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Population Dynamics and Breeding Space Niche of Four Heron Species in Tanghai Wetlands

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Abstract: The population dynamics and breeding behaviors of Black-crowned Night Herons (*Nycticorax nycticorax*), Egrets (*Egtetta garzetta*), Chinese Pond Herons (*Ardeola bacchus*) and Great Egrets (*Casmerodius albus*) were observed in Tanghai Wetlands, Hebei Province from August 2004 to July 2005. Further, we studied the relationship of nest space distribution and directly calculated the nest density of vertical and horizontal levels, the niche overlapping index and the niche breadth. The results showed that there were two breeding areas, named Area Ⅰ and Area Ⅱ. The maximum population occurred in the period from April to September and was approximately 5800 individuals. Area Ⅰ was occupied earlier than Area Ⅱ by approximately half a month. In the breeding period, Black-crowned Night Herons were dominant in numbers and most occupied the upper nests of the core areas. Great Egrets also took the upper nests but they have the smallest population. Most Egrets took the middle nests of the edges of the area. Chinese Pond Herons, with a smaller population than the Egret, mostly nested in the edges, but some of them also took the lower nests of the core area. On the whole, the vertical niche of Egrets is the widest, the horizontal niche of Black-crowned Night Herons is the widest and the niche breadth of Chinese Pond Herons is the largest. The nest distribution pattern is the most similar between Chinese Pond Herons and Black-crowned Night Herons, and the niche overlapping index of Chinese Pond Herons and Egrets is the largest. Black-crowned Night Herons and Great Egrets control Egrets and Chinese Pond Herons in competition. Rich food and the optimal ecological environments lead to plenty of herons in the wetlands. In addition, it is a distinguishing feature of the four species that nests are built in poplar trees over 22 m tall.

Key words: Tanghai Wetlands; Breeding herons; Population dynamics; Nest areas; Spatial niche

河北唐海湿地四种鹭的种群动态和繁殖空间生态位

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摘要: 2004 年 8 月—2005 年 7 月对河北唐海湿地夜鹭(*Nycticorax nycticorax*)、白鹭(*Egtetta garzetta*)、池鹭(*Ardeola bacchus*)、大白鹭(*Casmerodius albus*)的种群动态和繁殖行为进行了观察, 并对巢群关系进行了研究。统计了 4 种鹭垂直和水平巢位的巢密度, 计算了不同种鹭巢的生态位重叠、生态位宽度值。结果: 4 种鹭在唐海数量最多月份为 4—9 月, 最大量达到了近 5 800 只。共有Ⅰ、Ⅱ两个巢区, 迁来Ⅱ区时间较Ⅰ区晚半个月左右。除池鹭外, 3 种鹭之间均有争巢现象, 后期趋于稳定。迫于密度压力和竞争, 部分白鹭和池鹭取食范围较广。除大白鹭外, 其他 3 种鹭同种间均有混交现象。在混巢区, 夜鹭迁来最早, 数量最大, 为优势种, 多数占据中心区的顶巢; 大白鹭数量最少, 亦占据中心区的顶巢; 白鹭迁来较晚, 占据中位巢; 池鹭迁来最晚, 数量较白鹭少, 多数在边缘区单独筑巢, 少数在中心区占下位巢。白鹭巢的垂直生态位最宽; 夜鹭巢的水平生态位最宽; 池鹭巢的综合空间生态位最宽。池鹭和夜鹭巢位的空间格局最为相似, 池鹭和白鹭的生态位重叠较大。夜鹭的数量最多、大白鹭的个体最大, 导致其处于优势; 白鹭和池鹭数量少、个体小, 导致其处于劣势。唐海湿地内丰富的食物和适宜的林带是鹭鸟密度较大的主要原因。此外, 鹭类只筑巢在散布的、双行杨树林带均高为 22 m 以上区域, 是该地鹭类巢区的主要特点。

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The Ardeidae birds are one of the important families belonging to wetland ecosystems, and are viewed as indicator for environmental assessment (Zhu, 2005). Most of the Ardeidae birds have left for the north, especially the Tanghai Wetlands, with the increase of the greenhouse effect around the world (Wang & Zhang, 2004). Studies on the distribution area of herons have been carried out since the 1980s. Reports about the community structure of northern herons only come from Ningxia (Ren, 1994), Henan (Zhang et al, 1994) and Shandong Province (Yang, 2000). At present, population ecology is a research priority for Ardeidae birds (Zhu, 2005). In light of the excellent ecological conditions of Tanghai Wetlands, we discuss the population dynamics and breeding niches of four heron species, namely Egrets, Great Egrets, Black-crowned Night Herons and Chinese Pond Herons, which are all widespread and dominant in population in China (Zhu, 2005).

