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Original article

Aspects of the breeding ecology and behaviors of the Bar-tailed Lark (*Ammomanes cinctura*) from Ha'il region in north of Saudi Arabia

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ABSTRACT

The Bar-tailed Lark (*Ammomanes cinctura*) breeds in desert and semi-desert areas of the Saharo-Sindian region, from north-west Africa through the arid plains of the Arabian Peninsula to the Sind. Despite having a wide distribution, little information is available on the breeding ecology of this species. This study was conducted in a desert in the north of Saudi Arabia, where the daytime ambient temperature may exceed 40 °C. In contrast, the night ambient temperature may reach less than 10 °C in late spring and early summer. The objectives of this study were to collect some baseline data on some aspects of the breeding ecology of this species and to record the nest attendance behavior. The study found that Bar-tailed Larks preferred to nest under shrub trunks, which may camouflage both nests and incubating parents against predators and protect eggs, nestlings and incubating parents from hostile weather conditions. Moreover, nest attendance was high, as Bar-tailed Lark parents incubated their eggs $95.97 \pm 2.62\%$ over the entire day, and they seemed to maintain the eggs at temperatures around 23–33 °C. In addition, they incubated more at night than during the daytime. Temperatures under the shrubs at night fell below 21 °C, thus parents increased the nest attendance to warm the eggs and prevent the embryos from exposure to lethal temperatures.

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1. Introduction

The Bar-tailed Lark (*Ammomanes cinctura*) has a very large distribution, breeding on the desert and semi-desert areas of the Saharo-Sindian region from north-west Africa across the arid plains of the Arabian Peninsula to the Sind (Aspinal, 2010; Jennings, 2010; BirdLife International, 2020). This species nests on arid, open, sandy or gravel plains usually away from human settlements (Jennings, 2010). It is evaluated as Least Concern (BirdLife International, 2020). The Bar-tailed Lark population of the Arabian Peninsula could amount to less than one million pairs in dry years, but this could be doubled in wet years (Jennings, 2010; Symes et al., 2015). Its population on the north of Saudi Arabia was between 36,000 and 217,000 pairs (Jennings, 2010).

The Bar-tailed Lark nest is an excavated cup on the ground, which is made from small twigs and dry grasses and lined with

softer materials such as wool, hair and feathers. The lip of the nest is usually surrounded by a pebble pavement to support the nest (Jennings, 2010). In the Arabian Peninsula, egg-laying usually occurs during March–April, but some eggs were found in February, and nest-building has been reported in late May (Jennings, 2010). The Arabian clutch contains two to five eggs, but the most common are four (Jennings, 2010). Despite having wide distribution, the breeding ecology of this species is poorly known. Therefore, the objectives of this study were to: 1) collect some baseline data on some aspects of breeding ecology of this species in a harsh environment in the north of Saudi Arabia where the daytime ambient temperature may exceed 40 °C and the night ambient temperature may reach less than 10 °C in late spring and early summer, 2) record the nest attendance behavior and estimate any disturbance or threats that may face eggs, nestlings and incubating adults.

2. Methods

2.1. Study area and data collection

This study was conducted between the 15th of April and 8th of May in 2014, 15th of April and 15th of May in 2019, and 10th of April and 6th of June in 2020 in a flat desert area about 30 km

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south-east of Hail city, north of Saudi Arabia ($27^{\circ} 16' N 42^{\circ} 07' E$) (Fig. 1). The study area is a sparsely vegetated desert, dominated by the halophytic shrubs (*Haloxyton salicornicum*) and the annual plant (*Asphodelus tenuifolius*) (Figs. 1 and 2). Searching for nests was difficult because the suitable area for the nesting was vast, so a four-wheel car was driven at a speed of 10–30 km/h to flush the incubating birds, when a nest was encountered, it was photographed and its location was recorded using a GPS receiver (Garmin e-Trex). A trail camera (Moultrie M-880i Gen 2, Trail Camera, Mossy Oak Bottomland) was used to record the nest attendance behavior of adults and any disturbances or threats on the incubating adults, eggs and nestlings over 24 h for at least five days. The camera was placed about 1.5 m from each nest and was programmed to take an image every minute (Fig. 2). The camera recorded both diurnal and nocturnal activities with infrared sensors. The installation of the camera did not last more than 10 min, and the parents returned to the nests only few minute later. In total, 7200 images were obtained and analyzed. Using a temperature data logger (Thermochron iButton, Embedded Data Systems, DS1922L-F5), the ground surface temperature (T_{ground}) in an open area about 1 m from each nest, the temperature under the eggs directly (T_{underEgg}) and the temperature near the nest under the shrub's shade ($T_{\text{underShrub}}$) were recorded for each nest every one minute during the five-day period of the study.

