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Nest-Site Characteristics of the Brown-Eared Pheasant *Crossoptilon mantchuricum* in Huanglong Mountains, Shaanxi Province, China

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Authors' Contribution
HL, XL and ZL conceived the study. RW and YW executed the study. HL, YF and DW analyzed the data and wrote the manuscript.

Key words
Brown-eared pheasants, *Crossoptilon mantchuricum*, Huanglong mountains, Logistic regression, Nest-sites.

ABSTRACT

Nest-site characteristics are essential for the survival rate of avian nests. We monitored nesting attempts of the "Vulnerable" brown-eared pheasant (*Crossoptilon mantchuricum*) to compare microhabitat characteristics of successful and unsuccessful nests in the Huanglongshan Nature Reserve, Huanglong County, Shaanxi Province, China, from 2006 to 2014 except for 2008. Forty (62.5%) of the 64 nests that we monitored were successful. Successful nest sites had greater tree cover, increased cover and density of shrubs, and more low-lying shrub cover (1.0 m in height) than unsuccessful nest-sites. Forward elimination stepwise logistic regression was worked out with the above significantly different variables and their first-order interaction as independent variables. Finally, regression equation with the lower Akaike's Information Criterion for small sample sizes (AICc) value was regarded as the optimal model. The model indicated that nest-site success of brown-eared pheasants was negatively related to cover of shrubs, and first-order interaction between cover of trees and cover of shrub at a height of 1.0 m, suggesting bigger cover of shrubs, cover of trees and cover of shrub at height of 1.0 m were the best predictors of nest success from a diverse predator community. In addition, brown-eared pheasants have a preference for rock-cavities. Therefore, based on nest-site selection of this eared pheasant, we strongly suggest that moderate logging activity and prohibition of local peoples' firewood collection in the core areas may provide some optimal nest habitat for the brown-eared pheasant.

INTRODUCTION

Organisms are rarely distributed randomly in time or space, and patterns in habitat use are presumed to be the consequence of naturally occurring selective pressures (Clark and Shutler, 1999). Nest-site selection is a critical aspect of avian survival and reproductive success that is likely influenced by the need to reduce inter- and intra-specific competition (Cody, 1981; Friedemann *et al.*, 2017), and to avoid predation (Lloyd and Martin, 2004; Crowe and Longshore, 2013). Nest success has been linked to numerous environmental factors including predator behavior, weather, female quality, and the location of the nest (Flint and Grand, 1996; Traylor *et al.*, 2004; Sherry *et al.*, 2015). The vegetation used as a nest substrate is especially important, as it often provides for camouflage and shelter (Ong-In *et al.*, 2016; Muposhi *et al.*, 2016). For most species of birds, nest predation is probably the most common cause of nest failure (Goodnow and Reitsma, 2011). Many birds must contend with suites of nest predators that often carry out specialized search strategies for finding nests (Liebezeit and George, 2002). Understanding, how birds manage to reproduce amid such conditions requires, among other things, research into relationship between nest-site characteristics and nest predation.

The brown-eared pheasant is listed among the high-priority nationally protected animals in China, and is classified as "vulnerable" by International Union for the Conservation of Nature (IUCN) because of its restricted range (<13,000 km^2), small population (<17,900 birds), and severely fragmented habitat (Li *et al.*, 2014; IUCN, 2017). Understanding the environmental characteristics that influence nest-site selection and their impact on

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reproductive success is critical for conserving this species (Zhou *et al*., 2011; Mikula *et al*., 2014). Brown-eared pheasants typically nest on the ground and are likely adapted to maximally conceal nests to reduce the risk of loss to predators during incubation (Liu *et al*., 1991; Li and Lian, 2010). Several authors have reported quantitative data on the brown-eared pheasant's nesting habitat (Liu *et al*., 1991; Li and Lian, 2010). However, differences between successful nests and unsuccessful nests have not been investigated. Identifying the features of the surrounding environment that are linked to successful nesting, and determining how these features influence success, would increase our understanding of the species' specific habitat needs and improve our ability to maintain suitable habitat for the species (Warkentin *et al*., 2004). In this paper, we investigated whether habitat characteristics at successful nests differed from those of unsuccessful nests for brown-eared pheasants in the Huanglongshan Nature Reserve, Huanglong County, Shaanxi Province, China, and we identified the key variables affecting the success of nest-site selection of the bird.

