雉鸡(*Phasianus colchicus*)营巢生境的模拟分析研究

倪喜军[1,2*]，郑光美[1]，张正旺[1]，刘迺发[3]

(1. 生物多样性与生态工程教育部重点实验室，北京师范大学生命科学学院，北京　100875；2. 中国科学院古脊椎动物与古人类研究所，北京　100044；3. 兰州大学生物学系，兰州　730000)

摘要：将多元统计学方法与地理信息系统结合对动物的栖息地进行适宜性分析，是近年动物栖息地研究者和管理者都十分感兴趣的方面。本研究采用马氏距离法，利用地理信息系统模拟甘肃雉鸡的营巢生境。模拟结果表明，与已知营巢生境相似水平为 0.95 的区域面积，仅占整个研究区的 0.68%，而与已知营巢生境迥然不同($P<0.05$)的区域面积占 79.08%。营巢生境与非营巢生境在生境类型组成和地形因素上存在多方差异，营巢生境中农田和草坡占有极大比例，用于营巢的区域总是更接近生境的边缘。特别是接近于农田、草坡和白桦阔叶林等生境，表明倾向于在这几种生境的边缘附近营巢。营巢生境的平均海拔比非营巢生境低，坡度也较缓，坡向则更偏于东南方。在同一生境类型内部，用于营巢的区域和不利用的区域之间也存在很大差别，营巢区域总是更接近生境的边缘。某一生境周围的其它生境类型也会影响雉鸡的营巢选择。

关键词：栖息地模拟；GIS；雉鸡；栖息地选择

Modelling study on the nesting habitat of ring-necked pheasant (*Phasianus colchicus*)

NI Xi-Jun[1,2*], ZHENG Guang-Mei[1], ZHANG Zheng-Wang[1], Liu Nai-Fa[3]　(1. *Ministry of Education Key Laboratory for Biodiversity Science and Ecological Engineering, College of Life Science, Beijing Normal University, Beijing* 100875; 2. *Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Science, Beijing* 100044; 3. *Department of Biology, Lanzhou University, Lanzhou* 730000)

Abstract: Researchers and managers pay great interest in the combined use of Geographic Information System (GIS) and Multi-variable analysis. In this research, ring-necked pheasants' nesting habitat was modelled based on Mahalanobis distance by using GIS. In 1997 and 1998, fifty-one nests of wild ring-necked pheasants were discovered and orientated in Gansu, China. Distances from nests to 14 habitats' edges, measured by GIS, were used as habitat characteristic variables. Terrain factors of elevation, slope and aspect were calculated basing on digital elevation model. We generated raster layer of every variable, and calculated Mahalanobis distance value for all the grids by using GIS. The result shows that the areas, which are similar to the known used areas at the significance level of 0.95, cover only 0.68% of the whole region. On the other hand, the dissimilar areas ($P<0.05$) occupy 79.08% of the total area. There are many differences of habitat composition and terrain characteristics between nesting areas and non-nesting areas. Farmland and Grass Mountain Slope occupy very large proportion in the nesting habitat. Compared with non-nesting habitat, the nesting habitat is of lower elevation, more gently slope and more southeast-facing aspect. In a special habitat, nesting area and non-nesting area are also of great distinction. The nesting area is usually

Foundation item: This project is supported by National Natural Science Foundation of China (No. 39830030)

* Correspond address: P. O. Box 643, Beijing 100044, China

Received date: 1999-11-14; **Accepted date**: 2000-06-10

Brief introduction of author: NI Xi-Jun (1972～), male, born in Heilogjiang Province, associate professor, PhD., engaged in research of Ornithology and Palaeomammalogy.

near to the edge of the habitat. The types of a special habitat's neighbouring habitats will affect pheasants'selection on some region in the habitat for nesting.

Key words: habitat modelling; GIS; ring-necked pheasant; habitat selection
文章编号: 1000-0933(2001)06-0969-09 **中图分类号**: Q958, Q959.7 **文献标识码**: A

In management and research work of wildlife, it is necessary to deeply understand wildlife's habitat requirement and also to accurately assess suitable habitat availability for animals. In recent years, multi-variable analysis has been widely used in the study of wildlife habitat selection. The methods are useful for researchers to find out the key factors that affect animals'distribution[1~4]. Geographic Information System (GIS) came to be used in 1960s, and is being used more wildly along with the rigorous development of the technique of computer soft-and hard-ware. GIS has now become an important tool in wildlife research and management work[5]. The combined use of GIS and multi-variable analysis, to do wildlife habitat suitability analysis, has been paid great attentions by researcher. That is an improtant development in the research area of wildlife ecology[6~11].

In China, it is still on a beginning stage to use GIS in wildlife research and management work.

Ring-necked pheasant (*Phasianus colchicus*) is a species of Galliforms, which is most widely distributed and has the largest survival range. Ring-necked pheasant has been introduced to almost 50 countries and becomes an important species of game birds[12]. Numerous research works on the introduced pheasants have been done, but very few study on the native pheasants have been carried out in China[4,12]. In this research, ring-necked pheasant's nesting habitat was modelled based on Mahalanobis distance in GIS.

