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Article

Detected foraging strategies and consequent conservation policies of the Lesser Kestrel *Falco naumanni* in Southern Italy

Marco Gustin[1], **Alessandro Ferrarini** [2], **Giuseppe Giglio**[1], **Stefania Caterina Pellegrino**[1], **Annagrazia Frassanito**[3]

[1]LIPU (Lega Italiana Protezione Uccelli) - BirdLife International, Conservation Department, Via Udine 3, I-43100 Parma, Italy
[2]Department of Evolutionary and Functional Biology, University of Parma, Via G. Saragat 4, I-43100 Parma, Italy
[3]Alta Murgia National Park, via Firenze 10, 70024, Gravina in Puglia, Bari, Italy
E-mail: sgtpm@libero.it, alessandro.ferrarini@unipr.it

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Abstract

The reduction in both the extent and quality of foraging habitats is considered the primary cause of the Lesser Kestrel *Falco naumanni* population decline. A proper knowledge of Lesser Kestrel's foraging habitat selection at local scale is necessary for its conservation. Using accurate GPS devices, we investigated the patterns of local movements and land-cover type selection of 9 Lesser Kestrels in the main colony in Italy (Alta Murgia National Park, Gravina in Puglia and the surrounding rural areas) during the hatching period. The goals of our work were to individuate: 1) the preferred foraging habitats, 2) the potential sexual divergences in foraging movements and in 3) foraging habitat selection, 4) the relationship between foraging movements and the spatial arrangement of land codes. We detected significant sexual divergences in foraging movements and habitat selection. Lesser Kestrels preferred pseudo-steppes and significantly avoided ligneous crops and forested areas. While males selected positively pseudo-steppes, females used both pseudo-steppes and cereals in proportion to their availability. Foraging selection was influenced by the interplay between the spatial arrangement of land codes and the sexual divergences in foraging strategies. On the basis of our results, we have been able to propose suitable local-scale conservation actions to the Alta Murgia National Park and to the local administrations: a) the enlargements of the park's boundaries; b) the purchasing of land parcels; c) the provision of suitable nesting sites near the higher quality areas; d) the optimal timing for harvesting. Our study is the first contribution to the assessment of the foraging strategies and the necessary conservation policies of the Lesser Kestrel in Southern Italy.

Keywords Alta Murgia National Park; data-loggers; foraging movements; hatching period; sexual divergences; special protection area.

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1 Introduction

Resource selection studies are commonly conducted because it is generally assumed that if animals select habitat disproportionately to their availability, that habitat improves their fitness, reproduction and survival (Stephens and Krebs, 1986). From foraging theory strategy, it’s also known that if land cover change causes impoverishment and/or loss of preferred hunting habitats, a species would obtain a lesser hunting yields, with direct implications for its conservation.

Changes in land-use, both with concurrent aspects of global change, have a strong impact on the structure of biological communities (Gil-Tena et al., 2009). Many species of conservation interest in Europe are considered associated with traditional farm landscapes and the semi-natural habitats they produce and maintain (Tucker and Evans, 1997). Land abandonment has been an important land-use change in recent decades (Ostermann, 1998). The decrease in farming mainly affected the least productive agricultural land, and activated the recovery of semi-natural vegetation (Sirami et al., 2008). In most of the Mediterranean region, land abandonment has occurred during the last century, leading to the naturalization and vegetation closure of many areas, thus favouring the spread of forests (Debussche et al., 1999). This caused a decrease of open grassland-like habitats and an increase in shrubland and, on the long-term, woodland cover (Romero-Calcerrada and Perry, 2004), thus determining a decline of species tied to open habitats (Suárez-Seoane et al., 2002; Sirami et al., 2007), in particular migrant species associated with open farmland habitats (Sirami et al., 2008). On the other hand, agricultural intensification and abandonment of traditional farming had dramatic impacts on farmland birds (Donald et al., 2001), in particular on the quality of foraging patches and food availability (Donázar et al., 1993), thus affecting species’ fitness components such as the number of offspring that parents are able to raise (Tella et al., 1998).