2.2. Data analysis

Five days were considered as the unit of analysis ($n = 5$ days). Each day was divided into 12 two-hour periods. Following AlRashidi et al. (2010), the behavioral variable, nest attendance which could be defined as the percentage of the nest attendance time by incubating adults was calculated for each period. The averages of T_{ground} , T_{underEgg} and $T_{\text{underShrub}}$ were taken for each period. Following AlRashidi et al. (2010), the influences of T_{ground} and $T_{\text{underShrub}}$ on the nest attendance were investigated using linear mixed-effects models (Pinheiro and Bates, 2000), with the day as

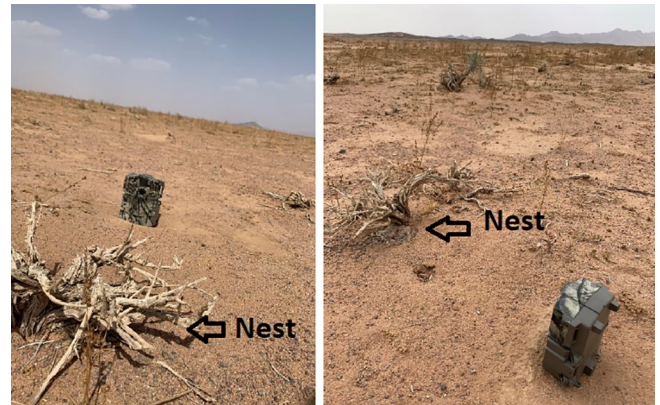


Fig. 2. A trail camera (Moultrie M-880i Gen 2 Trail Camera, Mossy Oak Bottomland), placed about 1.5 m from each nest to record the nest attendance behavior of adults and any disturbances or threats.

a grouping structure. A random intercept term for each day was included in the models. T_{ground} and $T_{\text{underShrub}}$ were included in each model as second-degree orthogonal polynomial covariate. The interaction between time period and temperatures was also included in each model. The response variable was arcsine square-root transformed to achieve normality. The statistical package R version 3.2.1 (R Development Core Team, 2015) was used for statistical analyses and drawing figures. Values are given as mean \pm SE.

3. Results

3.1. Egg-laying dates, nest locations and brood-rearing

Three nests were found. One nest was found on 02.05.2014 and the other two nests were found on 19.04.2019 and on 26.04.2019.

