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利用天然树洞繁殖的五种鸟的巢位特征及繁殖成功率

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摘要：对吉林省左家自然保护区次生阔叶林中的大山雀（*Parus major*）、沼泽山雀（*Parus palustris*）、普通　（*Sitta europacea*）、白眉姬　（*Ficedula zanthopygia*）和灰椋鸟（*Sturnus cineraceus*）5 种利用天然树洞繁殖的次级洞巢鸟进行了巢位选择和繁殖成功率研究。本研究中共发现 141 巢。五种鸟对树洞类型的选择存在种间差异，普通　不利用裂洞，沼泽山雀不利用啄洞，其它 3 种鸟对 3 种洞均有利用，但有一定的倾向性。对 5 种鸟 9 个巢位变量的比较中，只有洞口方向差异不显著（$p>0.05$），其它 8 个变量均差异显著（$p<0.05$），该结果说明 5 种次级洞巢鸟对巢位的选择具有其各自的需求。洞口横径、洞口纵径、洞处树直径、洞内径、巢距地高是巢位选择重要变量，它们决定不同种类对树洞的利用。巢损失多数出现在产卵之前和孵化阶段，44 个繁殖失败的巢中有 35 个在这两个阶段损失。大山雀的巢成功率最低，灰椋鸟的巢成功率最高。5 种鸟的孵化率都超过 90%。人为破坏和动物捕食是繁殖失败的主要原因，占总数的 61.4%。洞巢鸟巢位选择中的重要变量影响繁殖成功。普通　繁殖是否成功受洞口横径和巢高影响，沼泽山雀受洞口纵径、树胸径和洞内径影响，大山雀受洞口横径、巢高和洞内径影响，灰椋鸟受洞内径和洞深影响，白眉姬　受洞口纵径、巢高和洞口夹角影响。失败巢的洞口横径多大于成功巢的洞口横径，失败巢的洞深、洞内径小于成功巢的洞深、洞内径，成功巢的巢高高于失败巢的巢高。靠近地面的巢较容易损失，38 个繁殖失败巢中有 21 个巢高低于 2.5m，只有 2 个高于 4.5m。

关键词：巢位特征；繁殖成功率；次级洞巢鸟；巢位选择

Nest-site characteristics and reproductive success of five species of birds breeding in natural cavities

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Abstract: This study documents the nest-site characteristics and reproductive success of Ashy Starling (*Sturnus cineraceus*), Tricolor Flycatcher (*Ficedula zanthopygia*), Great Tit (*Parus major*), Marsh Tit (*Parus palustris*) and Nutchatch (*Sitta europaea*) breeding in natural cavities in the secondary forest of the natural protective area of Zuojia, Jilin Province in China. We found 141 active nests of five species of secondary cavity-nesting birds (SCNBs) at the study site during the breeding season in 1996. There exist significant differences between the five species of SCNBs in selecting cavity types. Nine nest-site variables were tested to see if they varied significantly among the 5 species. The results showed that only the

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compass orientations of nest entrance are not significant ($p>0.05$). But all the remaining eight variables are significant ($p<0.05$). The results indicate that the 5 species of SCNBs select nest-sites with their own nesting requirements. The horizontal diameter and vertical diameter of nest entrance, diameter of tree at cavity height, inner breadth of the cavity and the nest height above ground are important variables in nest-site selection and are predictive of species occupancy. Most of the nests that failed occur before the laying and hatching stage, as 35 out of 44 failed nests loss during these two stages. The nest success of Great Tit is the lowest and Ashy Starling is the highest. Hatching success among the five species of SCNBs' are at high level, all exceeding 90%. Depredation (included by man and animals) is the main cause for nest failure, accounting for 61.4% of total failure nests. SCNBs' reproductive success is influenced by important variables in nest-site selection. Reproductive success of Nutchatch is influenced by *HDE* and *NH*, Marsh Tit by *VDE*, *DBH* and *BC*, Great Tit by *HDE*, *NH* and *BC*, Ashy Staring by *BC* and *DC*, and Tricolor Flycatcher by *VDE*, *NH* and *CA*. The horizontal and vertical diameter of nest entrance of failed nests are bigger than those of successful nests, and the depth of the cavity and breadth of the cavity of failure nests are smaller than those of successful nests. Distances from ground level of successful nests are higher than those of failure nests. The nests close to the ground are more easier to lose, 21 out of 37 failure nests were under 2.5 m above ground level, and only 2 nests above 4.5 m from ground were lost.

