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Does nest box location and orientation affect occupation rate and breeding success of Barn Owls *Tyto alba* in a semi-arid environment?

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Abstract. To date, nest orientation and location in hole-nesting birds have been studied mainly in temperate regions and in diurnal cavity breeders. Here we studied the effect of exposure, orientation, and habitat on nest box occupation and breeding success of Barn Owls in a semi-arid environment. The occupation of nest boxes varied with exposure and orientation. A higher percentage of occupation and more Barn Owl nestlings per breeding attempt were found in nest boxes located in the shade than in the sun, and in those facing east/north rather than other directions. The temperature in the nest boxes varied, being lowest in those located in the shade and in those facing east. Nest boxes located in crop fields fledged more young per breeding attempt than those located in date plantations. We suggest that the higher nest box occupation and number of nestlings fledged was probably due to the lower temperatures in those boxes, an important factor in a hot/arid environment, although alternative explanations are also considered.

Key words: Barn Owl, *Tyto alba*, nest box, orientation, exposure, semi-arid, occupation, nestlings, breeding success

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Birds may select their nest sites in specific locations and orientations that maximize their chances to breed successfully. For example, east-facing nest cavities are warmed in the morning, north-facing ones receive the least amount of sunlight, and south-facing ones receive the most (Raphael 1985, Dhondt & Philips 2001, Wiebe 2001). Directional preference and avoidance of particular nest sites has been reported mainly in temperate regions (e.g. McEllin 1979, Raphael 1985, Toland & Elder 1987, Plesník 1991, Charter et al. 2007, Goodenough et al. 2008b) and to a lesser extent in arid regions (Austin 1974, 1976), where birds optimize sun exposure (Korol & Hutto 1984, Balgooyen 1990, Hooge et al. 1999, Ardia et al. 2006), thereby lowering incubation costs (Haftorn 1988, Yom-Tov & Wright 1993). Furthermore, offspring quality may also differ in nests according to orientation (Goodenough et al. 2008a).

In addition to nest orientation, exposure to shade versus sunlight may be important in semi-arid environments, with nests receiving direct sunlight reaching higher temperatures (Hartman & Oring 2003, Burton 2007). Secondary cavity breeders are restricted by the nest site selection of primary cavity breeders, thus hindering studies of orientation and location of such secondary cavity nesters using natural cavities. Nest boxes provide an alternative for studying occupation and breeding success.

Barn Owls *Tyto alba* are cosmopolitan secondary cavity breeders that breed in a wide variety of natural cavities, such as holes in trees, caves and man-made structures (Taylor 1994, Meyrom et al. 2008), but also in nest boxes (Taylor 1994), making them an attractive species for study in a semi-arid environment. Furthermore, most studies have dealt with the effect of temperature on nest exposure, location, and orientation in diurnal and not nocturnal cavity breeders. Unlike diurnal cavity breeders, Barn Owl adults spend most of the day time inside the cavities with their nestlings, increasing the possibility of the brood overheating in warmer climates. Here we studied the effect of: (1) exposure, (2) orientation (north, east, south and west), (3) habitat (crop fields vs. date palm plantations) and (4) temperature on nest box occupation and breeding success of Barn Owls located within a relatively small area in an semi-arid environment.

The study site was located in the Beit Shean Valley, Israel (32°30´N, 35°30´E), and 150–250 m below sea level. The climate is semi-arid with maximum and minimum mean daily temperatures (during March and July 1999) of 32.3°C and 16.7°C, respectively, and average yearly rainfall of 267 mm (for 2001 to 2006) (data from Sde Eliyahu Weather Station). The 90 km^2 study area comprised mostly fields of sweet corn, alfalfa, oats, and wheat, and some date palm *Phoenix dactylifera* plantations.

During 2002–2006 between 140 to 235 nest boxes (50 cm wide x 75 cm long x 50 cm high; entrance 25 cm high x 15 cm wide) at a height of 2.5 to 3 m above the ground were available year round for Barn Owls to breed. All the boxes had been introduced into the crop fields and date palm plantations by the farmers as a means of rodent control, with the nest entrances facing towards the crop field. They were monitored yearly.