1 Study area and methods

Study area locates in Xinglong Mountain National Nature Reserve in Gansu Province China. The nature reserve lies on N35°38″~35°58″, E103°50″~104°10″, where is on the northeast edge of Tibet. The reserve is 37 km long in east-west direction and 17 km wide in south-north direction. The total area is about 33.30 km². Forest ecosystem is the main protection object.

The reserve lies in the semi-high mountains region of inner continent. The climate is significantly affected by continental monsoon.

Based on the Basic Resource Survey of the Xinglong Mountain National Nature Reserve and according to the vegetation characteristics and land use pattern of the study area, the habitat was classed into 14 types. The following is description:

(1) Mixed Forest (MF) *Picea wilsonii*, *Betula platyphylla* and *Populus davidiana* are the main tree species. *Betula albo* and *Picea crassifolia* can be found sometimes. *P. wilsonii* is the dominant species. Mixed forest mainly distributed on the north or northwest slope of the mountain. The vegetation of mixed forest is dense, shaded, cold and moist.

(2) White Birch Broad-leaved Forest (WBBF) *Betula platyphylla* is absolutely the dominant species. The species usually form pure forest, but sometimes grows with *Populus davidiana* and *Quereus liaotungensis*. It usually distributed on the north or northwest slope of the mountain, and is the main forest type in the study area. Bush layer and grass layer are not very lush

(3) David Poplar Broad-leaved Forest (DPBF) *Populus davidianais* is main colonization species. Small patches of *Quereus liaotungensis* and *Betula platyphylla* are usually inlaid in this type forest. It distributes relatively wider and usually occupies the region of high elevation.

(4) Oak-birch Dense Shrubbery (ODS) It is the dense shrubbery of secondary growth after the destruction of original broad-leaved forest. The vegetation if low, but very dense. Main shrubbery species include young growing *Betula platyphylla*, *Populus davidiana* and *Quereus liaotungensis*, *Cotonester* sp., *Crataegus kansuensis*, *Hippophae rhamnoides*, etc..

(5)David Poplar-Cotoneaster Shrubbery (DPCS)　This type vegetation mainly covers the south slope of the mountain. Badly growing *Populus davidiana* forms the sub-arborous layer, and sometimes with companion species of *Querеus liaotungensis* and *Betula platyphylla*. Shrubbery layer grows relative well, including *Cotoneaster* sp., *Rosa hugonis*, *Hippophae rhamnoides*, *etc.*.

(6)Seabuckthorn-Cotoneaster Shrubbery(SCS)　Distributes on the dry south slope of the mountain. *Hippophae rhamnoides* is the dominant species, and usually mixed with *Cotoneaster* sp., *Rosa xanthina*. Shrubbery layer is usually sparse, but in some patches is very dense.

(7)Grass Mountain Slope(GMS)　Main species include *Stipa* sp., *Artemisia* sp., *Saussurea* sp., *Thymus mongolicus etc.*. This type vegetation mainly distributes on the dry south slope of the mountain.

(8)Young Growth of Chinese Pines in Valley(YCPV)　It is well growing artificial *Pinus tabulaeformis* young forest. Main companion shrubbery species include *Hippophae rhamnoides*, *Rosa xanthina*, *Cotoneaster* sp. *etc.*.

(9)Young Growth of Chinese Pines on Mountain Slope(YCPM)　It is artificial *Pinus tabulaefornis* young forest growing on dry mountain slope. The forest's growth state is very bad. Main companion shrubbery species include*Hippophae rhamnoides*, *Rosa xanthina*, *Cotoneater* sp., *ect.*

(10) Young Growth of Larches(YL)　It is well growth artificial young growth of *Laix principisrupprechtii*. The species forms pure forest. The ground is usually covered by pine needles in the forest. Grass cover is very sparse.

(11)Farmland (Fa)　Distributed on the lower region where adjoins the reserve. Wheat is main crop, and rape, flax are also planted in some places. In the winter, the ground of farmland is bare, and usually covered by snows on the north-facing slope.

(12) Nursery(Nu)　Used to cultivate saplings of *Picea wilsonii* and *Larix principisrupprechtii*. Vegetation is very low.

(13) Willow Shrubbery on Riversides(WSR)　Distributes on the rivulet sides in the valley. The main tree species are *Salix cathayana* and *S. heterochroma*. *Cotoneaster* sp., *Hippophae rhamnoides* can be found occasionally.

(14)Resident(Re)　Includes village, isolated house and threshing floor.

During mid-April to July, many local villagers work in farmland and also many villagers go into reserve to pick fern sprouts(*Pteridium quilinum*), a kind of delicious edible wild herbs, to sell. Pheasant nests were found by villagers during the period. More than 50 villagers went to pick fern sprouts every day. Fern grew in all kinds of nature vegetations. The pickers usually went to check every kind of vegetation to get more ferns, despite of ferns harvest in various vegetations was different. It was very difficult to find pheasants'nests. They were usually found by chance. So the nests found by villagers could approximately represent the distribution of nesting sites in various types vegetations. After a nest was found, researchers went to the place with the finder, and marked the nest site on a 1 : 50 000 topographic map. Habitat characters were also measured at the same time. Villagers who helped collect pheasant nests had a very stable fern-sprouts picking area. In this research, study area was selected according to the villagers fern-sprouts picking area and field working area.