Key words: nest-site characteristic; reproductive success; secondary cavity-nesting birds; nest-site selection.

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Nest-site selection is an important component of habitat selection by birds[1,2]. Nest-site selected by a species should represent the cumulative effects of evolutionary pressures that have maximized reproductive success[3].

SCNBs are birds that can not excavate cavity by themselves, and use natural cavities formed by decay or, more commonly, excavated by primary cavity nesters such as woodpeckers. They are an important component of many avian communities[4]. Characteristics of cavity nest-sites are important determinants of occupation by secondary cavity-nesting birds. Microhabitat variables influence nest-site use[5]. Van Balen *et al.*[6] showed that several characters, including cavity height and volume, and entrance diameter, determined cavity use by European Starings (*Sturnus vulgaris*), Great Tits (*Parus major*), and Blue Tits (*Parus caerileus*) in northern Europe. Nest-site characteristics also influence reproductive parameters of secondary cavity-nesters, and as a result, may be the important criteria in female mate choice for these birds[7].

Although considerable effort has been expended to study the nest-site selection and reproductive success within secondary cavity-nesting birds communities, little research has been devoted to the analysis of nest-site selection and reproductive success at the community level. Furthermore, many studies were done by using nest boxes, and not in natural cavities. At present, there is little information on the study of secondary cavity-nesting birds in our country.

There are seven species of SCNBs in our study area, but Broad-billed Roller (*Eurystomus orientalis*) use old nest of Pie to nest, only one nest of Hoopoe (*Upupa epops*) was found and it was built in a big hole on the root of a tree, so we selected Ashy Starling (*Sturnus cineraceus*), Tricolor Flycatcher (*Ficedula zanthopygia*), Great Tit (*Parus major*), Marsh Tit (*Parus palustris*) and Nutchatch (*Sitta europaea*) as study objects. The Great Tit, Marsh Tit and Nutchatch are resident birds, while the Ashy Starling and Tricolor Flycatcher are migration birds in our study area.

The objectives of our study are to describe the nest-site characteristics, reproductive success of the five species of SCNBs, and the relationship between the nest-site characteristics and reproductive success.

1 Study area and methods

1.1 Study area

This study was conducted in the secondary forest of the natural protective area of Zuojia, Jilin Province (126°00′～126°09′E, 44°1′～44°06′N). The elevation ranges from 200 m to 530 m. This area is the hill region of Chang-bai mountains transferring to plain. The forest in the area is secondary growth deciduous woods, the tree species dominated by *Quercus mongolica*, *Tilia mandshuria*, *Betula davurica*, *Salix pierrotii*, *Fraxinus mandshurica*, *Sophara faponica*, *Populus davidiana* and *Ulmus japonica*. The average age of trees ranges from 40 to 50 years old . The average height of trees ranges from 12.17 m to 16.2 m. The average height of the crown of trees ranges from 4.4 m to 7.5 m. The average diameter of trees ranges from 13.7 cm to 28.5 cm.

1.2 Study methods

A plot of 77 hm^2 was selected in our study area in 1996. Cavities were located by intensive search for all suitable trees in March before breeding season. We climbed trees by using spurs and looked into the cavity with a mirror and light. Each cavity was marked with flagging plastic tape. We inspected each cavity at 1～2 day intervals from beginning of April to the end of July to determine if it was being used. Cavity used was determined by the presence and physical condition of the nesting materials or cavities with eggs. We recorded the bird species that used cavities. A cavity was labeled as unused if no eggs or fresh nesting materials had been detected by the end of July.

