Nest characteristics affect microclimate and breeding success of lesser kestrel *Falco naumanni* in the Gela plain

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Summary / Microclimate is an important factor for nest site selection and it influences breeding success. Secondary-cavity nesters are compelled by nest site availability to select existing nest structures to optimize microclimate conditions. The lesser kestrel is a colonial raptor breeding in pseudo-steppe habitats. It does not build a nest but breeds under roof tiles or wall crevices of rural buildings. We studied 45 nest sites in five lesser kestrel *Falco naumanni* colonies located in the Gela Plain (Sicily). We measured microclimate by placing thermo loggers inside nests so that we could record temperature and relative humidity every hour, from laying to fledging period. Our results revealed a significant effect of nest orientation and nest type on the relative humidity, with the highest values in nests under tiles placed in N-NW sides. Temperature was higher in hole nests than in those under tiles. Nest orientation and nest type created a specific microclimate that affected the reproductive outcome. In particular, a nest under tiles in a S-SE side had a higher hatching success while a nest in a hole in a S-SE side had a higher chance to produce more fledglings.

Riassunto / Il microclima è un importante aspetto della selezione del sito di nidificazione e influenza il successo riproduttivo. Specie che non costruiscono il nido ma usano strutture preesistenti (*secondary-cavity nesters*) sono particolarmente limitate dalla disponibilità del sito riproduttivo poiché obbligate a selezionare strutture già esistenti al fine di ottimizzare le condizioni microclimatiche. Il grillaio è un rapace coloniale che nidifica in habitat pseudo-steppici. Nidifica sotto le tegole dei tetti o nei buchi di edifici rurali abbandonati. In questo lavoro abbiamo studiato 45 nidi in cinque colonie di grillaio situate nella Piana di Gela. Il microclima del nido è stato rilevato inserendo dei sensori termici, in modo da registrare temperatura e umidità relativa ogni ora del giorno, dalla deposizione delle uova all'involo dei pulcini. I risultati rivelano un effetto dell'esposizione e della tipologia di nido sull'umidità relativa con i valori più alti nei nidi sotto le tegole esposte a N-NO mentre la temperatura risulta più alta nei buchi rispetto alle tegole. L'esposizione e la tipologia di nido creano uno specifico microclima che sembra influenzare il successo riproduttivo. In particolare, un nido sotto le tegole esposte a S-SE presenta un maggiore tasso di schiusa mentre un nido in un buco esposto a S-SE invola più pulcini.

Introduction

Specific microclimate within the nest (i.e. temperature and humidity) is an important factor driving nest site selection and might influence breeding success (Martin 1998; Lloyd & Martin 2004). Some birds seem to actively choose certain cavities but not all birds build their own nests (Robert *et al.* 2010). Secondary-cavity nesters are compelled by nest site availability to select existing nest structures that minimize predation pressures while protecting eggs and chicks against climatic variations (Sarà *et al.* 2012). Such species may optimize microclimate by selecting specific nest sites characterized by specific exposures associated with suitable thermal characteristics. Several studies have in fact shown the importance of nest location and orientation with regard to solar radiation (e.g. Lloyd & Martin 2004). Nest microclimate can have important influences on parental reproduction in secondary cavity nesting birds. The lesser kestrel *Falco naumanni* is a small raptor breeding in colonies of variable size

(2-60 pairs, Catry *et al.* 2011; Sarà 2010) in pseudo-steppe habitats, choosing its hole-nest in cliffs, under roof tiles or wall crevices of rural buildings (Di Maggio *et al.* 2013). It does not build a nest but lays its eggs directly on the cavity floor after scraping the substrate. This species, former considered vulnerable, has recently changed its conservation status to "least concern", due to conservation actions in part of its range (Iñigo & Barov 2011). Also, the Gela plain lesser kestrel population, the largest in Sicily, has grown consistently over the last decade (Sarà 2010). In this species little is known about the effects of nest thermal characteristics on reproductive success, so the aims of this study are: 1) to determine the relationship between microclimate and nest site characteristics; 2) to evaluate whether and how nest site characteristics affects lesser kestrel breeding success.

Methods

The Gela plain, located in south-eastern Sicily (Italy, 378070N, 148190E), is one of the largest plains in Italy (about 474 km^2). Due to limited precipitation (350 mm/year), the agricultural landscape is composed of a mosaic of pseudo-steppes dominated by artichoke *Cynara* spp. fields and non-irrigated crops. Across the plain, numerous rural buildings, often partially destroyed or abandoned, host lesser kestrel nests (Di Maggio *et al.* 2014). Each colony is usually composed of a single building, or two or more small houses very close, but with different sides.