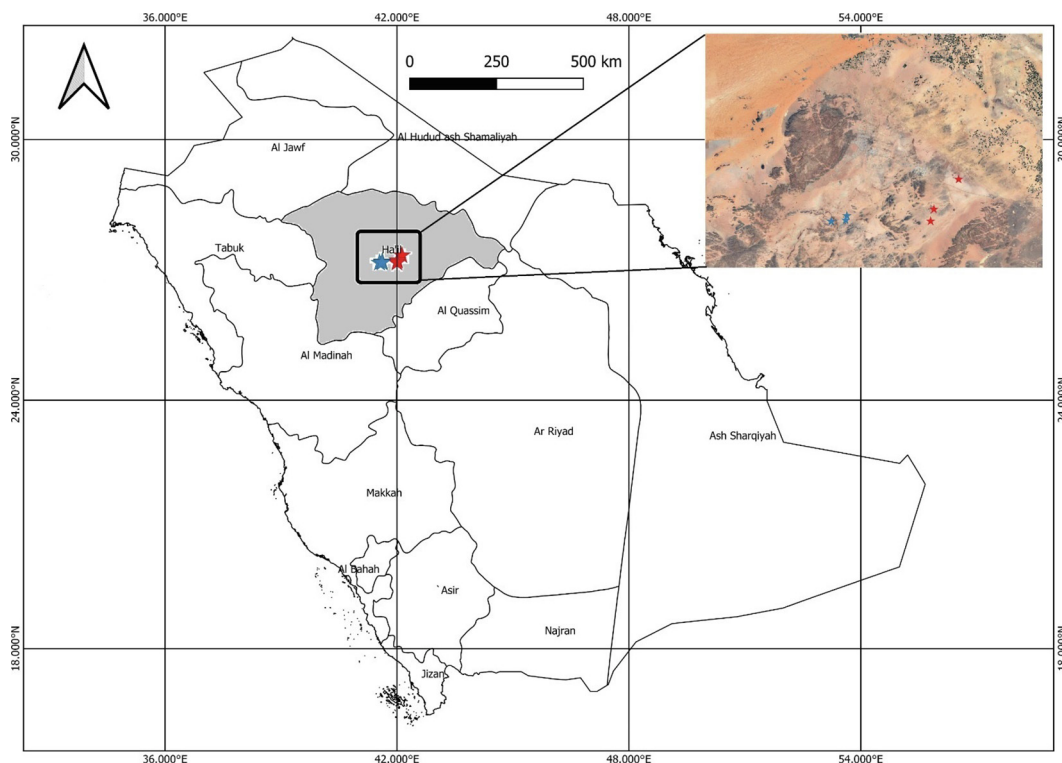


Fig. 1. A map of the study area showing the nest locations (red stars) and the locations of encountered chicks (blue stars).

A 20-day-old chick was encountered on 02.06.2020. In addition, two separated chicks from two families approximately 40 days old were encountered on 03.06.2020 (Table 1). Therefore, based on hatching dates and the estimated age of chicks, the breeding season may start as early as April, and it may last until the end of June.

All the nests were placed under dry trunks of halophytic shrubs (*Haloxylon salicornicum*) in the southeast side of the shrubs. The nest is an open cup made from twigs, dry grass and fine plastic threads lined with animal hair and wool (Fig. 3a). The nests were surrounded by some loose flattish pebbles, especially from the eastern and southern sides (Fig. 3b). After the hatching by four days, parents removed the pebbles to widen the nest to fit the size of the nestlings (Fig. 3c). The clutch size of the nest that was found in 2014 was three eggs, whereas the clutch size was four eggs for each nest found in 2019, all four eggs were hatched for one nest, whereas only three eggs were hatched for the other nest (Table 1). The eggs were reddish-white with dark black spots. All the nests were found after the clutch completion, so the incubation initiation date was not determined whether it was after the laying of the first or the last egg. The parents were not captured nor ringed, but I have stayed nearby the nests for at least one hour every day and observed both parents when they fed their nestlings, until they left the nest after one week of hatching date. In the five families that were re-sighted, at least one parent was observed with the chicks even when chicks could fly for long distances (Table 1).

3.2. Diurnal temperature variations

There were enormous diurnal temperature variations, the minimum of T_{ground} , T_{underEgg} and $T_{\text{underShrub}}$ at night was 7.51 °C, 20.61 °C and 15.10 °C, respectively, whereas the maximum daytime temperature was 51.47 °C, 34.60 °C and 47.06 °C respectively. The averages of T_{ground} , T_{underEgg} and $T_{\text{underShrub}}$ for the hottest two-hour period of the day (12:00–14:00 h) were 47.16 ± 0.76 °C, 30.41 ± 0.44 °C and 38.54 ± 1.66 °C respectively ($n = 5$ days) (Fig. 4a), whereas the averages of T_{ground} , T_{underEgg} and $T_{\text{underShrub}}$ for the coldest two-hour period of the day (04:00–06:00 h) were 10.34 ± 1.28 °C, 24.06 ± 0.69 °C and 16.56 ± 0.28 °C respectively (Fig. 4a). In general, at night (18:00–6:00 h), the averages of $T_{\text{underShrub}}$ for each two-hour period were higher than that of the averages of T_{ground} , but this was the opposite during the daytime for each two-hour period except the period (6:00–8:00 h) (Fig. 4a). The averages of T_{underEgg} for each two-hour period over the whole day did not fall below 23 °C and did not rise above 33 °C (Fig. 4a).