Measurements were made near the end of July after the young had fledged from the nests or failed. The following cavity variables were recorded for each cavity used: diameter of tree at breast height (*DBH*), diameter of tree at cavity height (*DNH*), nest height above ground (*NH*), compass orientation of nest entrance (*COE*), horizontal diameter of nest entrance (*HDE*) and vertical diameter of nest entrance (*VDE*), the depth of the cavity (*DC*) (from the bottom edge of the entrance to the floor), the inner breadth of the cavity (*BC*) (from the inside edge of the entrance to the rear wall), cavity angle (*CA*) (the angles of entrances directed below the horizontal were defined negative and above the horizontal were defined positive). Cavity type were classified according to principal mode of origin: (1) abandoned woodpecker cavity (old excavated cavity), (2) cavity that caused by natural wood decay or other reasons, we divided this kind of cavity into two types: knot cavity and splitting cavity.

We collected the following reproductive data: clutch size, hatching success (the percentage of eggs laid that hatched), nestling survival (the percentage of eggs hatched that fledged), fledgling success (the product of hatching success and nestling survival), nest success (the percentage of nests that fledged at least one young).

All data were analyzed using SPSS. Before statistical calculating was performed, the data were check for normality. Variables that were not normally distributed were transformed by log ($x+1$) to allow the use of parametric statistics (Sokal and Rohlf 1969). We performed a one-way analysis of variance (ANOVA) on each nest-site variable to test for differences among species. The difference in nest dimensions of successful nests and failed nests were tested by t-tests. The discriminant function analysis (DFA) was performed to select characteristic variables in nest-site selection. A significance level of 0.05 was used for all statistical tests. Unless otherwise indicated, all results are reported as means ± standard deviation. A few cavities were used by two species at different times during the breeding season. In such cases, we included that cavity's measurements twice (once for each species) in the analysis.

2 Results

2.1 Cavity type

We found 141 active nests of five SCNBs in the study plot during the breeding season in 1996. Seventeen nests were used two times among those nests. There exist significant differences among the five species of SCNBs in selecting cavity types (Table 1). Nutchatch uses old excavated cavities and a few kont cavities, but does not use splitting cavities; Marsh Tit does not use old excavated cavities; other three kinds of birds use all the three types of cavities in varying degrees. Overall, Nutchatch, Ashy Staring and Tricolor Flycatcher prefer to use excavated cavities; Marsh Tit and Great Tit prefer to use knot cavities.

Table 1 Cavities used by five SCNBs

Cavity types	Nutchatch	Marsh Tit	Great Tit	Ashy Starling	Tricolor Flycatcher	Used two times	Total
Knot cavities	4	10	13	5	7	2	39
Splitting cavities	0	4	5	3	2	1	14
Excavated cavities	40	0	10	22+3*	13	14	88

* Ashy starling occupied Great Spotted woodpecker's new cavities

2.2 Nest-site characteristics

Nine variables were tested using ANOVA to see if they varied significantly among the 5 species. The results (Table 2) showed that only the compass orientations of nest entrance are not significant ($p>0.05$), and the other eight variables are significant ($p<0.05$). The results indicate that the five species of SCNBs select nest-sites with their own nesting requirements.

The Ashy Starlings tend to select the largest cavities to nest, the variables of *HDE*, *VDE*, *DBH*, *DNH*, *BC* and *DC* they select are the largest. Marsh Tits prefer to occupy cavities with small *HDE*, *VDE*, *DBH*, and *BNH* and the *CA* are above horizontal. Tricolor Flycatchers tend to select cavities with small *BC* and *DC*, but the *NH* is the largest one. Nutchhatches, Great Tits and Ashy Starlings select the cavity angles that are below horizontal.

Table 2 Results of One-Way Analysis of variables[c] for 9 characterized nest-sites of five species of SCNBs

