wetlands. This is possibly because the egrets in the natural wetlands are less disturbed by humans, they are more alert to people at a relatively long distances, while in urban wetlands, they gradually developed tolerance to human interference due to long-term human interference and relaxed the warning distance and flushing distance.

Table 1
The average warning distance and average flush distance in three wetlands

	GNP(m)	HWP(m)	BWP(m)
AWD	107.5	49.6	59.9
AFD	56.1	33.5	42.7
AWD, average warning distance; AFD, average flush distance.			

Dwelling habitat selection of egret

Dwelling habitat selection in natural wetland

(1) The habitat in Cypress- Liquidambar forest

The three sets of control sample plots are in different directions in the SME, they are compared with the use of sample plots. Results are shown in Table 2.

There was no significant difference between sample and the first control group in that the distance from artificial interference, the distance from open water and the vegetation density, while there were significantly different in the slope, vegetation coverage and the coverage of the ground cover. There was no significant difference between the second groups in the slope, the distance from open water and the vegetation density, while the distance from the artificial interference, the vegetation coverage and the coverage of the ground cover were significantly different. In the third compared groups, there was no significant difference between the slope, the distance from the artificial interference and the distance from the water surface, while the vegetation density was significantly different, and vegetation coverage degree and ground cover coverage were extremely significant different. However, this result showed no practical significance, because tree crown was obviously destroyed by nibbling egret, ground cover plants were destroyed by egret manure, and leading to vegetation coverage degree and ground cover coverage were lower in sample plot than that in the control. Based on the analysis of the results of three groups and control plots, it can deduce that slope, human disturbance, and vegetation density are highly related to the selection of egret habitat.

Table 2
Comparison of the indexes between sample and control plots in SME

	Indexes	Sample plots	Control plots	T-test	
				T value	*P* value
	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
The first group	DOW	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
	Slope	0.14 ± 0.08	0.10 ± 0.04	1.118	0.278
	DAI	70.30 ± 11.51	3.30 ± 3.02	\	\
The second group	DOW	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
	DOW	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; DOW, distance from open water; GCC, ground cover coverage.

(2) The habitat in bamboo forest

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

When there were no differences in slope, distance to open water, egrets likely choose their habitat near artificial interference region. For vegetation selection, egrets were inclined to bamboo forest with greater vegetation coverage degree and coverage density rather than Cypress-Liquidambar forest. This tendency reduced their request on the distance of artificial interference.

Contrary to the SME habitat, the sample plots in the bamboo forest are closer to artificial disturbances than the control plots. According to previous studies, wetland waterbirds choose habitats tend to stay away from human interference. Therefore, it is speculated that when there is no difference in slope, distance from water surface, the egret's choice of habitat vegetation is more inclined to bamboo forest patch that with greater vegetation coverage and density than the Cypress-Liquidambar. This tendency makes it reduce the requirement for the distance to artificial interference.

In the habitat of BBE, the differences in vegetation coverage and vegetation density are significant. Based on field investigation, it is concluded that the most significant difference between the sample plot and the control plot is the vegetation. In this area, only the habitat site has large bamboo forest, while other areas are Cypress-Liquidambar forest and a small number of small bamboos. Therefore, the egret prefers the bamboo forest in large-scale habitat selection.

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
	Slope	0.19 ± 0.02	0.21 ± 0.05	-0.756	0.471
Bamboo Forest	DAI	20.60 ± 5.12	92.20 ± 6.18	-19.935	0.000
Estuary	DOW	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
	Slope	0.09 ± 0.05	0.08 ± 0.07	0.239	0.817
Baitangya Bay	DAI	113.00 ± 7.77	91.80 ± 17.7	2.441	0.054
Estuary	DOW	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; DOW, distance from open water; GCC, ground cover coverage

(3) Principal component analysis

Two main factors of habitat selection for egrets are obtained by using the method of principal component analysis (Table 4). The first principal component mainly consisted of distance from the artificial interference (0.918), distance from the water surface (0.870) and ground coverage (0.939), and

can be considered as the distance factor affecting egret habitat selection. On the other hand, the second principal component mainly consisted of vegetation coverage (0.956) and vegetation density (0.970), and considered as the vegetation factor that affecting egret habitat selection (Table 5).