Active nests (defined as a nest in which eggs were laid, after Steenhof 1987) were determined by visits during the 2002 to 2006 breeding seasons. Data from the first year of nest boxes (first breeding season) were excluded from the analysis because the occupation (breeding attempt) of nest boxes use was significantly lower than in the following years (Meyrom unpubl. data). To prevent pseudoreplication, breeding parameters were calculated as means of the years per nest box so that each nest box was only represented once in each analysis. The mean number of fledglings per nest box constituted the number of live young per breeding attempt found during banding minus the number of dead birds found in the nest boxes after the young had fledged divided by the number of years the nest box was available. Similar to breeding Barn Owls in the USA (Taylor 1994), in Israel too Barn Owls are very sensitive during incubation and abandon clutches when disturbed, so the clutch size of most pairs was unknown and are not presented here.

Orientation (the direction that the nest box entrance faced; north, east, south, or west), exposure (whether it was located in the shade or in the sun), and type of habitat (date plantation or crop fields) were recorded for all nest boxes. Nest boxes in the shade were located under trees and remained shaded throughout the study. Pre-calibrated Thermochron iButtons (Dallas Semiconductor) were placed inside three nest boxes located in the shade and three in the sun from May 25 to June 15, 2004. The data loggers recorded every 20 seconds. Temperature maximum, minimum, and amplitude (maximum minus the minimum divided by 2) were calculated for each day (n = 22). Thermochron iButtons were also placed in seven additional nest boxes, each facing each a different direction (north, east, south, and west) from August 13 to August 15, 2008. The data loggers recorded every 5 seconds.

All statistical tests were two-tailed. Kolmogorov-Smirnov test was used to check normality prior to analyses. Number of fledglings per breeding attempt in relation to the studied parameters were analyzed using three-way ANOVA (GLM). T-test was used to compare between the temperature of nest boxes located in the shade and those exposed to the sun, and one-way ANOVA, followed by Tukey post-hoc test, was used to compare between temperatures of the different orientations. Nest occupation (yes/no) was tested using a logistic regression with the following independent variables: orientation (categorized; north, east, south, west), exposure (categorized; in sun and in shade), habitat (categorized; crop fields, date plantation), year (categorized; 2002–2006) and nestbox ID. Because nestbox ID was not significant in the model it was removed. In each categorized variable the last category (orientation: west, exposure: shade, habitat: date plantation, year: 2006) was set to zero as a reference value. Levels of significance were set at $p < 0.05$. All results are presented as mean ± SE. Statistical analyses were performed using Statistica 8.0 software and SPSS for Windows version 16.

The percentage of nest box occupation significantly varied with exposure and orientation, but not with habitat (Table 1, Fig. 1). Occupation of shaded nest boxes (65.9% ± 0.03%, n = 115) was higher than of exposed nest boxes (53.8% ± 0.03%, n = 113). A negative trend revealed occupation of nest boxes to be higher in north-facing (65.8% ± 0.05%, n = 46), and east-facing (70.1% ± 0.04%, n = 40), than in south-facing

Table 1. Results of logistic regression for nest box occupation by Barn Owls as a function of orientation, exposure, habitat, year and box ID. In each categorized variable the last category was set to zero as a reference value.

Factor	β	SE	df	p value	Exp (β)	Upper CL	Lower CL
Orientation			3.00	< 0.01			
North	0.34	0.23	1.00	0.13	1.41	0.90	2.20
East	0.43	0.24	1.00	0.07	1.54	0.97	2.44
South	-0.17	0.20	1.00	0.40	0.85	0.58	1.25
Exposure — Shaded	0.61	0.16	1.00	< 0.001	1.84	1.34	2.53
Year			4.00	< 0.001			
2002	0.28	0.22	1.00	0.22	1.32	0.85	2.04
2003	0.59	0.22	1.00	< 0.001	1.80	1.17	2.77
2004	1.20	0.23	1.00	< 0.001	3.31	2.13	5.15
2005	0.14	0.20	1.00	0.49	1.15	0.78	1.68
Habitat — Crop field	0.28	0.17	1.00	0.09	1.33	0.96	

(53.7% ± 0.03%, n = 96) and west-facing nest boxes (58.12% ± 0.05%, n = 46). Occupation of nest boxes located in crop fields (61.6% ± 0.03%, n = 157) was not significantly higher than those in date palm plantations (56.0% ± 0.04%, n = 71). A difference was found between percentage of occupation between years and nest box ID (Table 1).

The number of nest boxes that fledged nestlings varied with exposure and habitat, while no significant differences were found between orientations (Table 2, Fig. 2). More nestlings were fledged in shaded nest boxes (3.6 ± 0.2, n = 115) than in exposed ones (3.0 ± 0.2, n = 113); and in nest boxes located in crop fields (3.4 ± 0.1, n = 161) than in date palm plantations (2.9 ± 0.2, n = 71) (Table 2).