The study was conducted in 2010, from April to July. We studied 45 nests in five lesser kestrel colonies of different size. Colonies were located within two different areas of the plain: the core area, where the surface of all cropland land uses was $\geq$50 % within a radius of 500 m around the colony and an altitude between $0 \leq 100$ m a.s.l and the edge, where the cropland area was < 50% and the altitude > 100 m a.s.l. We measured nest microclimate by setting thermo loggers, so that temperature and relative humidity of the nest were recorded each day every hour, from the laying (April-May) to the fledging period (June-July). Each nest was checked at least 3-4 times in order to record the number of eggs and nestlings and then to measure hatching and fledging rates.

We used a generalized linear mixed model (GLMM, McCullagh & Searle 2000) with a normal distribution and an identity link function to describe the relationship between microclimate and the following features: 1) colony location, 2) nest-type and 3) nest orientation. Moreover, we used a second GLMM to test the relationship between hatching and fledging rate and nest characteristics. In both analyses we included colony and nest identities as random effects.

Discussion

Our results revealed a significant effect of nest type (tiles or wall holes) on the temperature inside nests with higher temperatures in holes than under tiles (Fig. 1, Tab. 1). Furthermore, we recorded an effect of nest orientation and nest type on the relative humidity with the highest values in nests under tiles placed in N-NW sides (Figg. 2 - 3, Tab. 2). We did not find any effect of the colony location on both temperature and relative humidity (Tab. 1 - 2), and this result suggested that differences in habitat and topography (i.e. altitude) did not reflect a relevant change in microclimate inside nests.

Nest orientation and type determined when and for how long a nest is exposed to direct solar radiation and wind. Additionally, nest orientation largely determined temperature and humidity within the nest. Other factors (e.g., parent presence or number of chicks) are warranted of further investigation for their potential effect on microclimate. Nest orientation and nest type resulted in a specific microclimate, affecting the reproductive success. In particular, a nest under tiles in a S-SE building side would have a higher hatching success (GLMM, $F_{side} = 3.114$, $P < 0.001$, $F_{type} = 63.87$, $P < 0.001$); additionally a nest in a hole in a S-SE side had a higher chance to produce more fledglings (GLMM, $F_{side} = 9.569$, $P < 0.001$, $F_{type} = 5.634$, $P < 0.001$; Figg. 4 - 5). Nest type and nest exposure compensate humidity, as a drier nest type (hole) in a wetter side (N-NW) should have the same relative humidity than the reverse combination (tile nest in dry S-SE side). Nest site characteristics (i.e. type and orientation) have in turn a strong impact on reproductive success through their effects on microclimate. This latter could in conclusion minimize thermal requirements of eggs and nestlings and improve reproductive success.

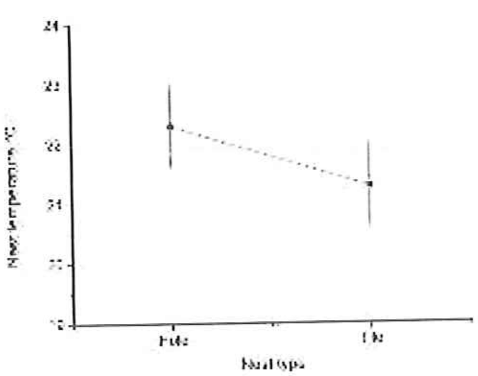

Figure 1: Temperature inside lesser kestrel nests as a function of nest type (GLMM, N = 45)

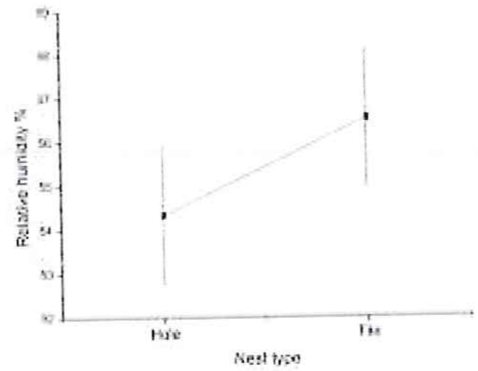

Figure 2: Relative humidity inside lesser kestrel nests as a function of nest type (GLMM, N = 45)