Table 4
Factor analysis of egrets'habitat selection in GNP

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			

Table 5
Rotated component matrix

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

DAI, distance from artificial interference; DOW, distance from open water; GCC, ground cover coverage

Egrets habitat selection in urban wetland

The results (Table 6) showed that there were no significant different between sample and control plots in slope, vegetation coverage, vegetation density, ground coverage degree, while significant different in distance from the artificial interference and distance to open water in HWP. In contrast, there were no significant different in vegetation coverage and vegetation density, but were significant different in slope, distance from the artificial interference, ground coverage degree, and distance to water surface in BWP.

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
HWP	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
	DOW	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
BWP	Slope	0.00 ± 0.00	0.08 ± 0.05	\	\
	DAI	61.33 ± 3.44	38.66 ± 23.78	3.235	0.007
	DOW	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; DOW, distance from the open water; GCC, ground cover coverage.

Comparison of egrets' habitat in Urban and natural wetland

The habitats of egrets in the two urban wetlands are tall trees. Therefore, the habitats of the egrets in HWP and BWP were tested for the significance of the difference in habitat factors only with the SME in GNP. The results are shown in Table 7.

There were significant different in distance from the artificial interference, vegetation cover degree and ground cover degree, while no difference in slope, distance to open water and vegetation density (Table 7) in HWP. In BWP, there were no significant difference in distance from the artificial interference and vegetation cover degree, while extremely significant difference in slope, distance to water surface, ground cover degree and vegetation density. However, the difference on plant factor in HWP is presumed to be the destruction by the egret. As the habitat in BWP is in the water, all the factors except the distance from artificial interference is fixed. Therefore, only the factor distance from artificial interference has reference significance.

Table 7
Comparison of the indexes of egrets'habitat between constructed wetland and GNP

	Indexes	Sample plots	Control plots	T-test	
				T value	*P* value
HWP	Slope	0.14 ± 0.08	0.11 ± 0.11	0.630	0.537
	DAI	70.30 ± 11.51	50.33 ± 4.94	\	\
	DOW	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
BWP	Slope	0.14 ± 0.08	0.00 ± 0.00	\	\
	DAI	70.30 ± 11.51	61.33 ± 3.44	\	\
	DOW	10.00 ± 10.54	0.00 + 0.00	\	\
	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

DAI, distance from artificial interference; DOW, distance from the open water; GCC, ground cover coverage.

The foraging habitat selection

Foraging selection in natural wetland

The foraging preference in natural wetland GNP showed in Table 8. Egret does not choose a certain type of habitat when foraging, they chose farmland, fish ponds, rivers and shoals as foraging sites. Egret would reduce the requirement of artificial interference distance due to the richness of food. They prefer areas with large water surface, a water depth of < 30cm (that is, no more than their lowest tarsal feather), the distance from artificial of > 60m or a coverage degree of > 0.5, the distance from dwelling habitat of < 1000m, and a distance from a river of < 300m.

Table 8
Egrets habitat selection preference in GNP

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, favorite; NP, unfavorite; R, randomly select; AR, almost randomly select; NS, no select.

Egret foraging habitat selection in urban artificial wetland

In the two urban artificial wetlands, there are few types of foraging habitats for egrets to choose, they only choose artificial rivers and artificial shoals for food.

The requirements for water depth in urban wetlands are the same as those mentioned above. The water depth of HWP artificial channel is 18.12 ± 3.83cm, while the depth of the artificial channel in BWP is > 1m, so the observed egrets are standing in the arid area on the river bank for food. For the artificial

interference, the average distance from artificial disturbances is < 50m, except for the shoal area in HWP. However, the value in HWP is not representative, because the area is design to stay away from human interference. The coverage degree of all foraging habitats is almost 0, presumably because the tolerance for artificial disturbances, limited foraging areas and almost all foraging area is exposed to the open area which reduced the egrets' requirement for the degree of coverage. As for the vegetation densities, similar to the egret foraging area in natural wetlands, most of the foraging habitats in urban wetlands are located in watery areas, and their vegetation density is extremely low. (Table 9)