MATERIAL AND METHODS

Study site

Field work was carried out in the forested area of Huanglongshan Mountain in the Huanglongshan Nature Reserve, Shaanxi, China (35°28′-36°02′N latitude, 109°38′-110°12′E longitude). The reserve is situated in the Huanglong Mountains in the northeast of Shaanxi Province, China. The study area has a sub-humid temperate continental climate and experiences an average annual temperature of 8.6°C, an annual rainfall of approximately 611.8 mm mainly concentrated from July to September and an annual evaporation capacity of 856.5 mm (Li *et al*., 2014). Within its total area of 81,753 ha, the reserve has a central core area of 21,289 ha for wildlife conservation (especially for brown-eared pheasants). Vegetation in the study area is mainly warm temperate deciduous broad-leaved forest and percentage of forest cover amounts to 84.6%. A recent survey of the Huanglongshan Nature Reserve divided the area into four major plant communities: 1) subtropical evergreen coniferous forest vegetation; 2) coniferous broadleaved forest; 3) deciduous broad-leaved forest and 4) farmland (for more details see Li and Lian, 2010).

Data collection

Field data were collected during each breeding season from 2006 to 2014 except for 2008. During each breeding season from early March to the end of May, owing to the thick shrub cover, it was difficult for us to find brown-eared pheasant nests. As a consequence, we systematically searched for the pheasant nests from two protection stations (Beisita and Shitaisi; Fig. 1) within the Nature Reserve within 25 meters on both sides of the transect line.

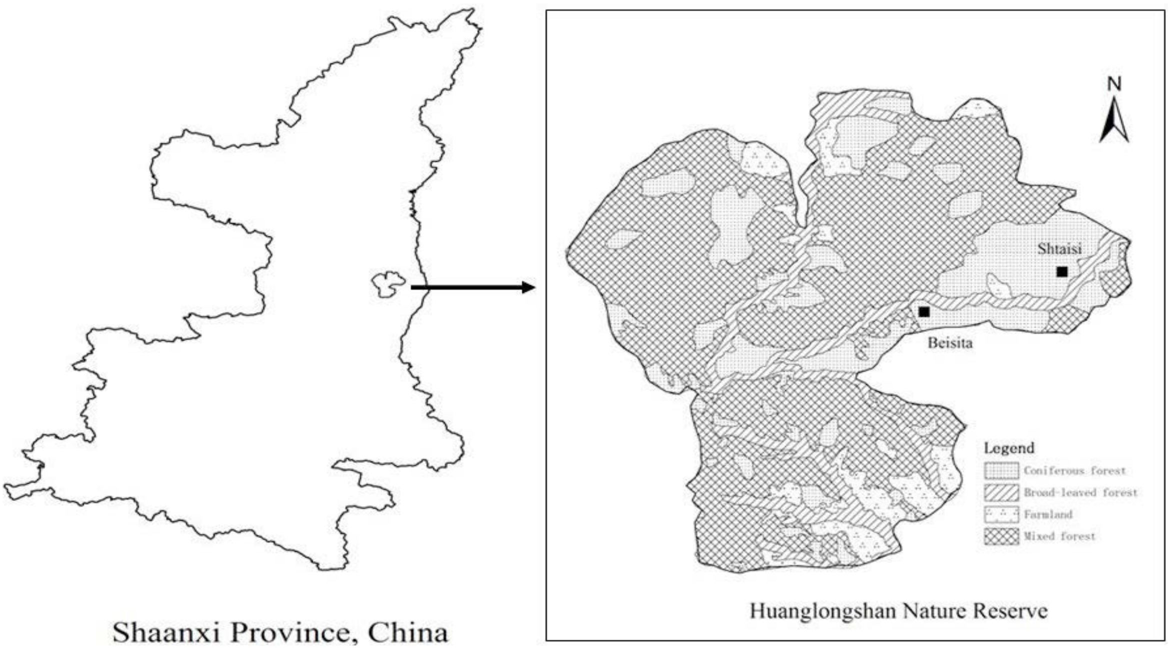

Fig. 1. Location and vegetation of Huanglongshan Nature Reserve (Yanan City, Shanxi Province, China) and the position of protection station used in the study area.