The Tanghai Wetlands are located in the southeast of Tangshan City (39°07′43″－39°27′23″N, 118°12′21″－118°43′16″E), and include some parts of the Tanghai County, the south of the Fengnan section in Tangshan and the southwestern coast of the Luannan County. The total area of the Wetlands is 760 km^2. There are nine natural rivers and artificial streams running through approximately 0.063 billion m^3 in the wetlands. It has various tidelands, salty-water swamps, ponds and fresh water reservoirs suitable for some organisms such as fish, shrimps and so on. All these have provided abundant food for birds, especially waterfowls, thus enabling it to be a favorable environmental condition for avian inhabitation and reproduction.

The altitude of the wetlands is approximately 2.7 m above sea level. The climate is warm and moist. The mean annual precipitation is 618.9 mm, mainly falling in July and August and accounting for 64% of the annual total. The mean temperature every year is 11.2 ℃.

In the wetlands, the breeding areas are roughly divided into Area Ⅰ and Area Ⅱ. Area Ⅰ lies in the east, 3 700 m away from the Tanghai County, and takes the shape of a sickle, the length of which is approximately 1 600 m and the width is 50 m. Area Ⅱ is a portion of the northwest, 17 000 m from the Tanghai county, covering from south to north (Fig. 1). On the basis of geographical division, the breeding areas are included in shelter belts. In Area Ⅰ, there are plenty of *Popus davidiana*, *Populusadensis*, *Populus nigral* variants and *Populus tomentosa*, and some *Salix babylonica*, *Robinia pseudoacacia*, *Ulmus pumila*, the height of which is more than 20 m. The vegetation types are considerably complex and include *Salix matsudana* variants, *Datura stramonium*, *Suaeda glauca*, *Suaeda salsa*, *Imperata cylindrical*, *Chenpodium serotinum* and *Plantago asiatica*. Comparatively, Area Ⅱ just consists of poplar trees above 22 m high.

1 Methods

1.1 Data capture

The fledglings left the nests from late August to the last ten days of December 2004. Their behaviors were tracked using $8-24\times50VM$ telescopes near the active sites every day or every second day. As long as herons appeared, their species and numbers were recorded using naked eyes or telescopes. During the breeding period from March to late July 2005, some behaviors such as foraging, hatching and mating were inspected from certain key positions. The total nests of each heron species were counted and the niches of each were noted down during the reproductive plateau.

1.2 Data process

The nest density of different areas was obtained by arithmetical methods. The following exponential formula was used to analyze the niche overlap (Sun, 2001):

$$C_{ih} = 1 - 1/2\sum \left| N_{ij}/N_i - N_{hj}/N_h \right|$$

In which: C_{ih} was the index between i species and h species; N_{ij} represented the numbers of i species in j ecological community; N_i represented the total numbers of i species in the breeding areas; N_{hj} stood for h species members in j ecological community; and N_h for the total of h species.

$\left| N_{ij}/N_i - N_{hj}/N_h \right|$ reflected the difference in resource requirements between two species. C_{ih} ranged from 0－1. Zero indicated non-overlap niches and 1 meant completely overlap.

All indexes were integrated according to the "sum α" equation (Cody, 1974) as follows:

$$\alpha = \alpha_H + \alpha_V/2$$

For calculating the niche breath, we applied the following equation:

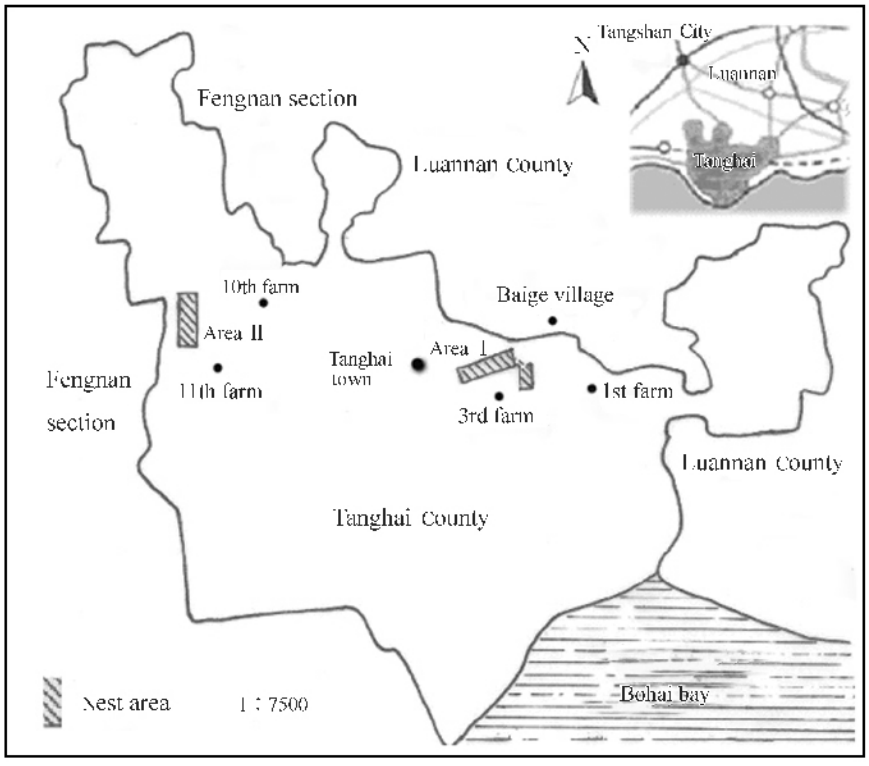

Fig.1　Location of Tanghai Wetlands and the nest areas of four types of heron

$$B_i = [\lg \sum N_{ij} - (1/\sum N_{ij})(\sum N_{ij}\lg N_{ij})]/\lg r$$

in which: B_i was the breadth of i species; N_{ij} represented consumption of i species for j resource; and r fixed the rank value of resources. B_i was any value from 0 to 1, in which 0 meant non-consumption, and 1 meant the same consumption degree for each resource.

2　Results and Analyses

2.1　Population dynamics

The first breeding group of herons originally settled in Area Ⅰ and Area Ⅱ in 1995 and 1996, respectively. Individuals of each group added up to 5 800 on top of the baseline population of 200. Generally, herons appeared in March and April, and migrated in late September and the first ten days of October. The total amounts fluctuated greatly during these periods, but became quite steady in the breeding period from May to August.

Black-crowned Night Herons arrived in the wetlands with the first group on the morning of March 14th and were all adults aged 3 – 4 years (Zhang et al, 2003). After hovering and tweeting for about ten minutes, they began to restore the old nests and drove out some other birds such as the Black-billed Magpie and Common Kestrel. Egrets were the next to move into this area from March 25th on. The next to arrive were Great Egrets with the smallest population. Chinese Pond Herons appeared last with the first group arriving on May 10th, which was moderate in numbers. They rebuilt old nests and at the same time expelled Black-crowned Night Herons. However, to some degree, they were tolerant with Egrets. In the reproductive peak, we counted each heron species. The results showed that there were 4 988 Black-crowned Night Herons, 640 Egrets, 372 Chinese Pond Herons and 56 Great Egrets in total (Tab.1 and Tab. 2).

Area Ⅰ was inhabited significantly earlier by the four heron species compared with Area Ⅱ, but Area Ⅱ was abandoned later. The time difference was about half a month. The four heron species liked inhabiting the old nests and settling in the same nest area every year, which suggested that they maybe come from different wintering areas.

2.2　Breeding behaviors and spatial distribution of niche

2.2.1　Breeding behaviors　Fledglings were fostered in the same nest area all the time. Egrets, Chinese

Tab. 1 The population size of the four heron species in Tanghai Wetlands (nest Area Ⅰ)

Date	Black-crowned Night Heron (*Nycticorax nycticorax*)	Egrets (*Egtetta garzetta*)	Chinese Pond Heron (*Ardeola bacchus*)	Great Egret (*Casmerodius albus*)
14 March	750	0	0	0
21 March	2 254	0	0	0
25 March	2 420	24	0	0
1 April	2 760	58	0	0
15 April	3 424	446	0	6
10 May	3 428	446	124	10
5 June	3 512	462	242	10
July – August	3 512	462	242	10
15 September	2 110	96	84	6
17 October	80	4	14	0
November – February	0	0	0	0

Tab. 2 The population size of the four heron species in Tanghai Wetlands (nest Area Ⅱ)