In the past, the reduction in quality and extent of foraging habitats has been the primary cause of decline for Lesser Kestrel (Negro, 1997; Peet and Gallo-Orsi, 2000). Extensive cereal fields, fallows, pasturelands and field margins in agricultural areas are usually considered the main habitats used by this species for foraging (Cramp and Simmons, 1980; Donázar et al., 1993; Tella et al., 1998). Arthropod abundance is usually higher in these types of land-use (Martínez, 1994; Moreira, 1999). On the other hand, for hunters such as the Lesser Kestrel, access to prey is also affected by vegetation structure (Shrubb, 1980; Toland, 1987), in particular by land cover offering shelter to prey, and height which obstructs hunting manoeuvres. This may explain why they usually avoid hunting in habitat patches with taller vegetation cover, such as abandoned crop fields or shrublands (Tella et al., 1998). In addition, the species has declined markedly in the last decades also because of agricultural intensification and pesticide use, which affected their foraging habitats and food availability (Parr et al., 1995; Bustamante, 1997; Tella et al., 1998; BirdLife International, 2004).

Despite the urgent need for the conservation of this species, at present little is known about foraging habitat selection of Lesser Kestrels in Italy (Sarà 2010). Due to this reason, in this paper we investigate the patterns of land-cover type selection of Lesser Kestrels in the main colony in Italy (Alta Murgia National Park, Gravina in Puglia and the surrounding rural areas) during the hatching period. The goals of our work were to individuate preferred foraging habitats within and outside the Alta Murgia National Park, and explore the hypothesis of potential foraging divergences with regard to sex. In fact, sexual differences in foraging habitat selection can be hypothesized to arise as a consequence of two necessities for females during the hatching period, i.e. spending as much time as possible in parental care and limiting energy requirements for foraging movements. No studies focus on this topic for Lesser Kestrels yet, but sexual divergences in foraging selection might have important consequences on conservation strategies for this species.

We also explored if the relationship between the Lesser Kestrel's foraging movements and the spatial arrangement of habitats may influence the foraging habitat selection. Based on our results, several management policies are proposed for the conservation of this important species in Italy.

2 Materials and Methods

2.1 Study area

The study area (Fig. 1) corresponds to the Alta Murgia National Park and the SPA (Special Protection Area) “Murgia Alta” IT9120007 (Apulia, Southern Italy) and is included within the IBA (Important Bird Area) “Murge” (Heath and Evans, 2000). It comprehends the main colony of Lesser Kestrels in Italy (Bux et al. 2008, Gustin et al., 2014), i.e. the town of Gravina in Puglia and the surrounding rural areas.

2.2 Study species

Lesser Kestrel is a migratory, colonial, small (body length 29–32 cm, wingspan 58–72 cm) falcon breeding mainly in holes and crevices in large historic buildings within towns and villages, or often in abandoned farm houses scattered across the countryside (Negro, 1997). The Lesser Kestrel is primarily insectivorous, feeding mainly on beetles, myriapods and grasshoppers (Franco and Andrada, 1977; Kok et al., 2000). It inhabits steppe-like ecosystems around the Mediterranean and central Asia. In Western Europe it is mainly a summer visitor, migrating to Africa in winter (Rodríguez et al., 2009). Today Lesser Kestrel is considered a “least concern” species (BirdLife International, 2013; Gustin et al., 2014).

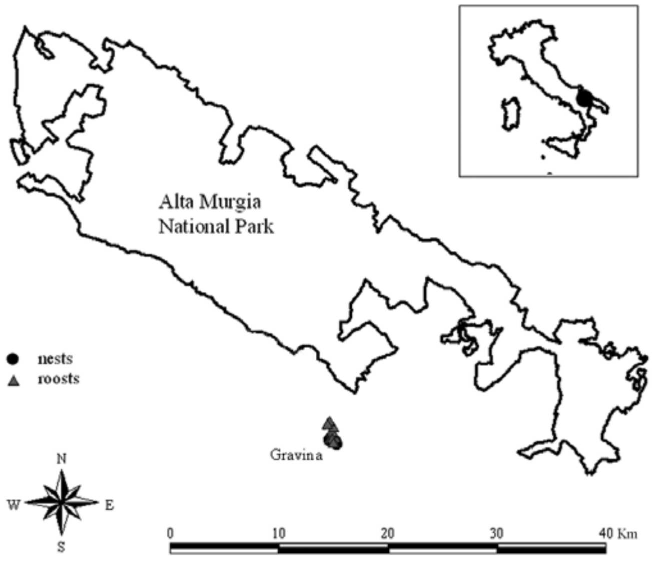

Fig. 1 Study area (Gravina in Puglia and Alta Murgia National Park; Apulia, Italy), nests and roosts. The study area corresponds to the SPA (Special Protection Area) “Murgia Alta” IT9120007 and is included within the IBA (Important Bird Area) “Murge”.