3.3. Daily routine of nest attendance

For the entire day, the mean total nest attendance was high 95. $97 \pm 2.62\%$ ($n = 5$ days). During the daytime (6:00–18:00 h), the total nest attendance was $93.78 \pm 4.56\%$. In contrast, at night (18:00–6:00 h), the nests were attended $98.56 \pm 0.81\%$ of the time ($n = 5$ days). The nests were attended over 92% of the time during each two-hour period except for the period (16:00–18:00 h) where

parents incubated 84.17 ± 10.42 (Fig. 4b). The averages of T_{ground} , T_{underEgg} and $T_{\text{underShrub}}$ of this period were 34.92 ± 0.90 °C, 33.06 ± 0.23 °C and 30.55 ± 0.30 °C respectively. In addition, in this period the shade of the shrubs completely covered the nests (Fig. 3a).

The ground temperature did not influence nest attendance (p -values for each explanatory variables were > 0.05), but what affected that was the temperature under the shrub; its effect was not linear and depended on the time of the day (Fig. 3; Table 2). The nest attendance reached almost 100% during the daytime in only one period (12:00–14:00 h) (Fig. 4b); this period was the hottest part of the day where the averages of $T_{\text{underShrub}}$ and T_{underEgg} for this period were 38.54 ± 1.66 °C and 30.41 ± 0.44 °C respectively (Fig. 4a). In contrast, at night the attendance of nests reached 100% during four periods (22:00–04:00 h) (Fig. 4b) where the averages of $T_{\text{underShrub}}$ for these periods were 21.74 ± 0.81 °C, 20.65 ± 0.44 °C, 19.02 ± 0.21 °C and 17.68 ± 0.22 °C respectively (Fig. 4a).

3.4. Nest disturbance

The cameras did not show any predators attacking incubating birds or eating the eggs or nestlings during the study. Yet, they did record some disturbance of incubating parents by livestock animals in three times (camels and sheep) during the daytime hours, the disturbance did not last more than 10 min. At night, the cameras recorded the Lesser Jerboa (*Jaculus jaculus*) wandering around the nests in five times but no disturbance of the incubating birds was occurred.

4. Discussion

Although there is little information available on the Bar-tailed Lark breeding ecology, some aspects of the breeding ecology of the species in Ha'il desert appear to be different from the other aspects reported from elsewhere. Jennings (2010) reported that the breeding season of this species started from February, while this study showed that it started from April which is consistent with that mentioned by Cowan and Newman (1998) who observed on 10 May 1996 an adult feeding two chicks, they also found a nest containing four nestlings on 24 April 1997. Although no chicks were encountered in April during the course of this study, which may indicate that the breeding season did not start in February or March, another study is required to be conducted in February to investigate that.

This study showed that the Bar-tailed Larks preferred to place their nests under the southeast side of the shrubs which differ from that reported by Jennings (2010) who mentioned that nests in the Arabia Peninsula have been placed under either the north or north-east side of a plant or rock to provide shade for eggs, nestlings and incubating birds. From the analyzed images, the shade of the shrub trunks started covering the nests from 10:00 h until it covered them completely at 11:00 h and after. Therefore, such a difference may be attributed to another environmental factor, and shrub trunks may support the soft nest materials preventing them from

Table 1

Parental care and nest fate of the Bar-tailed Lark based on at least one-hour observation from Ha'il region in north of Saudi Arabia.