Date	Black-crowned Night Heron (*Nycticorax nycticorax*)	Egrets (*Egtetta garzetta*)	Chinese Pond Heron (*Ardeola bacchus*)	Great Egret (*Casmerodius albus*)
27 March	560	0	0	0
1April	1 156	0	0	2
7 April	1 244	48	0	12
12 April	1 452	176	0	46
6 May	1 476	178	0	46
2 June	1 476	178	130	46
July – August	1 476	178	130	46
13 September	326	12	16	18
15 October	0	0	8	0
November – February	0	0	0	0

Pond Herons and Great Egrets were more active in paddy fields and ponds during the day, but some Egrets and Chinese Pond Herons also foraged in further areas, even the seaside, because of interspecies competition. Black-crowned Night Herons frequently foraged in ponds from sunset until the next morning, but some breeding pairs also looked for food nearby nest areas in the daytime, especially on cloudy days during the breeding peak. Fighting was particularly common in Egrets but rare in Chinese Pond Herons. In addition, Great Egrets directly attacked Black-crowned Night Herons with their beaks in order to successfully rob nests.

It was a usual occurrence that one female mated different males in all heron species except for Great Egrets. Herons generally laid eggs before setting up their nests. They incubated in turns during the early breeding period, but committed to a particular nest at a later time when the nest structure had reached a balanced state. In the nestling phase, adults bestowed great care on the young offspring. The larger the nestlings were, the shorter parents stayed with them. Meanwhile, food provided by adults was gradually coming from semi-digested fish and shrimps to fish about approximately 8 cm long. On the whole, Great Egrets had the longest incubation period of 25 – 26 days, and Chinese Pond Herons had the shortest of approximately 21 – 22 days.

2.2.2 Nest area dynamics At first, every pair of Black-crowned Night Herons inhabited upper nests in the optimal areas that had enough nests and a low amount of human activity. When the population reached 1/2 of the maximum number, several weak adults and most two-year old individuals were excluded to the fringes, and even to the middle nests when the amounts were 2/3 of the maximum. Egrets mainly inhabited the upper nests in the edges of the nest area because of a smaller population and smaller body size. However some Egrets were capable of possessing the middle nests of the optimal areas with the growth of the population. Great Egrets successfully competed for the upper nests of Black-crowned Night Herons. They were large and strong but less in population. Chinese Pond Herons solely inhabited the upper nests in the edges of the nest area in general because they are the smallest in size, while few of them inhabited the lower nests of the optimal areas. In late September, Great Egrets were the

first to leave breeding areas, and Chinese Pond Herons were the last.

2.2.3 Nest space niche The populations of four heron species were changeable during the early breeding period. Therefore niches were investigated to record accurate information about nest spatial distribution at the peak. According to statistical results, there were altogether 3 435 nests, of which 2 225 were Black-crowned Night Herons, 310 were Egrets, 164 were Chinese Pond Herons and 28 were Great Egrets, omitting the uninhabited nests. The four heron species displayed different preferences in different spatial niches. The niche breadth of each species is shown in Tab. 3.

Black-crowned Night Herons were dominant in numbers, but their vertical niche breadth was lower, comparatively, than that of Egrets, which had the highest niche breadth. Great Egrets had the lowest niche breadth. There was no significant difference in vertical niche breadth between Chinese Pond Herons and Egrets.

From a horizontal standpoint, most herons had particular preference for trunks for their nests. However, Black-crowned Night Herons and Chinese Pond Herons had no significant selectivity for different spaces and their horizontal niche was wide. Egrets primarily occupied the trunk areas, and Great Egrets completely inhabited the solid trunk areas.

Overall, Chinese Pond Herons had the widest vertical and horizontal niche. It demonstrated that Chinese Pond Herons lived in the inferior ecological environments as a result of poor strength, but on the other hand it also proved that they were more adaptive to different living conditions.

2.2.4 Niche relationships among the four heron species' nests The spatial distribution of nests was analyzed using the nest niche overlap (Tab. 4).

The overlap index between Egrets and Chinese Pond Herons was the highest. Conversely, it was lowest between Egrets and Great Egrets.

