Article

Water, Food Availability, and Anthropogenic Influence Determine the Nesting-Site Selection of a Desert-Dwelling Bird, Xinjiang Ground-Jay (*Podoces biddulphi*)

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Abstract: Nesting-site selection is an important aspect of the breeding process in birds, as it usually determines nesting and breeding successes. Many factors can affect bird nest-site selection, including anthropogenic disturbance. In an extreme desert environment, such as the Taklamakan Desert in China, birds' survival pressure is high, especially for rare species such as the Xinjiang Ground-jay (*Podoces biddulphi*). We studied nest-site selection in this species from March 2017 to May 2019. A Chi-square test, independent sample *t*-test, Mann–Whitney *U*-test, and generalized linear models were applied to possible nest-site selection factors for Xinjiang Ground-jays. The main determining factors were the distances to human settlements, water, and the edge of the oasis. Xinjiang Ground-jays nested near available water resources for easier access, which is important in arid environments. Individuals chose to nest far from the oasis edges and settlements to increase food availability and reduce interference from human activities, respectively. Overall, water, food availability, and anthropogenic influence were the main factors affecting the nest-site selection of Xinjiang Ground-jays in this study. Therefore, these results suggest that there is a trade-off between survival and reproduction. Further studies are required to verify whether similar site preferences may also apply to other desert-dwelling species.

Keywords: Taklamakan Desert; generalized linear models; disturbance; food abundance; *Podoces biddulphi*; nesting site; oasis habitat; edge effect; human influence; breeding success

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1. Introduction

Nest-site selection is a significant component of habitat selection and is one of the most important factors determining the survival and reproductive success of birds [1,2]. Nest-site selection refers to the choice of a specific location for nesting from all possible sites [3]; such specific sites tend to increase reproductive success. Recent research has focused on factors that may influence this process, including anthropogenic influence, predator pressure, distance to habitat edges, and vegetation characteristics such as vegetation type, plant composition, and spatial structure [4–8]. Moreover, access to water is also an important influencing factor for species inhabiting arid environments.

Deserts are extremely dry environments characterized by high ambient temperatures and low rainfall, species diversity, and population density, resulting in limited food and water supplies for the local species [8,9]. The Taklamakan Desert, located in the Tarim Basin in southern Xinjiang of China, has an extremely dry climate [10,11], an underlying

surface of quicksand, and sparse vegetation, which together produce a unique and fragile ecosystem [6,12–14]. As such, access to water and food are important limiting factors for the survival and reproduction of animals, especially birds, in this challenging environment.

For oasis-dependent species, the oasis edge is the boundary between the oasis and desert [15]. Vegetation coverage and species diversity are typically lower near the oasis edges than in the central area [16]; the former directly influences insect density and, thus, the resources available to insect-eating birds [17]. In addition, tall vegetation can provide good shelters for parents and nests [17,18]. Therefore, birds that reproduce in the desert may prefer to nest near the oasis center; however, this remains to be verified [19].

Anthropogenic influence is an important factor affecting the nest-site selection of birds [5,20,21]. Some studies indicate that an increase in human activities can negatively affect breeding bird communities, population dynamics [22], and the nest-site selection of Eurasian magpies (*Pica pica*) and Northern goshawk (*Accipiter gentilis*) [23,24]. As the Xinjiang Ground-jay's nesting area is located far from the nearest human settlement, it is unlikely that human activities directly affect the nest-site selection of this species. However, they can indirectly influence this process by changing the natural habitat [25], since farmers have turned the oasis into arable land, reducing the potential areas for this species to nest. Additionally, livestock has been reported to destroy the nests of the Xinjiang Ground-jay [25–28]. Therefore, such anthropogenic influence may have a negative influence on its nest-site selection.

The Xinjiang Ground-jay is an endemic bird species mainly distributed in the desert and semi-desert areas of the Taklamakan Desert. These birds build open bowl nests in Tamarisk shrubs between February and June, laying 1–3 eggs per clutch [29]. Limited research has focused on the breeding of Xinjiang Ground-jays and even less on their nest-site selection. This study aimed to reveal the key factors influencing the nest-site selection of Xinjiang Ground-jays and verify if the nest-site selection of desert-dwelling birds is unique compared to birds living in other environments.