To analysis ring-necked pheasants'nesting habitat characteristics, seventeen variables were selected and 51 nesting records found in 1997 and 1998 were taken as samples, the 17 variables represent 2 kinds of factors: terrain factors and habitat factors. The terrain factors include elevation, slope and aspect. We digitized 1 : 50 000 topographic map of the study area, and conversed it to IDRISI(GIS software)raster layers. Each raster layer contains 1200×1200 grids, and each grid represents a horizontal projection area of 5m×5m. By forming a digital elevation model of the study area in IDRISI, we got the elevation value of each grid. Then we could calculate the values of slope and aspect of each grid. The habitat factors include 14 variables. Each variable represents the distance from nest site to the edge of one type habitat. We gave the following definition; if a nest was in one type habitat, the value of distance to the habitat was negative; if a nest was out of one type habitat, the value of distance to the habitat was positive. Hill and Robertson[12] revealed that the distance to woodland edge would significantly affcet pheasant's habitat selection. In this research, "distances to various habitat edges" were selected as variables to reflect pheasant's selectivity to various habitat types.

Every nest site record was regarded as a sampling case, and normality test (K-s test, SPSS) for every variable was performed. Some variables indicated non-normality ($P<0.05$), so it was necessary to do transformations. First, we used the equality of $Var'=\ln(Var+A)$ to do transformation. In the equality, Var' was the transformed variable, Var was the untransformed variable, and A was constant. For the variables of the distances to Mixed Forest and David Poplar Broad-leaved Forest, $A=2000$; for the variable of distance to Grass Mountain Slope, $A=200$; for the others, $A=1000$. The second step was to do centralization transformation by using the equality of $X'_{ij}=(X_{ij}-\overline{X}_i)/S_i$, $(i=1,\cdots,17; j=1,\cdots,51)$. Normality test indicated all transformed variables had normality.

We modelled the pheasant's nesting habitat basing on the Mahalanobis distance[9]. The calculation formula of Mahalanobis distance is:

$$d = (X - \overline{X}) \cdot S^{-1} \cdot (X - \overline{X})$$

where X was a vector of 17 dimension (17 variables), $\overline{X}$ was a mean vector of 17 dimension estimated from the set of 51 samples (51 nest sites); S was the estimated covariance matrix calculated from the set of 51 samples; S^{-1} was inverse matrix for S. Mahalanobis distance can be used to measure the dissimilar degree of two vectors.

Assuming multivariate normality, Mahalanobis distance approximately distributes as Chi-square with $n-1$ degree of freedom, where n equals the number of habitat character. [9]

We produced Layers for all the variables and used IDRISI to calculate Mahalanobis distance values. A map layer that containing a Mahalanobis distance value in each grid was produced. Each grid in the Mahalanobis distance layer indicated the degree of dissimilarity between the site of the grid and the set of the samples (nest sites). Check Chi-square distribution table, and show P-values associating with the Mahalanobis distance.

According to the result of ring-necked pheasant's nesting habitat modelling based on Mahalanobis distance, the areas containing P-values greater than 0.95 were regarded as nesting habitat, and the areas containing P-values less than 0.05 were ragarded as non-nesting habitat. Compared the differences of habitat composition, terrain characteistics and distances to various types habitats between nesting habitat and non-nesting habitat. Mean and standard deviation values of the two groups were calculated based on the values of the grids in IDRISI. Because the sample size was very large, we could regard that X_1-X_2 distributed as normality[13]. H_0: $\mu_1=\mu_2$, stochastic value $\mu=(X_1-X_2)/S_{X_1-X_2}$ would distribute as standard normality, where $S_{X_1-X_2}=(S_1/n_1+S_2/n_2)^{1/2}$.

2 Results

2.1 Nesting Habitat Modelling

The result of modelling based on Mahalanobis distance is shown in Plate Ⅰ. The map shows the P-value of difference between the grids in study area and the mean characteristics (calculated from 51 nest records) of ring-necked pheasant's nesting sites. The smaller P-value, the greater difference to nesting sites; and the greater P-value, the greater similarity. In Plate Ⅰ, twelve colors indicate 12 significant levels.

The area of the regions similar with known nesting sites is very small. The accumulated area percentage of the region with similarity degree above 0.95 is 0.68%; the accumulated area percentage of the region with similarity degree above 0.5 is 6.47%. On the contrary, the area of the region dissimilar with the known nesting sites is very large. The region with similarity degree below 0. 05 accumulatedly occupies an area percentage of 79. 08% of the total area(Fig. 1).