	Nutchatch Mean sd.	Marsh Tit Mean sd.	Great Tit Mean sd.	Ashy Starling Mean sd.	Tricolor Flycatcher Mean sd.	F values	P
*HDE**	4.65±0.97	3.85±2.01[a]	5.42±6.21	7.06±3.23[b]	5.62±2.03	3.276	0.013
VDE	4.35±0.92	2.62±1.23[a]	2.95±0.98	5.25±0.96[b]	4.31±0.85	31.089	0.000
DBH	24.80±5.28	21.70±6.76[a]	27.72±7.12	28.18±6.15[b]	23.41±5.16	4.764	0.001
DNH	25.31±4.73	24.70±8.31[a]	25.98±6.54	28.77±5.56[b]	24.78±4.62	2.545	0.042
NH	302.9±156.9	268.9±112.8	180.7±83.6[a]	336.1±123.1	359.6±152.7[b]	7.545	0.000
BC	12.25±3.65	10.46±4.15	11.73±4.58	14.02±3.59[b]	9.16±1.86[a]	6.396	0.000
DC	17.97±5.01	15.21±4.25	17.29±5.90	24.94±8.93[b]	9.95±3.53[a]	21.044	0.000
COE	151.8±103.8	150.4±63.1[a]	188.0±82.4[b]	170.3±112.3	155.2±89.8	0.575	0.555
CA	−8.55±18.77[a]	5.36±21.6[b]	−6.89±12.09	−4.21±21.11	2.91±9.11	2.824	0.027

* *HDE*, horizontal diameter of nest entrance; *VDE*, vertical diameter of nest entrance; *DBH*, diameter of tree at breast height; *DNH*, diameter of tree at cavity height; *NH*, nest height above ground; *BC*, inner breadth of the cavity; *DC*, depth of the cavity; *COE*, compass orientation of nest entrance; *CA*, cavity angle a: the smallest value of each variable; b: the largest value of each variable; c: *HDE*、*VDE*、*DBH*、*DNH*、*NH*、*BC*、*DC* are reported in cm, compass orientation of nest entrance (*COE*) and *CA* are reported in degree

The discriminant function analysis (DFA) was performed to select characteristic variables in nest-site selection. (results found in Table 3). Four discriminant functions were extracted from the DFA, all of them are significant (x^2 test, $P<0.05$). The four discriminant functions accounted for 100% of the total discriminating power of the model. Correlation coefficients were used to assess the importance of the original variables on canonical axis as suggested by Williamsn[8]. DF1 is most highly correlated with *VDE* and to a lesser extent with *BC*; DF2 is characterized by *BC*; DF3 is influenced by *DNH* and *NH*; DF4 is a measure of *HDE*. Those characteristics determine species occupancy.

Table 3 Summary of discriminant function analysis performed on nest-site characteristics of five species of SCNBs

Variables	Canonical discriminant function coefficients			
	1	2	3	4
*HDE**	−0.008	0.113	−0.140	0.697
VDE	0.813	−0.361	−0.297	−0.270
DBH	0.028	0.207	−0.231	0.297
DNH	0.136	0.081	0.727	0.100
NH	0.176	−0.383	0.090	0.322
BC	0.051	0.244	0.729	−0.086
DC	0.412	0.568	0.203	−0.014
COE	−0.103	0.156	−0.111	0.248
CA	−0.061	−0.302	0.275	0.563
Canonical correlation	0.731	0.539	0.360	0.302
Eigenvalue	1.149	0.409	0.149	0.101
% variance explained	63.5	22.7	8.2	5.6
Chi-square(x^2)	178.56	76.84	31.20	12.74
Significance	0.000	0.000	0.005	0.047

* See table 2

2.3 Reproductive success

Twenty of the 141 active nests in our study area were destroyed by forest cutting management, and were not included in analyzing reproductive success (Table 4). The average clutch size of Great Tits is the largest (9.33±2.39, $n=12$). Most of these nest failures occur before the laying and hatching stage, 35 out of 44 failed nests loss during the two stages. The five species of SCNBs' hatching success are at high level, all exceeding 90%. Great Tits has a high rate of eggs loss before hatching (51 out of 163), but hatching success and fledgling success of it are the highest, it is 98.2% and 89.3% respectively. Nutchatches' nestling survival is the lowest and Tricolor Flycatchers' is the highest. The nest success of Great Tits is the lowest, and the nest success of Ashy Starling is the highest (78.8%).

2.4 The relationships between nest-site characteristics and reproductive success

We analyzed the reasons for failed nests (Table 5). Depredation (included by man and animals) accounts for 61.4%, and is the main reason that causes nest failure. There were 7 nests destroyed by a gale, it was a suddenness. In addition, competition for nest-sites caused 6 nests to fail.