Or once one pair was encountered, we continued tracking activities of this pair till they returned to the nest. Once a nest was located, we marked it with coloured tape a few meters away and monitored its reproductive progress. All nests were found either in the egg-laying stage or during the incubation. Nests were monitored every one to three days until their fate was determined. Eggs were considered abandoned if they were cold and/or not covered by the sitting hens on successive visits. We examined nests for evidence of predation (tracks, broken eggshells, or the entire clutch missing), or hatching (clean eggshell breakage). We defined nests as successful if one or more eggs hatched. Owing to an annual rainfall mainly concentrated from July to September in the study area and no information on female quality, we collected field data without regard for rainfall and female quality. When a nest-site was located, we established a 10 m × 10 m plot centered on the nest which was then subdivided for sampling vegetation at different scales (Lu and Zheng, 2003; Li and Lian, 2010). Specifically, each 10 m × 10 m plot was divided into four quarters (5 m x 5 m) and five small plots (1 m x 1 m) were established, one at each corner of the large plot and one at the center (Fig. 2). The 10 m × 10 m plots were used to evaluate trees; the 5 m × 5 m plots were used for shrubs and 1 m × 1 m plots for grasses and herbs. For all nest sites, the following parameters were measured: 1) altitude (m; measured by global positioning system), 2) slope degree (measured by a compass), 3) slope aspect (measured by a compass), 4) cover of trees (percentage), 5) cover of shrub (percentage), 6) cover of grasses (percentage), 7) cover of shrub at height of 0.5 m, 1 m, 2 m and >2 m, 8) average height of trees (m), 9) average diameter of trees at breast height of 1.3 m (cm),10) average height of shrubs (m), 11) density of shrubs (inds/m^2), 12) average height of grasses (cm), 13) distance to nearest trail (m), 14) distance to nearest water source (m), and distance to the edge of woods (m). We also estimated percentage cover with an ocular tube (Lu and Zheng, 2003).

Data analysis

For normally distributed variables (one-sample Kolmogorov-Smirnov Z test, P>0.05), independent-samples T-tests were used to identify significant differences between sites with successful nests and ones with unsuccessful nests. Mann-Whitney U tests were used for data that were non-normal. For all variables that differed between successful sites and unsuccessful ones, we firstly calculated Spearman's rank correlation coefficients. If the absolute values of correlation coefficients among the above variables were equal to or more than 0.70, we retained only the variable we regarded as having the more direct biological relevance for brown-eared pheasants (Lahaye and Gutiérrez, 1999). Then univariate analysis of logistic regression was derived with the above retained different variables and their first-order interaction as independent variables. In univariate analysis, the variables with probability less than 0.25 were retained (McGrath *et al*., 2003). We then evaluated the remaining variables and their first-order interactions as independent factors in using logistic regression, with success/failure (1/0) of the nests as the dependent variable. We generated multiple logistic regression models to determine which variables were most closely related to nest success or failure (Franco *et al*., 2000). According to regression results, we calculated the Akaike's Information Criterion (AIC) and Akaike's Information Criterion for small sample sizes (AICc) to choose the most parsimonious model that offered the highest accuracy with the least variables (Anderson and Burnham, 1999; Pan, 2001; Ong-In *et al*., 2016). The lower the value of AIC or AICc, the more important the factor to nest-site' selection of this pheasant (Anderson and Burnham,1999; Boyce *et al*., 2002). To assess goodness of fit, we also conducted Hosmer-Leweshow tests, calculated the values of optimal cut-off points, and the accuracy of successful and unsuccessful nests, and the total model (Hosmer and Lewshow, 2000). In all statistical tests, a probability of 0.05 or less was accepted as significant difference and means are given as Mean±SD. All statistical analyses were conducted in SPSS 17.0 for Windows.