2.2 Characteristics of Nesting Habitat and Non-nesting Habitat

Comparing ring-necked pheasant's nesting habitat with non-nesting habitat, we can find that the nesting habitat contains only 6 habitat types. Among the 6 habitat types, Farmland occupies 74. 01% of the area of nesting habitat and Grass Mountain Slope occupies 18. 08%, both of the proportions are much higher than in the whole study area. The other 4 habitat types, White Birch Broad-leaved Forest, David Poplar Broad-leaeved Forest, Seabuckthorn-Cotoneaster Shrubbery and Young Growth of Chinese Pines in Valley, take an total area percentage less than 10%(Table 1). The proportions of all the 4 habitats types in nesting habitat are less than the proportions in the whole study area.

Table 1 Habitat composition of nesting area, unused area and the whole research area(%)

Habitat type	Nesting habitat 1. 56 km²	Non-nesting habitat 18. 07km²	Whole research area 22. 85km²
MF	0	9. 95	8. 69
WBBF	4. 24	21. 55	17. 18
DPBF	2. 26	16. 48	16. 94
ODS	0	2. 89	1. 58
DPCS	0	7. 73	8. 44
SCS	1. 40	8. 78	8. 80
GMS	18. 08	4. 94	4. 90
YCPV	0. 01	0. 94	0. 77
YCPM	0	2. 39	1. 58
YL	0	1. 13	1. 08
Fa	74. 01	17. 36	22. 25
Nu	0	0. 64	0. 68
WSR	0	1. 95	1. 77
Re	0	3. 71	5. 33

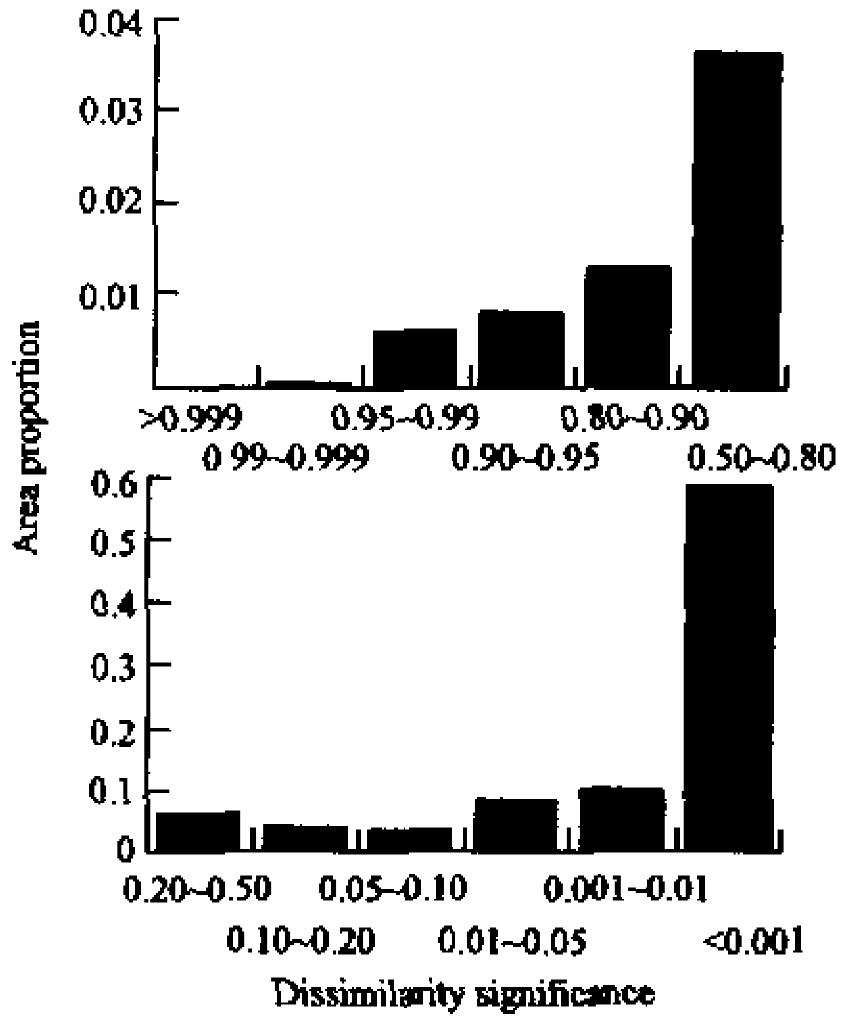

Fig. 1 Area proportion of available area of various dissimilarity significance

Because the non-nesting habitat has a very large area, which account for 79. 08% of total area, the habitat composition of the non-nesting habitat is very similar with the whole study area. But in non-nesting habitat, White Birch Broad-leaved Forest takes the greatest area percentage of 21. 55%. The value is much higher than in the whole study area. In addition, Oak-Birch Dense Shrubbery and Young Growth of Chinese Pines on Mountain Slope also have much higher percentages than in the whole study area. The percentage of farmland in non-nesting habitat is high, reaching 17. 36%, but the value is much less than the proportion of 22. 25% in the whole study area.