Table 4 The reproductive success of five species of SCNBs

	Nutchatch $n=27$	Ashy starling $n=33$	Marsh Tit $n=14$	Great Tit $n=25$	Tricolor flycatcher $n=22$
	Mean Sd. n	Mean Sd. N	Mean Sd. n	Mean Sd. n	Mean Sd. n
Average clutch size	[a]6.13 1.03 24 [b]6.43 0.60 21	6.13 1.20 31 6.25 1.17 28	6.92 1.31 12 7.18 0.98 11	8.58 2.71 19 9.33 2.39 12	6.00 1.33 18 6.36 0.74 14
Average number of nestlings	[a]5.46 2.21 24 [b]6.24 0.70 21	5.39 2.25 31 5.96 1.43 28	6.08 2.27 12 6.64 1.29 11	5.79 4.87 19 9.17 2.25 12	4.61 2.75 18 5.93 1.212 14
Hatching success	[a]89.1 (131/147) [b]97.0 (131/135)	87.9 (167/190) 95.4 (167/175)	88.0 (73/83) 92.4 (73/79)	67.5 (110/163) 98.2 (110/112)	76.9 (83/108) 93.3 (83/89)
Average number of fledglings	[a] 4.71 2.85 24 [b] 5.38 2.36 21	4.87 2.49 31 5.40 1.99 28	5.33 2.74 12 5.82 2.27 11	5.26 4.93 19 8.33 3.45 12	4.28 2.93 18 5.50 1.99 14
Nestling survival	86.3 (113/131)	90.4 (151/167)	87.7 (64/73)	90.9 (100/110)	92.8 (77/83)
Fledgling success	[a]76.9 (113/147) [b] 83.7 (113/135)	79.5 (151/190) 86.3 (151/175)	77.1 (64/83) 81.0 (64/79)	61.4 (100/163) 89.3 (100/112)	71.3 (77/108) 86.5 (77/89)
Nest success	[c]66.7 (18/27)	78.8 (26/33)	64.4 (9/14)	44.0 (11/25)	59.1 (13/22)

a: The nests that failed before laying were not included; b: Only the nests that hatched successfully were included; c: The nests that fledged at least one young were included

T-test was used to portray the characteristics of nest-sites that influence reproductive success (Table 6). Reproductive success of Nutchatch influences by *HDE* and *NH*, Marsh Tit by *VDE*, *DBH* and *BC*, Great Tit by *HDE*, *NH* and *BC*, Ashy Staring by *BC* and *DC*, and Tricolor Flycatcher by *VDE*, *NH* and

CA.

The *NH* of successful nests is higher than that of failure nest, except Marsh Tit. We divided the *NH* of failure nests into four classes, but the failure nests caused by gale were not included (Fig. 1). The nests closer to the ground are more easily to suffer loss, 21 out of 37 failure nests lost under 2.5 m. Only 2 nests above 4.5 m were lost.

Table 5 The implication of failed nests

	Destroyed by man	Preyed on by animals	Nest-site competition	Destroyed by wind	Uncertain reasons
Nutchatch	5	1	1	2	0
Ashy starling	3	1	0	3	0
Marsh Tit	0	2	1	0	2
Great Tit	2	6	4	1	1
Tricolor Flycatcher	2	5	0	1	1
Total	12	15	6	7	4
%	27.3	34.1	13.6	15.9	9.1

3 Discussion

3.1 Cavity types

Cavity formation is strongly associated with wood decay. Nearly all of the non-excavated cavities we found appeared to have developed through natural decay. Indeed, the most common form of decay is when fungi invade a tree's heartwood, through wounds left by dead limbs[9,10]. 37.6% of 141 SCNB nests found throughout our study area were located in non-excavated cavities. Excavated cavities are also associated with wood decay because woodpeckers prefer to excavate cavities in areas of the tree where the wood has been softened by decay[11~13]. There exists significant difference for the five SCNBs in selecting cavity types. Nutchatch, Ashy Staring and Tricolor Flycatcher prefer to use excavated cavities; Marsh Tit and Great Tit prefer to use knot cavities. Individuals may select different types of cavities to avoid eviction by a larger species or predation. Nutchatch change their nest entrance diameter with mud to protect their nests.