Table 9
Data from sample plots of egrets foraging habitat in HWP and BWP

Habitat type	Water depth(cm)	DAI(m)	DDH(m)	Cover degree	Vegetation coverage
HAC	18.12 ± 3.83	44.87 ± 25.03	323.00 ± 243.12	0.00 ± 0.00	0.00 ± 0.00
Huanhuaxi shoal	8.50 ± 1.51	145.16 ± 15.65	21.33 ± 5.92	0.00 ± 0.00	0.00 ± 0.00
BAC	0.00 ± 0.00	45.00 ± 11.14	313.33 ± 63.90	0.00 ± 0.00	0.30 ± 0.10
Bailuxi shoal	18.44 ± 3.87	47.66 ± 11.14	578.55 ± 668.90	0.04 ± 0.13	0.38 ± 0.16
Average	13.92 ± 7.26	69.00 ± 45.60	340.73 ± 452.70	0.15 ± 0.07	0.19 ± 0.20

HAC, Huanhuaxi Artificial channel; BAC, Bailuxi Artificial channel; DAI, Distance from artificial interference; DDH, Distance from dwelling habitat

Discussion

Egret's large-scale habitat selection

The egrets are preferring to dwelling at a river junction area. However, there is no report on the influence of river junction estuaries on egret habitat selection in river wetland. Our results may explain a certain relation between river junction estuaries and egret habitat selection. There are five river junction estuaries located in the middle and downstream of Gouxi river, among which three were found to be egret habitats. We found that egrets out and return along the direction of the three rivers when they go foraging and return. The river may play a role as a landmark to help them gather and back to the nest. Besides, the water surface of the junction estuary area is larger than the non-junction area. This is consistent with the conclusion that waterfowl prefer to select their dwelling habitats with a large area of open water (Yang et al., 2000; Zhang et al., 2003; Zhang et al., 2005; Yan, 2006; Yan et al., 2007; Wu, 2012; Yan et al., 2014).

Egret's microhabitat selection

Combining all the sample data, it can be found that the factor of slope has a strong correlation with the choice of egret, but there is no evidence to show the causality of the slope and the egret habitat selection. The slope may affect the habitat selection by affecting the smoothness and vegetation coverage of the forest canopy. Combining with the fact that the egret prefers the bamboo forest plate as a habitat, the bamboo forest canopy is smoother and vegetation coverage is higher compared to the cypress-liquidambar plate. However, due to the limit of this investigation, it could not be confirmed by this research.

Suggestions for egret's habitat Construction

For urban wetland parks in Sichuan province construction, the area should be planted coniferous and broad-leaved mixed forests or bamboo forest, which is suitable for egrets nesting and perching. Distance from artificial interference of greater than 90m and less than 20m from water surface would be better. If no other heron needs the niche of the shrubs as a habitat, the configuration of the lower shrubs and ground cover should be as sparse as possible to reduce the damage of the egret feces to the vegetation. Water area with depth less than 0.3m should be expanded, and the distance from artificial interference should be maintained more than 60m. Meanwhile, the design of waterfront should be emphasized, water bays with better shelter should be increased.

Conclusion

Guarding and flushing distances of egret were longer in natural wetland than those in urban constructed wetland, which suggested that egret had better tolerance due to human activity disturbance, and shortened guarding and flushing distances in urban constructed wetland.

The distance factor and the vegetation factor are the two key factors in dwelling habitat selection of the egret. In natural wetlands, egrets tend to dwelling at an area with a slope of < 0.2 (which can be equal to the smoothness of the forest canopy), a vegetation density of about 0.3 (3–4 if it is a patch of bamboo forest), vegetation coverage > 0.5, and distance from the water surface < 40m, distance from artificial disturbance > 60m, forest belt length > 100m, width > 20m. In the urban wetland, the distance from the artificial interference was the most limiting factor for dwelling habitat selection.

For the foraging habitat selection, they prefer areas with large water surface, a water depth of < 30cm (that is, no more than their lowest tarsal feather), the distance from artificial of > 60m or a coverage degree of > 0.5, the distance from dwelling habitat of < 1000m, and a distance from a river of < 300m. In urban wetland, they selected shoals of artificial rivers and lakes as their foraging sites, which reduced requirements for distance from disturbed area and cover degree.

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Conflicts of interest/Competing interests

The authors declare that they have no competing interests.