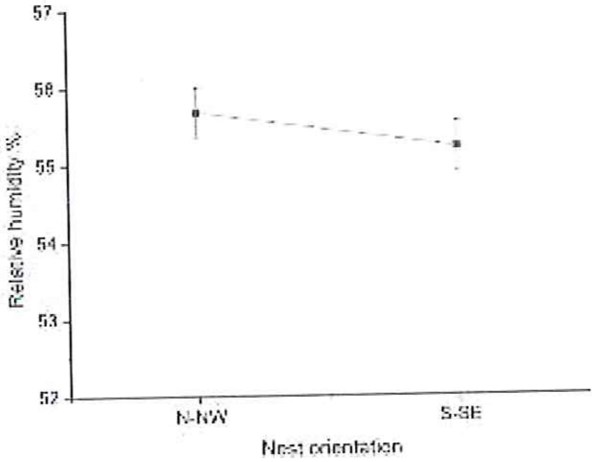

Figure 3: Relative humidity inside lesser kestrel nests as a function of nest orientation (GLMM, N = 45)

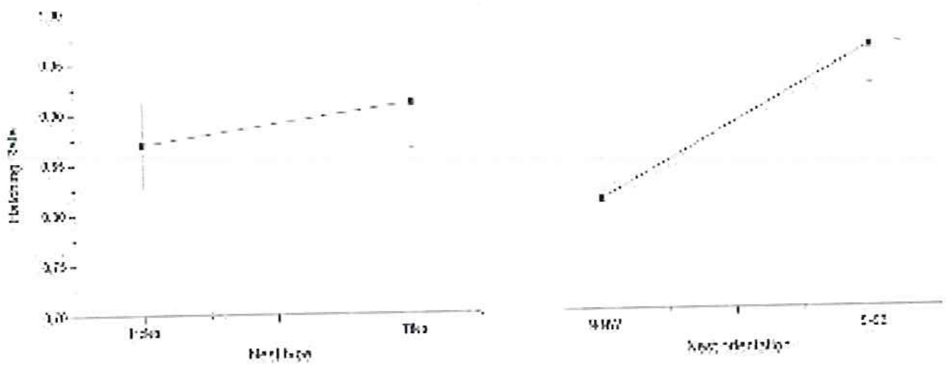

Figure 4: Hatching rate of lesser kestrel as a function of nest type and nest orientation (GLMM, N = 45)

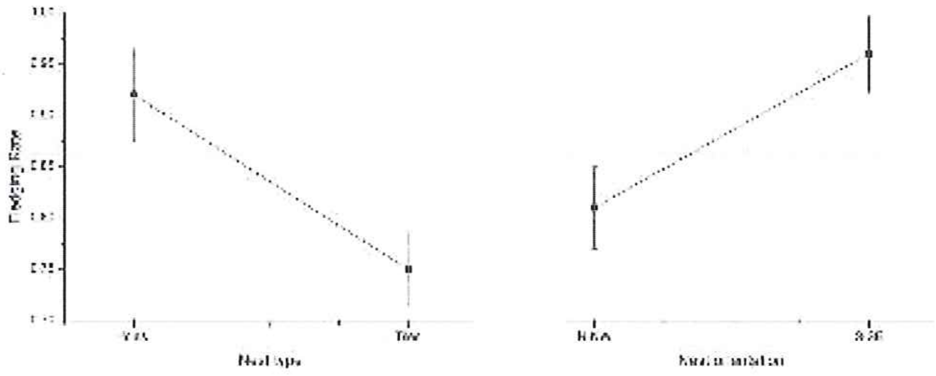

Figure 5: Fledging rate of lesser kestrel as a function of nest type and nest orientation (GLMM, N = 45)

Explanatory variable	Parameter estimate	F	P
Intercept	20.588		1.000
Colony location	0.483	1.628	0.202
Nest type	1.242	612.208	**< 0.001**
Nest orientation	0.073	3.614	0.570

Table 1: Effects of colony location, nest type and nest orientation on temperature (°C) measured inside lesser kestrel nests (GLMM, N = 45). In bold variables that significantly predicted nest temperatures

Explanatory variable	Parameter estimate	F	P
Intercept	51.922		0.999
Colony location	-0.892	0.445	0.505
Nest type	-2.557	293.127	**< 0.001**
Nest orientation	6.366	30.905	**< 0.001**

Table 2: Effects of colony location, nest type and nest orientation on relative humidity (%) measured inside lesser kestrel nests (GLMM, N = 45). In bold: variables that significantly predicted relative humidity

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