Daily temperature amplitude differed between nest boxes located in the shade (mean 7.2°C) and in the sun (mean 9.3°C) ($t = -5.3$, $n = 22$, $p < 0.001$). Likewise, daily minimum (shade: 19.8°C and exposed: 17.4°C) ($t = 6.6$, $n = 22$, $p < 0.001$) and maximum (means 34°C and 36°C,

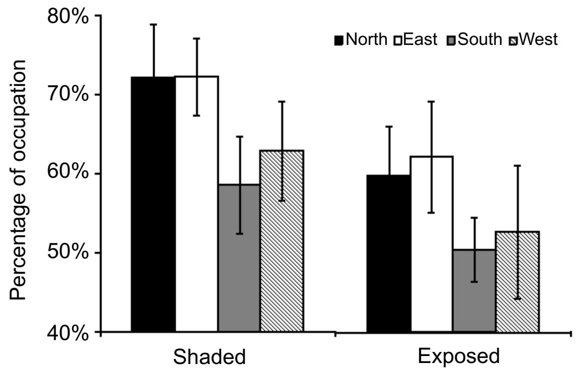

Fig. 1. Nest box occupation as a function of exposure and orientation of the two habitat types. Error bars indicates ± SE. Statistics in Table 2.

respectively) ($t = -2.2$, $n = 22$, $p < 0.05$) temperatures also differed between the two exposures.

The temperature differed among nest boxes facing the different orientations ($F_{3,2436} = 4.2$, $p < 0.01$), with the average temperature of nest boxes facing east (30.2°C) being lower than in those facing south (30.9°C, Tukey test, $p < 0.05$), west (31.0°C , Tukey test, p <0 .05), and north (30.9°C, Tukey test, $p < 0.05$).

Semi-arid environments can reach extremely warm temperatures, which at our study site rose to well above 40°C during the breeding season. Nest boxes placed in locations that conduce to lower internal nest temperatures might be preferred over those with higher temperatures. Even though the data relating to internal temperature were only obtained for three days, those nest boxes located in the shade and those with entrances facing east were clearly shown to have lower temperatures and a higher percentage of occupation. During a heat wave the difference in temperature between nest boxes facing different directions or sun exposures may be only as little as 2°C, but this difference can mean a difference in the survival of nestlings. For example, during a three-day heat wave at the study site in 2002 with temperatures reaching above 45°C, more nestlings died in nest boxes exposed to the sun than in those located in the shade (Aviel unpubl. data). In this study, not only was Barn Owl occupation higher in nest boxes located in the shade but they also fledged more young. Other species have also been shown to prefer shaded nests (Hartman & Oring 2003). Burton (2007) demonstrated an interspecific latitudinal trend by ground-nesting passerines, in which those pairs located at lower latitudes breed more in shaded areas than they do at higher latitudes.

Table 2. Results of three-way ANOVA (GLM) for number of Barn Owl nestlings fledged per breeding attempt as a function of the orientation, exposure and habitat of nest boxes.

Source of variation	df	F	p
Corrected Model	15	1.817	0.034
Orientation	3	1.662	0.176
Exposure	1	8.690	0.004
Habitat	1	9.163	0.003
Orientation*Exposure	3	0.762	0.517
Orientation*Habitat	3	0.891	0.447
Exposure*Habitat	1	1.385	0.240
Orientation*Exposure*Habitat	3	1.143	0.333

Alternatively, Barn Owls may have selected east-facing nest boxes and nest boxes located in the shade because of reduced exposure to prevailing winds (Conner 1975, Balgooyen 1990). If this is the case, our finding contrasts Austin (1974, 1976), who found that Cactus Wren *Campylorhynchus brunneicappilus* occupation and breeding success in nests facing predominating winds was higher, and suggested that this was an adaptation to moderate nest climate. At our study site the effect of wind would be expected to be less in shaded nest boxes than in exposed ones, because the prevailing winds (from the west) bring hot air and thus probably increase nest temperature, although this remains to be tested experimentally.