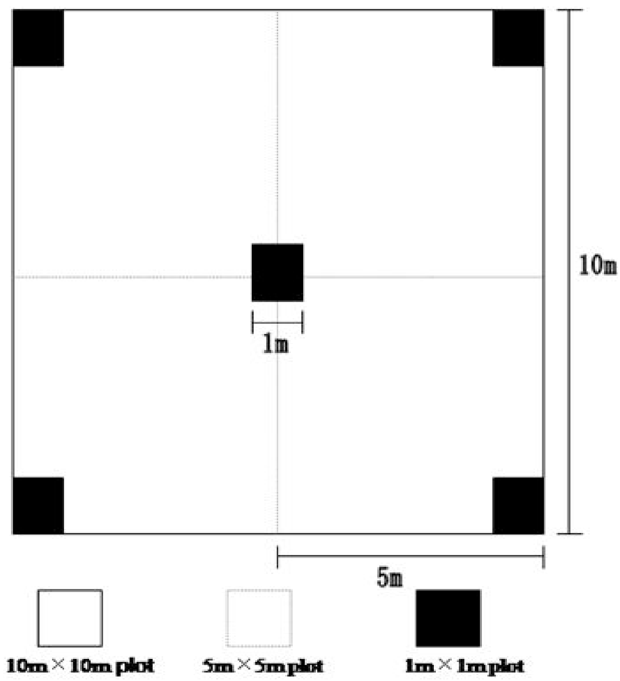

Fig. 2. The sampling scheme of 10m×10m, 5m×5m and 1m×1m plots.

Table I.- Comparison of habitat variables between successful and unsuccessful nest-sites of brown-eared pheasant and nest-sites preference from 2006 to 2014 except for 2008.

Variables	Successful (n=40)	Unsuccessful (n=24)	Z-value[a]	T-value[b]	P
Altitude (m)	1250.71±79.69	1232.61±67.08		0.817	0.417
Slope degree(°)	24.85±10.26	27.72±7.02		-1.078	0.285
Cover of trees	0.47±0.15	0.38±0.11		2.463	0.017*
Average height of trees (m)	11.22±2.18	10.63±2.22		1.06	0.293
Average diameter of trees (cm)	22.00±4.11	21.24±4.80		0.619	0.538
Cover of shrub	0.58±0.11	0.44±0.12		4.337	0.000**
Density of shrubs (Inds/m^2)	4.49±2.15	2.87±1.02		3.04	0.004**
Average height of shrub (m)	1.69±0.21	1.72±0.26		-0.45	0.654
Cover of grasses	0.40±0.19	0.41±0.15		-0.261	0.795
Average height of grasses (cm)	16.50±1.78	15.88±1.21	-1.89		0.059
Cover of shrub at height of 0.5 m (%)	41.14±9.02	39.55±10.38	-0.964		0.335
Cover of shrub at height of 1.0 m (%)	45.68±5.76	36.54 ±9.38	-3.456		0.001**
Cover of shrub at height of 2 m (%)	16.39±7.14	17.55±8.16		-0.562	0.576
Cover of shrub at height of >2m (%)	5.28±3.22	6.18±3.56		-0.965	0.339
Distance to trail (m)	37.51±8.14	38.94±7.95	-0.516		0.606
Distance to water source (m)	81.67±17.75	91.30±25.32	-1.573		0.116
Distance to edge of woods (m)	98.24±26.46	87.39±30.16	-1.336		0.182
Nest-sites under rock walls and large stones (Indvs)	22	12			34 in total
Ones at the base of shrubs (Indvs)	8	4			12
Ones under fallen trees (Indvs)	10	2			12
Ones beside tree roots (Indvs)	0	6			6

a, Mann Whitney U-test; b, Independent samples t-test; *, $P<0.05$; **, $P<0.01$.