Identification	Finding date	Clutch size	Fate	Parental care	
				During incubation stage	After hatching
Nest 01	02.05.2014	Three eggs	Unknown	Both parents	Unknown
Nest 02	19.04.2019	Four eggs	All hatched	Both parents	Both parents
Nest 03	26.04.2019	Four eggs	Three hatched	Both parents	Both parents
Chick 01	02.06.2020	Unknown	Unknown	Unknown	One parent
Chick 02	03.06.2020	Unknown	Unknown	Unknown	One parent
Chick 03	03.06.2020	Unknown	Unknown	Unknown	One parent

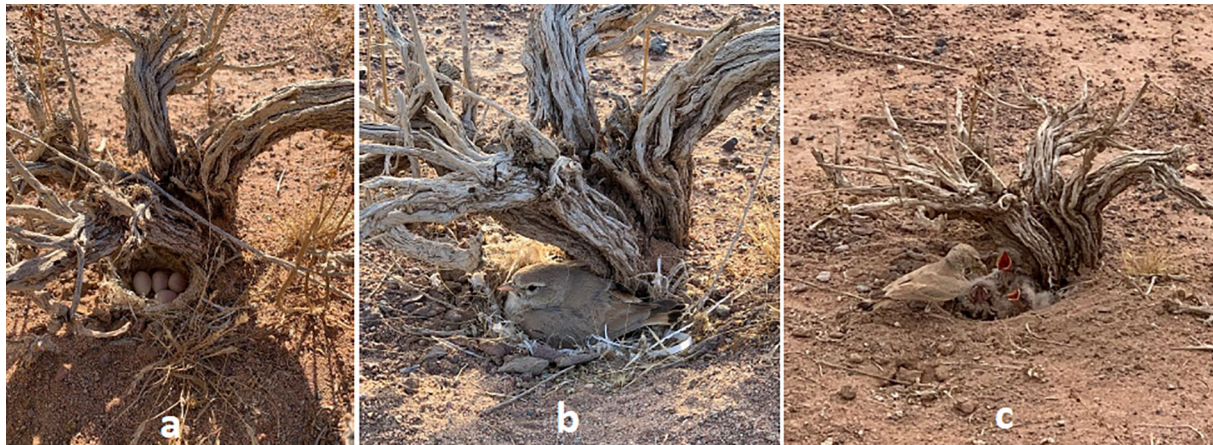


Fig. 3. A Bar-tailed Lark nest showing: (a) the shade of the shrub trunks covering the entire nest (the photo was taken at 4:40 PM), (b) the shrub trunks seemed to match the incubating adult plumage, the pebbles surrounded the nest from two sides, (c) a parent feeding the chicks, the pebbles surrounding the nest have been removed to widen the nest.

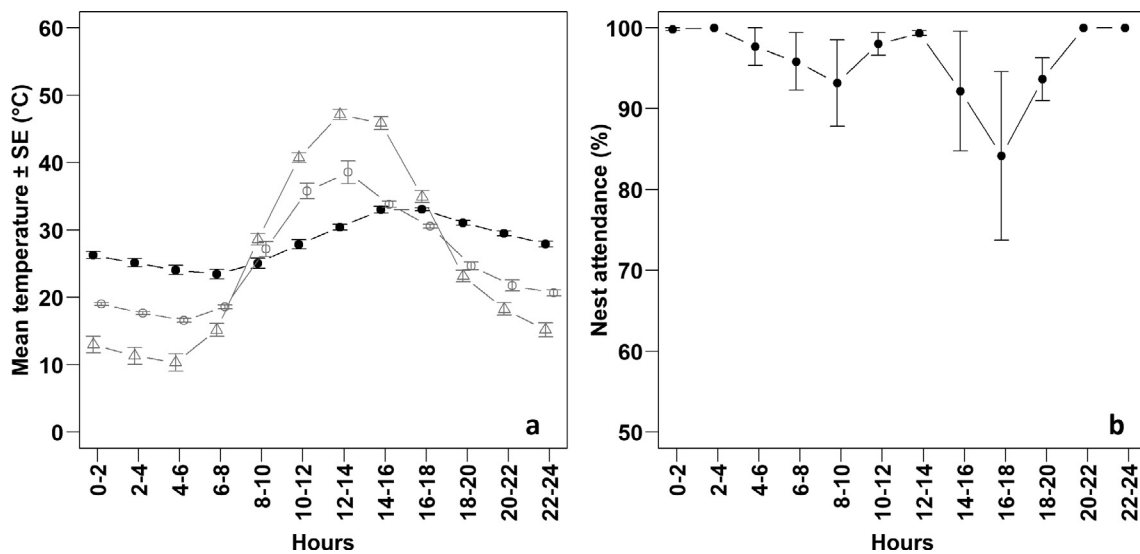


Fig. 4. (a) Ground surface temperature in an open area about 1 m from nests (opened triangle), the temperature under the eggs directly (filled circles) and temperature near the nest under the shrub's shade (opened circles), (b) nest attendance (%), (mean ± SE for each two-hour period).