Ethics approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

LL: Supervision, Conceptualization, Resources, Writing - Review & Editing;

XH: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation and Writing - Original Draft;

WYT: Investigation;

LGY: Investigation, Writing - Review & Editing;

LWD: Resources, Conceptualization;

LN: Writing - Original Draft, Writing - Review & Editing;

All authors read and approved the final manuscript.

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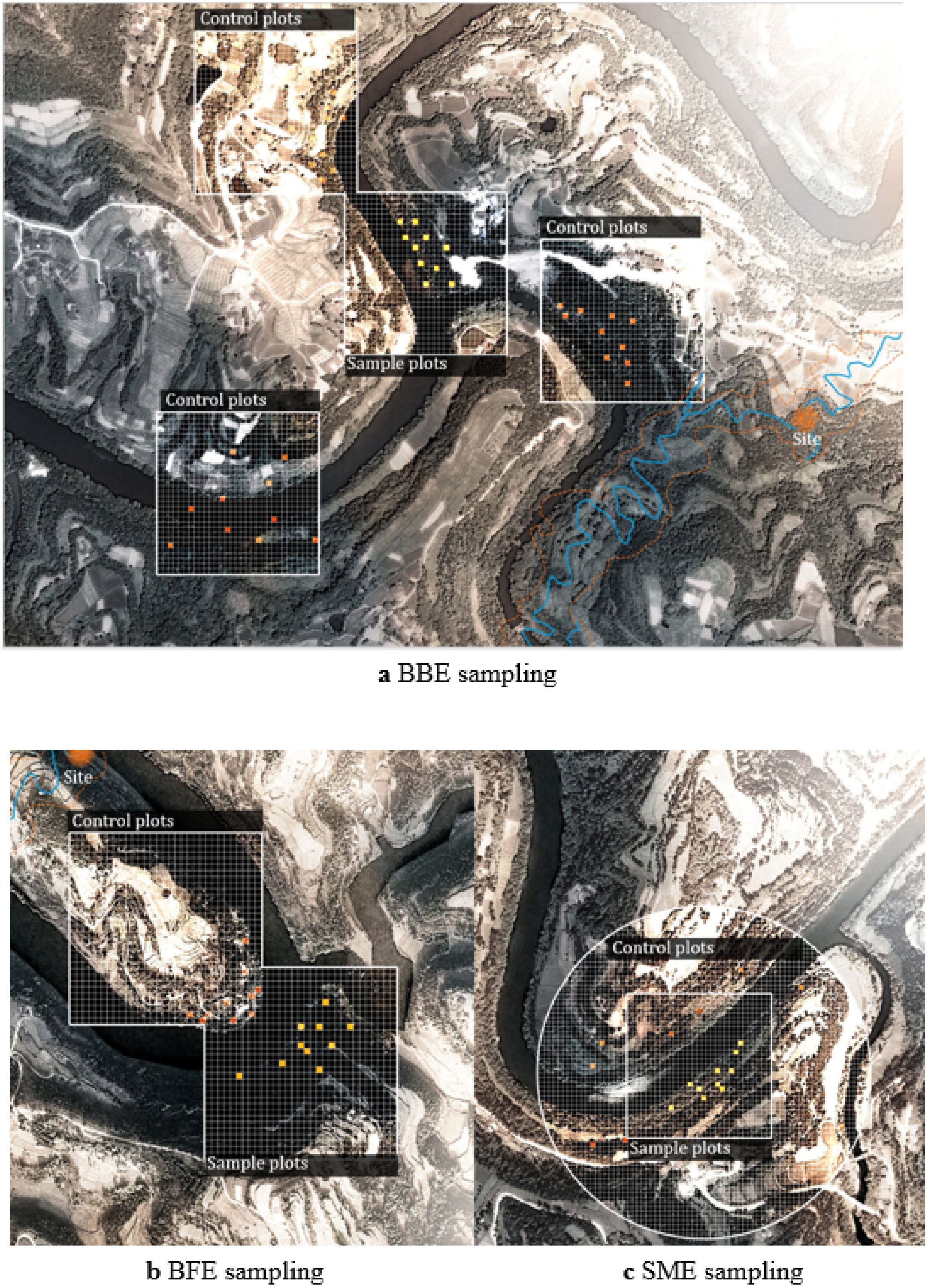
Figures