2.3 Data sampling

Nine individuals (4 males and 5 females) were surveyed in a period of 20 days from June 20th to July 9th 2012 in the colony of Gravina in Puglia. Surveys were conducted using TechnoSmart GiPSy-4 data-loggers (backpack harness; 23x15x6 mm; total weight: 1.8 g plus 3.2 g battery), that provided for each GPS point information about date (dd/mm/yyyy), local time (hh:mm:ss), latitude (degrees-minutes-seconds), longitude (degrees-minutes-seconds), altitude (meters above mean sea level) and instantaneous speed (km/h). Data acquisition occurred every 5 minutes during two time periods: day (08:00-19:00 H local time) and night (02:00-06:00 H local time). In situ surveys allowed us to locate nests and roosts used by the observed individuals. Birds were captured at their nest boxes when they were delivering food to their nestlings and fitted with data-loggers. To download the data from the data-loggers, birds were recaptured at their nest boxes after batteries were exhausted three days later.

2.4 Data analyses

GPS data were imported into the GIS GRASS (Neteler and Mitasova, 2008). Layers used for the subsequent analyses were: a) boundaries of the Alta Murgia National Park, b) land cover at 1:10,000 scale (provided by the Apulia Region), c) digital terrain model (DTM) of the study area (digitized at 1:10,000 scale by the authors from available topographic maps of Apulia Region), d) nest and roost locations.

We estimated home-ranges using fixed kernel estimators (Worton, 1989) at 95% isopleth, which were calculated with least-squares cross-validation and adjusted to extreme locations (Worton, 1989). The 95% isopleth (HR95 from now on) is most widely used in the literature and represented the full home range.

Foraging points (FP) have been individuated using two steps. First, for each GPS point we achieved flight height above ground level (a.g.l. hereafter) by subtracting terrain elevation (indicated by DTM) from altitude a.s.l. (provided by data-loggers). Second, among the GPS points having flight height a.g.l. equal to 0, we chose only those ones having an instantaneous speed (provided by GPS) equal to 0. We privileged this conservative approach rather than using also GPS points with low instantaneous speed (e.g., less than 1 or 2 km/h) because we preferred to miss some FP rather than being at risk of including also non-foraging points. These two steps allowed us to detect locations of the study area where Lesser Kestrels remained motionless at ground level (i.e., instantaneous speed and flight height a.g.l. equal to 0). Detected FP thence represented strike attempts (i.e., strikes in which the bird landed on the ground), not necessarily successful captures. For the purposes of this work we considered that strike attempts were a type of foraging habitat selection.

Foraging habitat selection was investigated at the following levels:

a) FP as compared to habitat availability in HR95;
b) male FP as compared to habitat availability in HR95;
c) female FP as compared to habitat availability in HR95.

Thomas and Taylor (1990) distinguished three types of use-availability design used in the studies of habitat and resource selection. In design I studies, the animals are not identified; the habitat use and availability are measured at the scale of the population. In design II studies, the animals are identified and the use is measured for each one, however, the availability is measured at the scale of population. In design III studies, the animals are identified and both the use and the availability are measured for each one. The choice of the proper use-availability design can be evaluated only in reference to a specific data set and a specified model (Hurlbert, 1984). In order to decide which type of design to use, we applied the pairwise test of multiple associations (Janson and Vegelius, 1981; Ludwig and Reynolds, 1988). The pairwise test is based on a chi-squared test between all possible pairs of point patterns selected for comparisons. Yates correction factor has been calculated to account for bias resulting from cases of low cell frequencies. These tests were applied to both the whole set of GPS points (for testing association in space use, and thence in resource availability) and FP (for testing association in resource use during foraging activities).

Last, in order to evaluate forage habitat selection in relation to availability (i.e., the disproportionate use of some foraging areas over others when compared to what was available), we used a chi-square goodness-of-fit test with Bonferroni simultaneous confidence intervals (Neu et al., 1974; Byers et al., 1984). We avoided compositional analysis (Aebischer et al., 1993) because it is preferable when the number of individuals is at least equal to the number of habitat classes (Cherry, 1996).