The study also reveals that the distances from ring-necked pheasant's nesting habitat to edges of various habitat types are much shorter than the distances from non-nesting habitat. It indicates that ring-necked pheasant tends to nest near habitat edges. The distance from nesting habitat to White Birch Broad-leaved forest, Grass Mountain Slope, Farmland and Resident are all less than 500m(115. 4~328. 4m), that shows ring-necked pheasant more prefers to nest in or near these habitats. But still there are some habitats (Mixed forest, David poplar broad-leaved forest and Willow shurbbery on riversides), to which the distances from nesting habitat are longer than from non-nesting habitat(Table. 2). By analyzing the terrain factors, and compared with non-nesting habitat, the nesting habitat is of lower elevation, gentler slope and more southeast-facing aspect (Table 2).

2.3 Difference Between Nesting Area and Non-nesting Area in Special Habitat

Some habitat types in nesting habitat can also be found in non-nesting habitat, especially Farmland that takes a great proportion not only in nesting habitat, but also in non-nesting habitat. As a result, it is necessary to do additional analysis for the habitat types appearing in nesting habitat.

Table 2 Differences of distance to habitat edges and terrain factors between nesting habitat and non-nesting habitat

Distance to habitat edges	Nesting habitat $N=5767^*$		Non-nesting habitat $N=619568^*$		U value	Significance
	Mean	S. D.	Mean	S. D.		
MF	1978.3	489.8	1320.1	1291.1	98.9118	$P<0.001$
WBBF	175.3	167.1	444.2	531.4	−116.8085	$P<0.001$
DPBF	1076.9	266.9	828.2	1002.6	66.5283	$P<0.001$
ODS	1188.3	700.6	2147.1	1279.5	−102.3423	$P<0.001$
DPCS	744.7	276.5	835.0	774.9	−23.9458	$P<0.001$
SCS	716.4	414.3	817.1	681.9	−18.2259	$P<0.001$
GMS	205.4	303.4	776.2	616.6	−140.1853	$P<0.001$
YCPV	840.1	522.6	1880.0	1211.2	−147.4740	$P<0.001$
YCPM	668.3	457.9	1994.8	1321.7	−211.9231	$P<0.001$
YL	783.9	468.6	1922.1	1257.0	−178.5711	$P<0.001$
Fa	115.4	658.8	1765.3	1814.0	−183.8209	$P<0.001$
Nu	956.9	566.7	2321.4	1542.4	−176.8573	$P<0.001$
WSR	1648.5	384.6	1235.8	1112.7	78.4939	$P<0.001$
Re	328.4	285.0	1116.8	1111.4	−196.6247	$P<0.001$
Elevation(m)	2360.9	75.5	2479.8	243.5	−114.1726	$P<0.001$
Slope(degr.)	21.4	5.7	26.3	13.7	−63.3882	$P<0.001$
Aspect(degr.)	145.7	107.1	157.1	116.6	−8.0546	$P<0.001$

* Number of raster, size of each raster's projection on horizontal surface is 5m×5m.

Compare the difference of distances to the habitat edges from nesting area and from non-nesting area in White Birch Broad-leaved Foreat, David Poplar Broad-leaved Forest, Seabuckthorn-Cotoneaster Shrubbery, Grass Mountain Slope and Farmland. The results are shown in Table 3. It can be revealed that the nesting areas are always nearer to the habitat edges than non-nesting areas in each type habitat, especially in White Birch Broad-leaved Forest and Farmland. In the 2 types habitats, the distances from nesting areas to the habitats edges are much shorter than from non-nesting area.

Table 3 Comparison on the distance(m) to habitat edges between nesting area and non-nesting area in special habitats

Habitat Type	Nesting area			Non-nesting area			U value	Significance
	N	Mean	S. D.	N	Mean	S. D.		
WBBF	446	14.4	9.1	108064	83.2	59.9	146.6425	$P<0.001$
DPBF	221	82.9	21.3	91528	91.3	75.5	5.7587	$P<0.001$
SCS	136	61.8	30.7	50662	76.1	57.6	5.4002	$P<0.001$
GMS	1367	27.4	17.6	22464	44.5	32.0	32.7794	$P<0.001$
Fa	3596	95.0	53.7	139348	190.0	156.3	96.1436	$P<0.001$

In the 5 types habitats mentioned above, distances to other types habitats edges from nesting areas and non-nesting areas are also significantly different (Fig. 2). In White Birch Broad-leaved Forest, distances from nesting areas to Mixed forest, David Poplar Broad-leaved Forest, David Poplar-Cotoneaster Shrubbery and Willow Shrubbery on riversides are much farther than from non-nesting areas ($P<0.001$), while distances from nesting areas to the other habitats are significantly shorter ($P<0.001$). The distances from nesting areas to Grass Mountain Slope, Farmland, Resident and Seabuckthorn-Cotoneaster Shrubbery are less than 500m (28.0～427.2m). It means that these habitats may greatly affect ring-necked pheasant's selection of nesting areas in White Birch Broad-leaved Forest. In David Poplar Broad-leave Forest, the distances from nesting areas to most of other habitats are greater than from non-nesting area ($P < 0.001$). But the distances to Mixed Forest, David Poplar-cotoneaster Shrubbery, Seabuckthorn-Cotoneaster Shrubbery and Willow Shrubbery on Riversides are shorter($P < 0.001$), and are all less than 500m (91.8 ~437.7m). The situations in Seabuckthorn-Cotoneaster Shrubbery and Grass Mountain Slope are similar with in White Birch Broad-leaved Forest. The distances from nesting areas to most of other habitats are less than from non-nesting areas ($P < 0.001$). In seabuckthorn-Cotoneaster Shrubbery, the distances from nesting areas to most of other habitats are less than 500m (62.8~435.8m). But in Grass Mountain Slope, only the distances to White Birch Broad-leaved Forest, Farmland and resident are less than 500m (37.7~442.8m). In farmland, the distances from nesting areas to all the other habitats are significantly shorter than from non-nesting areas($P < 0.001$), and the distances to White Birch Broad-leaved Forest, Grass Mountain Slope and Resident are less than 500m (185.9~245.6m).