The percentage of nest boxes occupied by Barn Owls differed among the different directions, probably due to the lower temperatures found in east/north-facing than south/west-facing nest boxes. South/west-facing nest boxes receive the most direct sunlight while east-facing boxes receive direct sunlight only during the morning hours, which may be beneficial to warm the nest

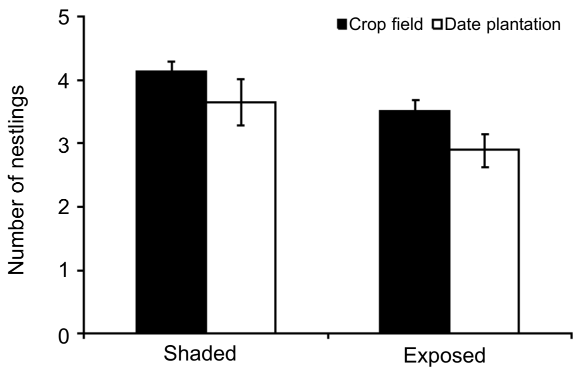

Fig. 2. Number of Barn Owl nestlings as a function of nest box exposure and habitat of the two habitat types. Error bars indicates ± SE. Statistics in Table 2.

sites after the nighttime cold. The Common Kestrel *Falco tinnunculus* from the same region was shown to breed in significantly more east-facing nests in date palm trees (62%) than in nests facing other directions (Charter unpubl. data). The findings of other studies of owls breeding in natural nest cavities and not nest boxes, in semi-arid environments, differ. Elf Owls *Micrathene whitneyi* were found to breed non-randomly in nest sites oriented to the north (Hardy & Morrison 2001), whereas Screech Owls *Otus kennicotti* bred in nest sites randomly in all directions (Hardy & Morrison 2003).

The breeding success of Barn Owls has been reported to differ among habitats, and this was associated mainly with differences in prey abundance (Taylor 1994). The results of the present study also revealed a difference between habitats, with more young fledged in nest boxes located in crop fields than in date plantations. The diet of Barn Owls breeding locally in the different habitats was previously found to differ in this region (Charter et al. 2009), with significantly more Levant Voles *Microtus socialis guentheri*, which are the largest crop pest in Israel, being found in their diet in crop fields than in date plantations. The difference in the number of nestlings was most likely due to the greater abundance of prey in crop fields.

The finding here that the Barn Owls preferred shaded nest boxes with lower temperatures contrasts the findings of some other avian species in temperate zones that were shown to select nest boxes with warmer temperatures (Hooge et al. 1999, Ardia et al. 2006), possibly because in colder climates pairs breeding in warmer cavities may increase their breeding success (Hooge et al. 1999, Wiebe 2001). This is not always the case, however, as Goodenough et al. (2008a,b) found that warm south-west facing nest boxes at their temperate study sites were avoided. The results of the present study, carried out in a semi-arid environment, demonstrate the potential effect of climate on breeding success and nest selection. Further studies in semi-arid environments are needed in order to better understand the effect of wind, and whether orientation and location of nests is species-specific.

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STRESZCZENIE

[Wpływ umieszczenia i ekspozycji skrzynek lęgowych na ich zajmowanie i sukces lęgowy płomykówki w środowisku półpustynnym]

W przypadku dziuplaków wpływ umieszczenia miejsca lęgowego i jego ekspozycji na biologię lęgów badany był głównie w środowiskach klimatu umiarkowanego. W pracy badano jak czynniki te wpływają na lęgi płomykówek gniazdujących na terenach półpustynnych Izraela. W latach 2002–2006 badano zajmowanie skrzynek lęgowych przez te sowy, oraz określano liczbę wyprowadzanych piskląt. Dla każdej skrzynki opisano: orientację otworu wejściowego (jeden z 4 kierunków świata), środowisko (pola uprawne, plantacje daktylowców) oraz czy znajduje się w cieniu czy na słońcu. Zmierzono również temperatury panujące wewnątrz skrzynek. W analizach, dla danej skrzynki brano pod uwagę średnią wyliczoną dla lat, w których była ona dostępna dla ptaków.

Stwierdzono, że skrzynki lęgowe umieszczone w cieniu i te skierowane na północ lub wschód były częściej zajmowane i z nich płomykówki wyprowadzały więcej piskląt (Tab. 1, 2; Fig. 1, 2). Ze skrzynek znajdujących się przy polach uprawnych sowy wyprowadzały więcej młodych niż z tych przy plantacjach daktylowców (Tab. 2; Fig. 2). Temperatury panujące w skrzynkach odznaczały się dużą amplitudą, ale najniższe stwierdzano w skrzynkach znajdujących się w cieniu, oraz tych skierowanych na wschód.

Preferowanie miejsce lęgowych o niższych temperaturach (przeciwnie niż w dotychczasowych pracach) jest związane ze specyfiką klimatu.