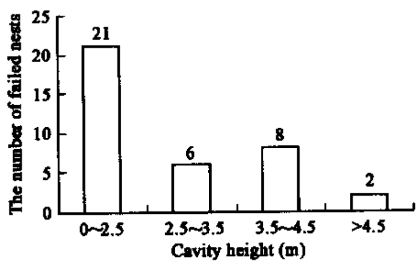

Fig. 1 The relationship between nest height and nest loss

3.2 Nest-site characteristics

SCNBs select cavities depending upon a particular species' nesting requirements. Eight out of nine variables in our study differ significantly ($p<0.05$) among the five species of SCNBs. The results indicate that the 5 species of SCNBs selected nest-sites with their own nesting requirements. This may be determined by their body size and evolution progress. We found that the horizontal diameter of nest entrance, vertical diameter of nest entrance, diameter of tree at cavity height, inner breadth of cavity and the nest height above ground are important variables in nest-site selection, they determine species occupancy. Entrance size certainly limits cavity use by a particular species as there is a minimum size of cavity that an individual can pass through. Individuals may select the smallest cavity possible to avoid eviction by a large species or predation[14,15]. Barbara[15] found that the volume of the cavity is more important than entrance size in determining species occupancy.

There is little agreement among studies of cavity-nesting birds concerning the importance of cavity-

Table 6 The nest-site characteristics of successful nests and failure nests

Species	Item	*HDE*[a]	*VDE*	*DBH*	*DNH*	*NH*	*BC*	*DC*	*COE*	*CA*
Nutchatch	SN[b] $n=18$	4.52±1.01	4.33±1.23	23.87±5.43	25.37±5.07	321.7±170.4	12.56±3.37	18.42±6.29	136.4±98.6	−10.28±11.67
	FN $n=9$	5.36±0.98	4.52±0.86	25.53±4.65	23.84±4.16	208.9±67.1	11.92±2.43	17.14±4.08	200.7±106.5	−4.29±15.14
	T value	−2.107	−0.743	−0.910	0.439	2.334	−0.349	−0.374	−1.768	−0.880
	Sig.	0.044*	0.463	0.370	0.664	0.026*	0.730	0.711	0.087	0.368
Marsh Tit	SN $n=9$	4.33±2.28	2.11±0.53	18.58±5.85	22.11±9.26	241.1±86.6	8.83±2.65	17.33±3.04	150.6±50.0	2.56±19.33
	FN $n=5$	2.98±1.67	3.54±1.66	27.32±4.32	29.36±3.25	319.0±146.6	13.40±5.03	11.40±3.44	150.0±89.2	11.0±18.6
	T value	1.227	−2.439	−2.099	−1.668	−1.267	−2.262	3.347	0.015	−0.794
	Sig.	0.243	0.031*	0.013*	0.121	0.229	0.043*	0.06	0.988	0.443
Great Tit	SN $n=11$	4.29±0.95	2.87±0.68	29.44±7.68	26.14±7.95	214.5±72.1	12.36±4.06	20.36±2.91	177.3±71.2	−5.36±10.78
	FN $n=14$	6.77±3.70	2.99±0.88	26.60±6.73	25.89±5.72	153.2±55.3	11.32±4.97	15.23±4.44	194.7±90.4	−7.88±13.09
	T value	2.656	−0.389	1.033	0.098	2.554	0.579	3.381	−0.525	0.531
	Sig.	0.013*	0.701	0.311	0.922	0.017*	0.567	0.002*	0.604	0.600
Ashy Staring	SN $n=26$	7.48±3.60	5.31±1.04	29.09±6.03	29.30±5.37	337.3±115.2	14.75±3.81	26.67±9.46	173.3±104.8	−4.00±22.85
	FN $n=7$	5.94±1.59	5.11±0.74	25.76±6.13	27.35±5.36	332.8±149.9	12.06±1.91	20.56±5.75	162.2±137.0	−4.78±16.78
	T value	1.225	0.530	1.405	0.927	0.092	2.679	2.246	0.249	0.107
	Sig.	0.230	0.600	0.170	0.361	0.927	0.012*	0.034*	0.805	0.916
Tricolor Flycatcher	SN $n=13$	5.41±2.43	4.04±0.80	23.84±5.07	25.16±4.68	411.9±153.3	9.00±1.78	9.62±3.36	169.6±103.9	0.23±5.45
	FN $n=9$	5.94±1.33	4.72±0.71	22.79±5.53	24.24±4.75	295.0±95.7	9.39±2.06	10.44±3.91	134.4±64.4	6.78±8.36
	T value	−0.601	−2.101	0.459	0.902	2.200	−0.473	−0.533	0.899	−2.231
	Sig.	0.555	0.049*	0.065	0.657	0.04*	0.641	0.600	0.379	0.037*