RESULTS

Nest-sites preference

We found 64 nests from 2006 to 2014 except for data in 2008 due to inclement weather. Of 64 nests (Table I), 34 (53.13%) were under rock walls and large stones, 12 (18.75%) at the base of shrubs, 12 (18.75%) under fallen trees, and 6 (9.38%) beside tree roots. These data suggest that brown-eared pheasants have a preference for rock-cavities (x^2 = 28.50, df = 3, P = 0.000, n = 64). And among a total of 64 nests in Huanglongshan Mountains, 40 (63.5%) were successful: the highest success rate (55%) was under rock walls and large stones, 20% at the base of shrubs, 25% under fallen trees, and the lowest one (0%) besides tree roots (Table I). Of the 24 failed nests, twelve were depredated by large-billed crows (*Corvus macrorhynchos*) based on peck marks on eggshells; four by wild boar (*Sus scrofa*) or badger (*Meles meles*) or Siberian weasel (*Mustela sibirica*), based on animal tracks found near the nest and/or in nest, and four probably failed due to raptors based on finding the framework of the eared pheasant near the nests. Avian predators in the area include Northern goshawk (*Accipiter gentiles*), Eurasian sparrow hawk (*Accipiter nisus*), Northern harrier (*Circus cyaneus*), Cinereous Vulture (*Aegypius monachus*) and/or common kestrel (*Falco tinnnnculus*). The three nests were abandoned by the pheasants during incubation with eggs remaining intact in the nest, most probably caused by avian predators, which may have killed egg-laying hens when they left for food and/or water in the daytime. The last one was accidentally destroyed by the farmer or grazing animals.

Beside the damage caused by wild boar or badger or Siberian weasel (four nests) and by the farmer (one), others may have been caused by avian predators. Hence the data on 18 failed nests were pooled for statistical analysis. Differences were evident in tree cover, cover of low-lying shrubs, overall density of shrubs, and overall shrub cover between unsuccessful nest-sites and successful ones (Table I). In addition, correlation coefficients for four significant variables were < 0.6, hence the above four significant variables were retained, and the univariate logistic regression was carried out with each of these four variables and their first-order interaction as independent variables. Consequently, all independent variables and their first-order interaction were retained owing to their having a P-value less than 0.25. These variables and their first-order interaction were used to conduct multiple logistic regression with success /failure (1/0) of the nests as dependent variables. This process yielded 2 logistic regression models for the brown-eared pheasant (Table II). Based on AIC_C scores for the two models, we drew a conclusion that regression equation II with the lower AIC_C value was optimal. The model is formally expressed as: $\pi(x) = e^{g(x)} / (1 + e^{g(x)})$, g(x) = 7.989 - 0.813x cover of shrub - 0.298x cover of trees×cover of shrub at 1.0 m height. This optimal model indicates that nest-sites success of brown-eared pheasants was negatively related to cover of shrubs, and first-order interaction between cover of trees and cover of shrub at height of 1.0 m.

Assessing the goodness-of-fit

We assessed goodness of fit using Hosmer and Leweshow tests. For this test, subjects were divided into deciles based on the predicted probability, Chi-square value was calculated from observed and expected frequencies. The test indicated that goodness of fit in the models II was adequate ($x^2 = 1.984$, $df = 8$, $P = 0.981$).

Results also showed that cut-off points which optimized the correct classifications were about 0.40 for the models. For brown-eared pheasants, CT was 89.8%, which was considered as the accuracy of the model; CP for nest-sites observed to be successful was 90.2%, CA for nest-sites observed to be unsuccessful was 88.9%. The values of CT, CP and CA for the model showed that it had generally satisfactory accuracy.

DISCUSSION

For pheasant species, many studies have shown that vegetative cover is important for nest-site selection (Lu and Zheng, 2003; Li and Lian, 2010; Wu and Liu, 2011). However, few of those studies determined which specific variables contributed significantly to nest-site success. For the common pheasant (*Phasianus colchicus*), percent vertical and horizontal obstructions were the top two predictors of nest success, suggesting that no single set of habitat characteristics might offer protection from a diverse predator community that featured a diverse array of nest-searching techniques and detection abilities. For the western population of the brown-eared pheasant in the northeast of Shaanxi, owing to the lack of rainwater and an annual rainfall mainly concentrated from July to September (Li and Lian, 2010), our results showed that shrub cover, and a first-order interaction between tree cover and shrub cover at the height of 1.0 m were the best predictors of nest success (Table II).