Tab. 3 The nest density of the four heron species in different layers (per hectare) and their niche breadth

	The density of vertical spatial nests			The density of horizontal spatial nests			Niche breadth
	Upper nest $h \geqslant 18$ m	Middle nest $16 \leqslant h < 18$ m	Lower nest $h < 16$ m	Trunk $d \leqslant 1/3$ r	Near branch $1/3\ r < d < 2/3\ r$	Far branch $d \geqslant 2/3$ r	$B_{iv} + B_{ih}$
Black-crowned Night Heron (*Nycticorax nycticorax*)	127.12	22.35	10.02	63.54	55.20	40.75	0.57 + 0.99
Egret (*Egtetta garzetta*)	7.15	9.91	5.16	13.95	6.69	1.58	0.97 + 0.77
Chinese Pond Heron (*Ardeola bacchus*)	6.53	2.59	2.63	5.17	3.64	2.94	0.91 + 0.97
Great Egret (*Casmerodius albus*)	2.01	0.00	0.00	1.70	0.31	0.00	0.00 + 0.00

r refers to the radius of tree crowns, d refers to diameter and h refers to height.

Tab. 4 The overlap index of the four heron species' nests

Species	Vertical spatial nests	Horizontal spatial nests	Total (α)
Black-crowned Night Heron (*Nycticorax nycticorax*) – Great Egret (*Casmerodius albus*)	0.594	0.550	0.572
Black-crowned Night Heron (*Nycticorax nycticorax*) – Chinese Pond Heron (*Ardeola bacchus*)	0.760	0.958	0.859
Black-crowned Night Heron (*Nycticorax nycticorax*) – Egret (*Egtetta garzetta*)	0.525	0.771	0.648
Egret (*Egtetta garzetta*) – Chinese Pond Heron (*Ardeola bacchus*)	0.766	0.813	0.790
Chinese Pond Heron (*Ardeola bacchus*) – Great Egret (*Casmerodius albus*)	0.557	0.592	0.575
Egret (*Egtetta garzetta*) – Great Egret (*Casmerodius albus*)	0.322	0.779	0.551

3 Discussion

Every year Black-crowned Night Herons appear in Area Ⅰ at almost the same time as those in Ningxia and Henan Province, but they arrive in Area Ⅱ more closely to those in Qufu, Shandong. Chinese Pond Herons settle in the breeding areas half a month and 20 days later than those of Shandong and Zhejiang Province, respectively. This indicates that the reproductive period of Ardeidae birds is correlated with latitude. The higher

the latitude is, the later the reproductive period is. Herons of the wetlands should be further studied as one of the northernmost reproductive groups.

In the wetlands, aquiculture provides adequate food for herons, and coast shelter-belts planted in the 1960s make good habitat for setting up nests. All of these make the population size of the four heron species increase year by year.

Black-crowned Night Herons and Great Egrets are the predominant species, which is in accordance with the conclusion of Custer & Osbom (1997). The nest spatial distribution is regular either in vertical layers or in horizontal layers. The structure of nest areas is quite steady in the breeding peak Black-crowned Night Herons and Chinese Pond Herons primarily inhabit the core regions and the edges, respectively. These results are extremely similar to the results of the Egret Nature Reserve in Xiamen (Wu et al, 2001). Black-crowned Night Herons inhabited the upper nests, which is identical to that of Wu et al (2001) and also to that of Dongzhai in Henan (Zhang et al, 1994), Qufu in Shandong (Yang, 2000). However, the nests of Chinese Pond Herons are beneath Egrets', which is against the results of the Egret Nature Reserve in Xiamen (Wu et al, 2001). In addition, Egrets occupy the trunk areas while Black-crowned Night Herons and Chinese Pond Herons inhabit further branches, which is contrary to the opinion from Taigong Mountain (Zhu et al, 1998). Thus, it is evident that breeding behaviors of herons are significantly different in different districts. The differences not only come from heron preferences but also come from some external factors such as the structure of habitats, vegetation types and plant diversity as well as heron species composition. (Zhu et al, 1998).

Though Black-crowned Night Herons and Chinese Pond Herons inhabited different sites, the nest space model is roughly similar between them.

In the study, the niche overlap index reflects the degree of overlap between two species. It represents the degree of similarity of nest distribution patterns in the two areas. The higher the index, the greater the degree of overlap.

The breeding areas are characterized by sparse forest. Ardeidae birds have to select lofty poplar trees above 20 m high for nest sites. Black-crowned Night Herons successfully nest in trees over 22 m high, especially at the tops. This may suggest that the higher the nest areas are, the safer the nests are. Meanwhile, it is very convenient for them to guard the nests in the open spaces at night. Chinese Pond Herons commonly select diverse trees as nest sites such as poplars, *Ulmus pumila* and *Robinia pseudoacacia*. Egrets mostly live together with the other three species, and are more close to Chinese Pond Herons than Black-crowned Night Herons.

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