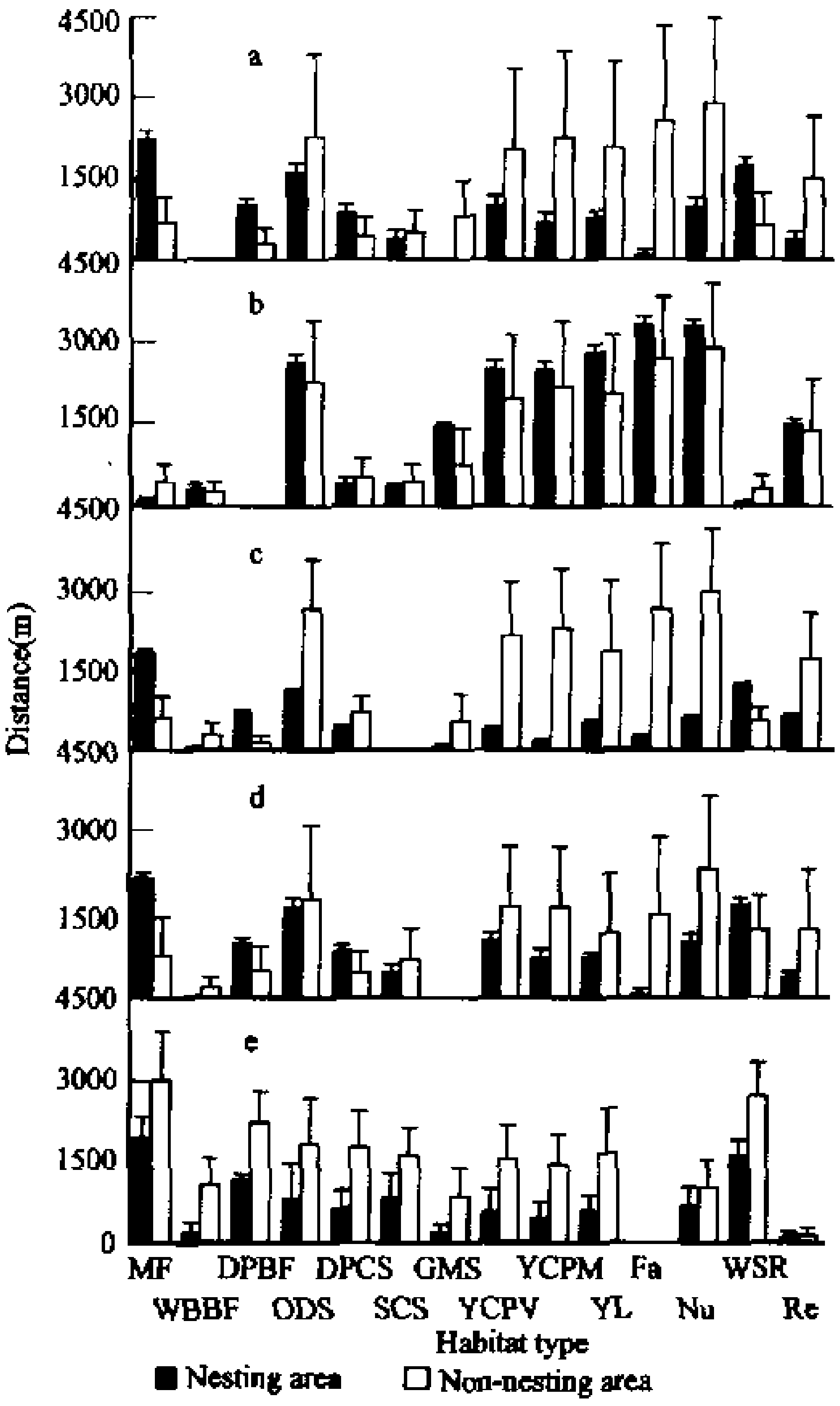

Fig. 2　Comparisons of distance from nesting areas and non-nesting areas in special habitats to various types neighbouring habitat edges
a, b, c, d, e, are habitat types WBBF, DPBF, SCS, GMS, Fa respectively; All the differences are below the statistical significance level of 0.001.