Predation pressure has a significant impact on habitat selection, and animals typically avoid habitats commonly used by predators (Houtman and Dill, 1998). In our study area, the greatest cause of nest failure for the brown-eared pheasant was avian predators, which accounted for 79.17% (n=24) of total unsuccessful nests. Many studies have emphasized that cover provided by the immediate nest environment can influence the survival rate of pheasants, and vegetation is generally the primary source of nest cover for birds (Martin, 1995; Clark and Shutler, 1999; Nan *et al.*, 2006). In our study, successful nest-sites were characterized by dense shrub and tree cover, especially cover of shrubs about 1.0 m in height. We speculate that shrubs provide concealment at the micro-environment scale; whereas trees provide cover on the macro-environment scale. For mammalian predators on our study site (*i.e.,* wild boar and badgers), most individuals remained far away from brown-eared pheasants nest-sites during the daytime due to human disturbances and automotive traffic in the area. At night, they approached the lower slope location for foraging; but we suspect that it is difficult for them to detect nest-sites of the brown-eared pheasant in the dark. In addition, wild boar often has shown to be the preference for potato field at night. We speculate that these factors led to the low frequency of predation by mammals that we observed (4 of 24 depredated nests).

Table II.- Modeling the relationship between nest success and habitat characteristics for brown-eared pheasants by using logistic regression.

Variable	B	Wald Z	P	-2 Log likelihood	n	K	n/K	AIC	AIC_C
Model I				38.909	64	3	21.33	44.909	45.309
Cover of trees×Cover of shrub at height of 1.0 m	-0.288	12.591	0						
Constant	5.012	9.446	0.002						
Model II				31.816	64	4	16	39.816	40.494
Cover of shrub	-0.813	4.721	0.03						
Cover of trees × Cover of shrub at height of 1.0 m	-0.298	10.819	0.001						
Constant	7.989	10.642	0.001						

Liu *et al*. (1991) reported that of 43 nests in total of brown-eared pheasants in Shanxi Province, 29 (67.43%, n=43) nested under a roof of dead sticks from trees logged by local people, whereas 2 (4.65%, n=43) besides larger stones. This result indicated that such roofs constructed by humans or natural disasters can be the nest-site preference primarily evolved in pheasants, because the nest was well concealed from all sides except for one entrance. However, in the Huanglongshan forested area of Shaanxi Province, there is a tendency for brown-eared pheasants to build nests under rock walls and large stones (53.13%, n = 64). We found that, in this area, forest canopy of Chinese pine (*Pinus tabulaeformis*) obstructs sunshine, which results in few shrubs growing in the forest. Therefore, the optimal habitats-those with abundant shrub cover-are uncommon. Cover for nest-sites is further reduced for that a forest protection project has been active in China for the past decade. This program has restricted logging, compelling local people to collect firewood from fallen trees and reducing the number of fallen trees that might otherwise be available as cover for nest sites. We therefore, suspect that brown-eared pheasants that might prefer to nest under a roof of dead sticks would have sought cover under rock walls or large stones instead, because dead sticks were a very limited resource in our study area. This response to a change in the environment suggests that the birds can adapt to human disturbances to some degree. In addition, we also found that a nest-site under the rock wall was reused by brown-eared pheasants in 2007, 2011 and 2014. This observation also substantiates the view that a potential shortage of suitable nest-sites can result in the reuse of nest-sites (Lu and Zhen, 2003). Fifty percent of depredated nests (50%, n = 24) were situated under rock walls and large stones, even though these nest-sites were well protected from above, in the front and the back of the nest (Tables I, II). This high depredation rate further proves that nest-sites under rock walls or large stones are not the best locations.

Understory vegetation can influence temporal patterns of habitat use (Nan *et al*., 2006; Wu and Liu, 2011). The first-order interaction between cover of trees and shrubs at a height of 1.0 m was negatively related to nest-sites success of brown-eared pheasant. However, in our study area, understory vegetation is generally sparse in places where tree cover is more intensive. Conversely, areas with dense understory of shrubs may provide refuge for pheasants (Lu and Zheng, 2003), but the vegetation may also prevent them from finding prey, especially avian predators and moving freely (Nan *et al*., 2006). This trade-off between tree cover and low-lying shrubs results in very few ideal nest-sites for birds. As a result, brown-eared pheasants were forced to nest under rock walls and large stones. However, such roofs constructed by humans or natural disasters should be the nest-site preference for this pheasants (Liu *et al*., 1991). Finally, we strongly suggest that moderate logging activity and prohibition of local peoples' firewood collection in the core areas may increase the availability of ideal nest habitat for the brown-eared pheasant.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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