2. Materials and Methods

2.1. Study Area

This study was conducted in Minfeng County, located on the southern edge of the Taklamakan Desert, Xinjiang, China (82°22'–85°55' E and 35°20'–39°29' N), ranging approximately 55.5 km². The Taklamakan Desert is the second-largest drift-sand desert in the world and the largest desert in China. It is composed of 85% active dunes and 15% fixed or semi-fixed shrub sand piles, which are the main habitats of animals [26,27]. It has a typical continental warm-temperate arid climate with hot, dry summers and cold winters. The frost-free period is approximately 194 days, annual sunshine is 2842.2 h, annual precipitation is 30.5 mm, annual potential evaporation is 2756 mm, and maximum and minimum temperatures are 41.9 °C and −23.9 °C, respectively. There are Gobi, oasis, and desert in this area [27]. The vegetation is mainly composed of Tamarisk (*Tamarix* spp.), Euphrates poplar (*Populus euphratica*), Alhagi (*Alhagi sparsifolia*), common reed (*Phragmites australis*), and Russian boxthorn (*Lycium ruthenicum*) [28]. Birds of prey, such as the Long-legged buzzard (*Buteo rufinus*), are the main predators of Xinjiang Ground-jays in the study area, followed by reptiles, such as the Forsyth's toadhead agama (*Phrynocephalus forsythii*), and insects [29,30].

2.2. Field Survey

Nests were identified by searching for and tracking adult birds. For this, we established a transect, which was covered on foot, across the area of suitable nesting shrubs. Once a bird was observed, we marked its location and searched the entire area within a 5 km buffer for shrubs to find a nest. The nests were numbered and named according to the order in which they were found, and their GPS coordinates were recorded and marked on a map, producing a polygon for the distribution area of Xinjiang Ground-jay nest sites. The study area was then divided into 500 × 500 m² plots, among which those including nests

(Figure 1) (24) were considered nest plots, and those without nests (198) were designated as non-nest plots. For each plot, we assessed two vegetation characteristics (vegetation type and cover), and five distance factors measured in kilometers (distance to water, path, settlement, grazing land, and oasis edge). Vegetation types were determined as trees, shrubs, or herbs according to which had the highest proportion in each plot. Vegetation cover was measured as the proportion of land where vegetation was present in each plot. Distance factors were measured from the center of the plot to the nearest water, path, settlement, grazing land, and oasis edge.

Figure 1. A nest of Xinjiang Ground-jay.

2.3. Data Analyses

We used the Chi-square test to compare the difference of vegetation type between the nest and non-nest plots, and the Kolmogorov–Smirnov test to examine the normality of the variables. As the distance to the nearest settlement variable was normally distributed, we used the independent sample *t*-test to assess the significant differences between nest and non-nest plots. Further, because the other six variables were not normally distributed, we used the Mann–Whitney *U*-test to evaluate the significant differences between the two types of plots. The value of statistical significance was set as 0.05.

Generalized linear models were used to determine the nest-site selection of the Xinjiang Ground-jay. The minimum adequate model was determined using Akaike's Information Criterion with its lowest value after fitting the full model [31,32]. The analyses were conducted with R version 2.8.1 [33].

3. Results

The seven factors (two vegetation characteristics and five distances) were compared between the Xinjiang Ground-jay nest and non-nest plots. There were no significant differences between nest and non-nest plots for vegetation type (Chi-square test: $\chi^2 = 4.676$, $df = 2$, $p = 0.097$) and vegetation cover (Table 1).

Table 1. Pair-wise comparisons for ecological factors between nest and non-nest plots of Xinjiang Ground-jay. (* means significant difference and ** means very significant difference).

Factor	Mean $\pm$ SE		<i>t</i> -Test	Mann–Whitney <i>U</i> -Test <i>P</i>
	Nest Plots	Non-Nest Plots		
Vegetation cover (%)	48.67 $\pm$ 4.43	42.17 $\pm$ 2.01	-	0.271 NS
Distance to water (km)	2.00 $\pm$ 0.20	3.06 $\pm$ 0.10	-	0.001 **
Distance to path (km)	5.55 $\pm$ 0.37	4.48 $\pm$ 0.21	-	0.042 *
Distance to settlement (km)	6.38 $\pm$ 0.25	5.50 $\pm$ 0.15	0.004 *	-
Distance to grazing land (km)	2.20 $\pm$ 0.09	1.30 $\pm$ 0.21	-	0.000 **
Distance to edge of oasis (km)	0.76 $\pm$ 0.11	0.43 $\pm$ 0.04	-	0.003 **

A significant difference between the nest and non-nest plots was found for distance to water, distance to path, distance to settlement, distance to grazing land, and distance to the oasis edge (Table 1).

Distance to water, settlement, and the edge of oasis were the main variables that influenced the nest-site selection of the Xinjiang Ground-jay. The distance to water was negatively related to the possibility of nest-site selection, while the distance to settlement and edge of oasis were positively correlated with the possibility of nest-site selection (Table 2).