There are great differences of terrain characters between nesting areas and non-nesting areas in all used habitats (Table 4). In White Birch Broad-leaved Forest, David Poplar Broad-leaved Forest, Seabuckthorn-cotoneaster Shrubbery and Grass Mountain Slope, Comparing with non-nesting areas, the nesting areas have characteristics of lower elevation, more gentle slope and more east-facing or north-facing aspect. The situation in farmland are exactly in contrast, comparing with non-nesting areas, the elevation in nesting areas is significantly higher, slope is greater and aspect is more south-facing.

3　Discussion

Modelling or assessing wildlife habitat status by using GIS has been paid great interests by researchers and managers in recent years. It is the relatively early representative work that Donovan *et al.*[6] established habitat suitability model based on GIS. They combined the standard habitat suitability index, proposed by U. S. Fish and Wildlife Service, with Michigan Resoure Information System, and produced a habitat suitability index model based on GIS. Pearce *et al.*[10] and Akcakaya *et al.*[11] used logistic regression to study the habitat selection of *Lichenostomus melanops cassidix*, and conducted population viability analysis by combining habitat data and population data in GIS. Aspinall and Veith[8] produced habitat mapping from wildlife survey data and satellite imagery in GIS. Basded on an analytical Bayesian probability method implemented with GIS, they studied the habitat suitability for *Numenius arquata* in a part of the Grampian Region, United Kingdom. Clark *et al.*[9] firstly combined Mahalanobis distance method with spatial analysis in GIS, and calculated the habitat using probability of female *Ursus americanus*. The presented study not only modelled the nesting habitat of ring-necked pheasant based on Mahalanobis distance method in GIS, but also committed detailed post-modelling analysis to depict the nesting habitat characteristics of the species. It could be a good example for researchers to predict wildlife's suitable habitat or commit habitat selection study. We suggest that the method could be widely used in the habitat selection study and habitat protection of endangered wildlife.

Table 4 Difference of terrain factors between nesting area and non-nesting area in special habitats

Habitat type	Terrain-Factors	Nesting area			Non-nesting area			U value	Significance
		N	Mean	S. D.	N	Mean	S. D.		
WBBF	Elevation	446	2422.0	42.9	108064	2627.4	193.8	−97.1020	$P<0.001$
	Slope	446	23.3	3.1	108064	33.0	9.2	65.7631	$P<0.001$
	Aspect	446	39.7	28.8	108064	175.9	134.2	−95.6143	$P<0.001$
DPBF	Elevation	221	2561.4	19.2	91528	2579.1	144.5	−12.8101	$P<0.001$
	Slope	221	31.1	2.4	91528	35.4	9.4	−26.3870	$P<0.001$
	Aspect	221	144.9	40.0	91528	163.1	97.4	−6.7185	$P<0.001$
SCS	Elevation	136	2520.1	13.6	50662	2674.2	134.3	−117.4543	$P<0.001$
	Slope	136	31.6	3.5	50662	31.5	9.3	0.4699	$P<0.001$
	Aspect	136	115.5	20.7	50662	159.1	54.6	−24.3004	$P<0.001$
GMS	Elevation	1367	2410.7	36.7	22464	2580.9	158.1	−117.5763	$P<0.001$
	Slope	1367	24.6	4.0	22464	29.1	9.4	−35.6390	$P<0.001$
	Aspect	1367	84.5	15.9	22464	146.0	77.3	−91.4904	$P<0.001$
Fa	Elevation	3596	2316.1	38.6	139348	2197.6	75.0	175.5291	$P<0.001$
	Slope	3596	19.0	4.9	139348	12.8	9.2	72.9262	$P<0.001$
	Aspect	3596	183.2	117.6	139348	132.6	123.5	25.4427	$P<0.001$

Comparing with other multi-variable analysis ,it has many advantages to establish wildlife habitat usage model basing on Mahalanobis distance analysis[9]. Many statistic methods, widely used in wildlife habitat study, need prior determination of used samples and unused samples. For limit of observation manner and observation time, it is often not easy to detect unused areas accurately. That may result in researcher's mis-conclusions. The basic idea of habitat modelling basing on Mahalanobis distance is to calculate the dissimilarity degree between an unknown site and a set of known used sites, and the method do not need prior detection of unused samples or contrast samples. If the assumption of multivariate normality is met, Mahalanobis distance approximately distribute as Chi-square ,and Mahalanobis distance values can be rescaled to P-values. If the assumption of multi-variate normality is not met, Mahalanobis distance values can also be recoded to (0,1)probability scale by using other alternations[9].

According to the P-value rescaled from Mahalanobis distance valuse, habitats can be classified into used habitats and unused habitats. In this research, we take the areas with P-value above 0.95 as nesting areas and the areas with P-value less than 0.05 as non-nesting area. The aim of this kind of classification is to take further steps to analyze animal's habitat selection. In order to make the result of habital selection analysis more accurate, it is necessary to use a relative restrict statistic criterions. This kind of classification does not mean that nesting pheasants will absolutely not use the areas with P-value less than 0.95.