Table 2

Mixed-effects models of the influence of temperature under shrub on the nest attendance of the Bar-tailed Lark. The average of $T_{\text{underShrub}}$ was included in the models as second-degree orthogonal polynomial, df values are numerator and denominator degrees of freedom, respectively. The influence of T_{ground} on the nest attendance of the Bar-tailed Lark was not significant (p -value > 0.05), and thus the model was removed.

Explanatory variables	Response variable % Nest attendance		
	df	F	P
Time period	11, 9	1.504	0.274
$T_{\text{underShrub}}$	2, 9	0.033	0.968
Time period × $T_{\text{underShrub}}$	22, 9	5.518	0.006

flying due to the prevailing wind that usually blows from the west during the afternoon period.

The current study found that the Bar-tailed Lark nests were surrounded by flattish pebbles, particularly from the eastern and southern sides; this result is partly in line with that mentioned by Jennings (2010), who reported that nests might be bordered by flattish pebbles from one side to support the nest materials.

In this study, the Bar-tailed Lark preferred to nest under shrub trunks, which may help in: 1) camouflaging both nests and incubating parents against predators, as some ground-nesting avian species select sites with a background that better match egg appearance and adult plumage (Fig. 3a and b) (Swaigood et al., 2017; Stevens and Ruxton, 2019); 2) protecting eggs, nestlings and incubating parents from hostile weather conditions (extreme temperatures, direct sunlight and strong winds) (Downs and Ward, 1997; Tieleman et al., 2008; AlRashidi et al., 2011) (Fig. 3a and b).

The mean total nest attendance for the entire day of this species was relatively high compared to a previous study AlRashidi et al. (2011) that carried out on the Kentish Plover (*Charadrius alexandrinus*), a species that breed under a shrub in harsh environments. This may be attributed to the absence of predation risk; no predators were recorded attacking the incubating birds or preying upon eggs and nestlings, and thus Bar-tailed Larks did not need to leave their nests in any specific period to avoid predation risk, in comparison to the Kentish Plovers, which usually leave their nests to distract predators and attract them away from their nests during late evenings (AlRashidi et al., 2011).

In most avian species, when the egg temperature drops below 25 °C, embryonic development stops, and when it exceeds 44 °C, embryos quickly die (Webb, 1987; Carey, 2002; Tieleman et al., 2008); thus Bar-tailed Larks seemed to maintain the eggs at a temperature around 23–33 °C (Fig. 4a). Moreover, they incubated more at night than during the daytime. Temperatures under the shrubs at night fell below 21 °C (Fig. 4a and b), and thus eggs may require warming and parents should increase the nest attendance to prevent the embryos from exposure to the lethal temperatures (Downs and Ward, 1997; Conway and Martin, 2000; Carey, 2002; Brown and Downs, 2003; Olson et al., 2006; DuRant et al., 2013). In addition, a noticeable reduction in nest attendance happened during the period (16:00–18:00 h), this is probably because temperatures were within the optimal temperature for embryo development (Fig. 4a and b) and thus incubating parents may leave their nests to forage (AlRashidi et al., 2010).

5. Conclusion

In conclusion, this study collected baseline data on some aspects of the Bar-tailed Lark breeding ecology in a desert in the north of Saudi Arabia. It provided the first data on the timing of breeding, clutch size, nestling periods, nesting site preferences and nest attendance, allowing a comparison to be made with other populations, particularly those in the Arabian Peninsula. Moreover, this study revealed that some aspects of the breeding ecology of this species in the north of Saudi Arabia seems to differ in some ways from the other patterns reported from elsewhere. Accordingly, future studies are recommended to collect more data on the breeding ecology of this species across its distribution range.

Declaration of Competing Interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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