a: See table 2; b: SN: Successful nests; Failure nests orientations. Several studies found significant directional orientation for cavity entrances[16~20], which has been interpreted as microclimaticaly beneficial. Other studies failed to find significant differences from randomly distributed orientations[21]. Compass orientati-ons of nest entrance in our study do not differ significantly ($p > 0.05$) among the five species SCNBs. They select few cavities in the orientations from northwest 315° to 360° and southwest 180° to 225°(Fig. 2), which may have been done to the fact that there are more chances to get sunlight in other directions except northwest 315° to 360° and the rainwater are easier to enter from orientations southwest 180° to 225° than other orientations in our study area. By selecting compass orientations of nest entrance parents can reduce the energy expend in maintaining the inner temperature of cavity and sealing the cavity entrance with their body when it rains or blows. We also compared the cavity angles, and results showed that Nutchhatchs, Great Tit and Ashy Starling select the cavity angles below horizontal. Birds may choose nest-sites primarily on the basis of limb (trunk) angle, and nest-entrance orientation may be only an indirect consequence of the limb angle[21].

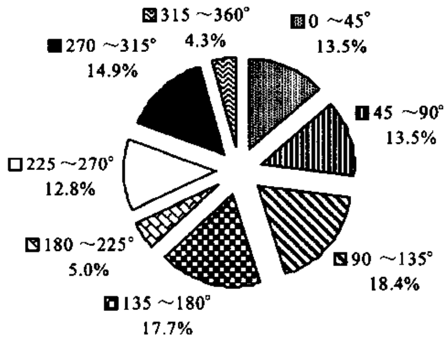

Fig. 2 The distribution of used cavity orientations

3.3 The relationships between nest-site characteristics and reproductive success Cavity-nesting is advantageous because cavities protect the brooding female and the offspring from weather and predators[22~24]. But we found the nest success in our study is not high (Table 4). We analyzed the reasons of failed nests (Table 5), indicating depredation (included by man and animals) accounts for 61.4%, is the main reason that caused nest failure. Several studies also found predation is commonly the greatest cause of nesting mortality among birds, for both open and cavity-nesting species alike[25,26]. Nest-site characters influence reproductive parameters of secondary cavity-nesters[7,15]. Several nest-site characteristics influence nest success of SCNBs respectively in our study, such as *HDE*, *VDE*, *NH*, *DC* and *BC*, and most of those variables are important variables in nest-site selection of SCNBs (Table 3). Most *HDE* and *VDE* of failure nests are bigger than successful nests, this may be because that small *HDE* and *VDE* are more effective than big ones in defending predators and competitors. The *DC* and *BC* are cavity volume variables, which of failure nests are smaller than those of successful nests', the results are consistent to other studies[23,14]. We think that the *DC* was related to losses owing to depredation. The *NH* of successful nests is higher than that of failure nests', it is clear that nesting closer to the ground greatly increases the likelihood of nest loss through depredation (included by man and animals). We divided the *NH* of failure nests into four classes, 21 out of 37 failure nests loss under 2.5 m. In addition, competition for nest-sites caused 6 nests failed, three cavities occupied by *Eutamis sibiricus* and three by other birds, this partly due to the cavity resource that is limited in our study plot.

Most of the nests that failed occurred before laying and hatching stages, 35 out of 44 failed nests lost during the two stages, the leaves above nests are smaller during the two stages than those behind the two stages, nests can be found easily by man and animals, so we think that the canopy above nests is the main reason that causes the nests failure before laying and hatching, but we did not go deeping into this question.

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