When do multi-variable analysis, habitat types factors are the most frequently selected variables. But habitat type variable can usually take binary value, 0 or 1, indicating belonging or not belonging some habitat. To get variables meeting multi-variate normality distribution, we must select variables that can indirectly represent the character of habitat types. In this research, we selected variables of "distances to various types habitats edges" to reflect the habitat types factors indirectly. The nearer animals acting sites to some habitat, the greater the influence of the habitat on the site. If the distance to some habitat is negative, it means that animals move about mainly within the habitat.

To take further steps to compare ring-necked pheasant's nesting habitats with non-nesting habitats, we can find not only the great difference of habitat composition, but also the significant difference of distances to habitat edges, elevation, slope and aspect. The areas used by nesting pheasants are always close to habitat edges, especially to the edges of Farmland, Grass Mountain Slope and White Birch Broad-leaved Forest. It indicates that ring-necked pheasants tend to nest in the vicinity of the edges of these habitats. From the aspect of terrain character, it can be found that ring-necked pheasants tend to select the areas of lower elevation, more gentle slope and more south-east facing aspect. But in special habitat, the situation may be different. In Farmland, the areas used by nesting ring-necked pheasants are of higher elevation, greater degree of slope, but the areas are much nearer the forest edges. "Near to the forest edges" becomes the main factor that affects ring-necked pheasant's nesting habitat selection in Farmland.

The factors affecting ring-necked pheasant's nesting habitat selection are of many ways. There are great differences between the used and the unused areas even in the same type habitat. Nesting areas are always near to the habitat edges. In a special habitat, the types of neighbouring habitats will also determine if the nesting pheasants will select some areas in the habitat. Ring-necked pheasant's nesting habitat selection is affected not only by the type of the selected habitat, but also by the types of neighbouring habitats. In various habitats, the affecting degree of neighbouring habitats is different.

Many previous researches have revealed that pheasants tend to nest in special habitats. For example, nesting females selected winter wheat field in North America high plain farmland landscape[14], while pheasants in UK preferred to nest in wookland in April and May[12]. Little attentions, however, have been paid to the influences of neighbouring habitats on pheasants' nesting habitat selection. This research suggests that the "edge effect" may be an important factor affecting birds' habitat selection. In habitat selection study, researchers should pay more attentions to the effect of "habitat complex", which is composed of many habitat types.

Reference

[1] Robertson P A, Woodburn M I A and Hill D A. Factors affecting winter pheasant density in British wooklands. *J. Appl. Ecol.*, 1993a, **30**: 459～464.

[2] Robertson P A, Woodburn M I A, Neutel W, *et al.* Effects of land use on breeding pheasant density. *J. Appl. Ecol.*, 1993b, **30**: 465～477.

[3] Zhang Zhengwang, Liang Wei and Sheng Gang. Studies on the nest site selection of Daurian Partridge. *Zoological Research*, 1994, **15**(4): 37～43(in Chinese).

[4] Ni Xijun and Zhang Zhengwang. Studies on habitat selection of ring-necked pheasant in winter and early spring. In: *Studies on Chinese Ornithology*. Beijing: China Forestry Publishing House. 1996, 246～252(in Chinese).

[5] Ni Xijun. The use of geographic information system for wildlife research. *Bulletin of Biology*, 1998, **33**(9): 3～6(in Chinese).

[6] Donovan M L, Rabe D L and Olson C E Jr. Use of Geographic Information Systems to develop habitat Suitability models. *Wildlife Society Bulletin*, 1987, **15**(4): 574～579.

[7] Fabricius C and Coetzee K. Geographic information systems and artificial intelligence for predicting the presence or absence of mountain feed buck. *South African Journal of Wildlife Research*, 1992, **22**(3): 80～86.

[8] Aspinall R and Veith N. Habitat mapping from satellite imagery and wildlife survey date using a Bayesian modeling procedure in a GIS. *Photogrammetric Engineering* & *Remoto Sensing*, 1993, **59**(4): 537～543.

[9] Clark J D, Dunn J E and Smith K G. A multivariate model of female black bear habitat use for a Geographic Information System. *J. Wildl. Manage.*, 1993, **57**(3): 519～526.

[10] Pearce J L, Burgman M A and Franklin D C. Habitat selection by helmeted honeyeaters. *Wildl. Res.*, 1994, **21**: 53～63.

[11] Akcakaya H R, Mclarthy M A and Pearce J L. Linking landscape date with population viability analysis: management options for the Helmeted Honeyeter *Lichenostomus melanops cassidix*. *Biological Conservation*, 1995, **73**(2): 169～176.

[12] Hill D A and Robertson P A. *The Pheasant: Ecology, Management and Conversation*. London: BSP Professional Books, Publ. Collins. 1988, 1～240.

[13] Liu Laifu and Cheng Shuxiao. *Biological Statistic*. Beijing: Beijing Nornal University Press. 1988, 196～199(in Chinese).

[14] Snyder W D. Ring-necked pheasant nesting ecology and wheat farming on the high plains. *J. Wildl. Manage.*, 1984, **48**(3): 878～888.