Table 2. Results of the minimum adequate model based on generalized linear models with the Xinjiang Ground-jay nest-site to the explanatory variables. Non-significant variables are not reported. The multivariate model was the best model according to Akaike's Information Criterion (AIC). β : regression coefficient; *P*: Likelihood Ratio Test. The AIC for the minimum adequate model was 116.81.

Explanatory Variables	β	SE	<i>P</i>
Distance to water	−1.2045	0.2680	<0.0001
Distance to settlement	1.0045	0.2531	<0.0001
Distance to edge of oasis	1.3319	0.4598	0.0038

4. Discussion

The results of our study showed that the distance to human settlements is one of the main factors influencing Xinjiang Ground-jay nest-site selection. Anthropogenic influence can negatively affect bird nest-site selection in many ways [5,22,34], both directly and indirectly. Direct influence includes hunting, noise, and roadkill caused by traffic [34,35], while indirect anthropogenic influence involves human-induced habitat loss or habitat degeneration and human-associated activities, such as livestock grazing, which causes breeding interference and nest destruction [25]. The great distance of nest sites to the human settlement found in this study was possibly caused by the indirect anthropogenic influence. Local villagers are mainly farmers and shepherds; the former have established arable land near the settlement in areas previously covered by native forest, reducing the availability of suitable habitat for the Xinjiang Ground-jay. Additionally, shepherds bring their sheep and cattle to graze in the oasis daily. These activities drive individuals to nest far from human settlements to reduce the potential effects of anthropogenic influence on their breeding.

The nest-sites of the Xinjiang Ground-jay tended to be close to water sources, which may be caused by the arid environment. Water is essential for the survival of all living organisms, and thus, it is the most important environmental factor affecting their number and distribution [36]. Although water appears to play a less dominant role in forest ecosystems [37], it is an important factor affecting the nest-site selection of birds in arid or semi-arid environments [8]. Our study area was located in the Taklamakan Desert, featuring extreme dryness, high ambient temperatures, and scarce water. Together, these factors increase the rates of energy expenditure and water loss due to evaporation by the desert dwellers; therefore, access to water is a particularly important limiting factor for bird

breeding success [9,14,38]. Accordingly, these individuals build nests near water sources to cope with dryness and high temperatures, which is consistent with observations of lesser prairie chickens (*Tympanuchus pallidicinctus*) and scaled quails (*Callipepla squamata*) [7,8].

Areas close to water generally have higher vegetation coverage and more species, which leads to an increased food abundance [17,39]. The Xinjiang Ground-jay is an omnivorous species, with adults mostly feeding on seeds and fruits, and young on lizards, insects, and other animals with high protein content [38]. Therefore, the Xinjiang Ground-jay builds nests close to water not only to overcome the disadvantages associated with drought, but also to obtain more food.

The distance to the edge of the oasis was also one of the main factors influencing the nest-site selection of ground jays as it can affect food availability and exposure to wind. In the desert environment, vegetation coverage and species richness in the oasis edge are lower than the central area. Thus, food availability, which is determined by species richness and abundance, is lower near the oasis edge than in the central areas [40,41]. Additionally, the wind speed near the oasis edge is higher than in the central area [42]. High wind speeds and their effects on sand are the main causes of reproductive failure of the Xinjiang Ground-jay in the desert [26]. Therefore, Xinjiang Ground-jays prefer to build nests further from the oasis edge.

Although the distance to the grazing land was not the main factor influencing Xinjiang Ground-jays' nest-site selection (Table 2), we found significant differences in the distances to grazing areas between the nest and non-nest plots, suggesting that these individuals may have avoided those areas (Table 1). As previously mentioned, livestock grazing disturbs bird incubation because they remove shrub leaves to eat, which directly destroys bird nests. The type of vegetation was also not a factor influencing the nest-site selection of the Xinjiang Ground-jay (Table 2), with no difference found between the nest and non-nest plots, probably because these are relatively limited in the study area. Xinjiang Ground-jays inhabit a desert with sparse vegetation composed of herbs, shrubs, and trees. Among them, most of the nest (96%) and non-nest plots (75%) were composed of shrubs.

5. Conclusions

The analysis of Xinjiang Ground-jays' nest-site selection showed that these individuals were influenced by a combination of human-induced habitat change and water and food availability in the desert. The results demonstrated the importance of resource availability in arid environments and highlight the effects of anthropogenic influence on nest-site selection. Whether these results can be applied to other desert-dwelling species requires further investigation; however, our study provides new insights to better understand the behavioral ecology of Xinjiang Ground-jays and assist their conservation efforts.

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