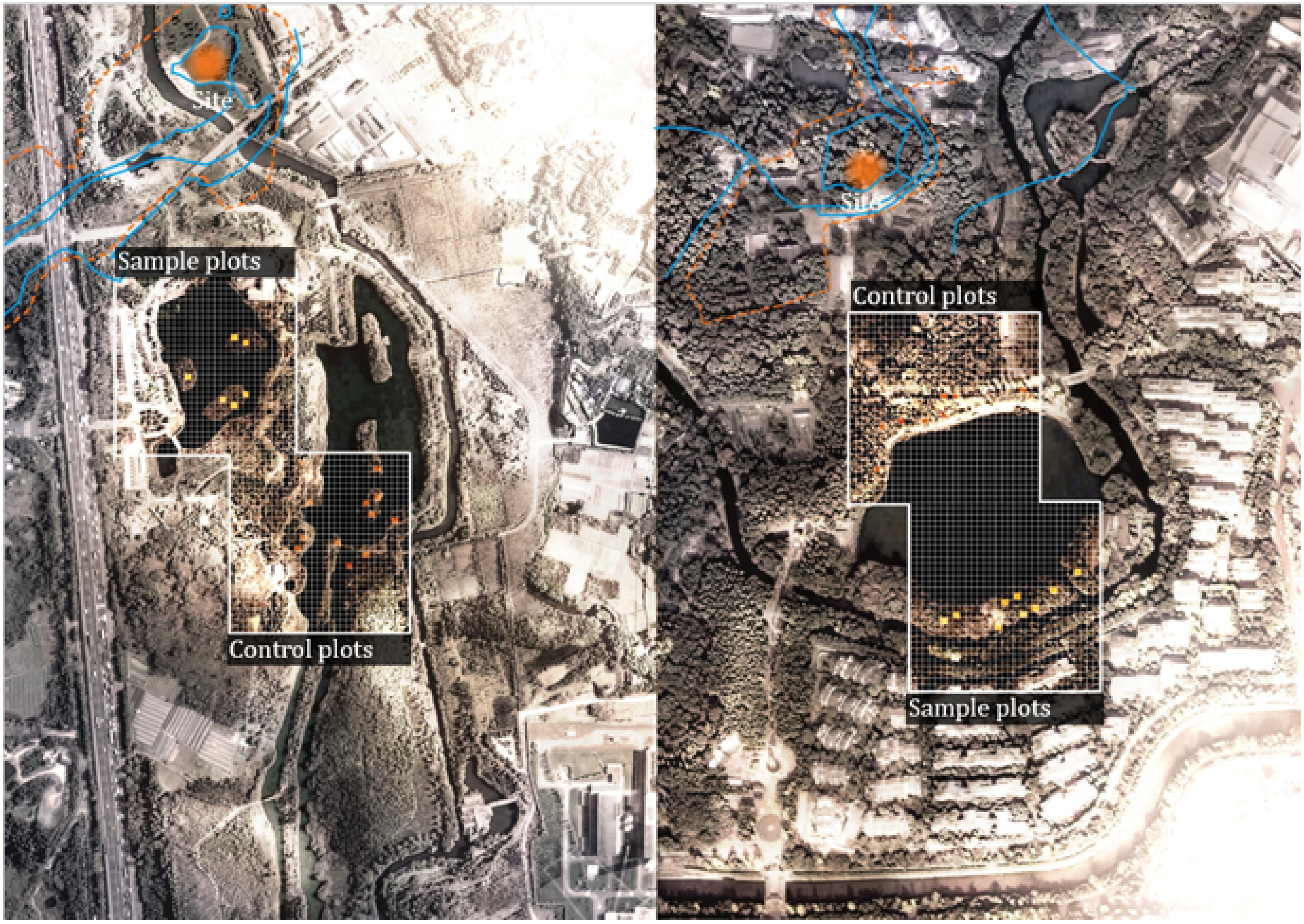
a BBE sampling

b BFE sampling

c SME sampling

Figure 1

Dwelling habitat sampling



a BWP sampling **b** HWP sampling

Figure 2

Foraging sampling