All the statistical analyses were considered significant for *P*<0.05.

3 Results

The monitoring period amounted to 311 hours (3726 GPS locations), of which 116 hours (1389 GPS points) for females and 195 (2337 GPS points) for males. Lesser Kestrels flew 3674.2 km in total, of which 966.5 due to females and 2707.7 to males. A total of 329 FP were detected and considered for successive analyses, of which 179 belonged to females (mean±SD: 35.80 ± 3.56) and 150 to males (mean ± SD: 37.50 ± 4.04).

Pairwise tests of multiple associations on space use (Table 1) suggested to measure the availability at the scale of population. In fact, all the 36 pairwise comparisons resulted positive, and 19 out of 36 were statistically significant (*P*<0.05). Instead, pairwise tests on feeding sites suggested to consider resource use separately for each Lesser Kestrel (Table 1). In fact, only 5 significant (*P*<0.05) positive associations remained, and many associations resulted negative (of which 5 were significant; *P*<0.05). Hence, a design II study (i.e., the use is measured for each animal, however the availability is measured at the scale of population) resulted most appropriate for our case study.

HR95 (35,503.07 hectares; Fig. 2) resulted prevalently composed of non-irrigated arable lands (AL; 24,852.8 hectares, 70.00% of HR95; Table 2) and pseudo-steppes (PS; 3936.1 hectares, 11.09%). Human settlements (1041.5 ha) cover about 3% of HR95.

The type of land-use most frequently utilized by foraging Lesser Kestrels (Table 3) was AL (214 FP; 65.05%), followed by PS (97 FP; 29.48%), NG (5 FP; 1.52%), HS (4 FP; 1.22%) and, to a lesser extent, the remaining codes. These differences between the number of foraging attempts in relation to land-use types were statistically significant (χ^2 = 940.89, d.f. = 9, *P*<0.001).

Table 1 Results of the pairwise tests of multiple associations on space use (3726 GPS points) and resource use (i.e., foraging sites; 329 GPS points) for the 9 surveyed lesser kestrels. The first column indicates the sex of the 9 individuals (F: female; M: male).

	Sex	1	2	3	4	5	6	7	8	9
Space use	F	▨	++	++	++	++	+	+	+	+
	F		▨	++	+	++	+	+	++	+
	F			▨	++	++	+	++	+	+
	F				▨	++	+	+	+	++
	F					▨	+	++	++	+
	M						▨	++	++	+
	M							▨	++	++
	M								▨	++
	M									▨
Resource use	F	▨	+	+	++	+	+	-	--	-
	F		▨	++	+	+	-	+	-	--
	F			▨	+	++	-	--	-	+
	F				▨	+	-	-	+	--
	F					▨	--	+	+	-
	M						▨	+	++	+
	M							▨	+	+
	M								▨	++
	M									▨

++ positive association (P<0.05); + positive association (P >0.05); - negative association (P >0.05); -- negative association (P <0.05).

Table 2 Description of the landcover types present in the lesser kestrel's home-range (35,503.07 hectares). For each code, the extent and the percentage with regard to the home-range are given.

Code	Description	Hectares	%
HS	continuous and discontinuous urban fabric, agricultural farms, mineral extraction sites	1041.5	2.93
AL	non-irrigated arable lands (cereals in particular, but also legumes, fodder crops, root crops, fallow land)	24,852.8	70.00
LC	ligneous crops (vineyards, fruit trees, olive groves)	1824.8	5.14
PS	pseudo-steppes (dry grassland grazed extensively by livestock herds)	3936.1	11.09
FO	broad-leaved forests, coniferous forests, mixed forests	3119.2	8.79
NG	natural grasslands	333.0	0.94
SV	sclerophylous vegetation	47.5	0.13
TR	transitional woodland/shrubs	274.1	0.77
BR	bare rocks	69.1	0.19
WA	water bodies and courses (including banks)	5.0	0.01

Table 3 Resulting foraging land use (number of feeding sites in the different landcover types) separately for the 4 male and the 5 female lesser kestrels under study. See Table 2 for the explanation of landcover codes.

ID	Sex	HS	AL	LC	PS	FO	NG	SV	TR	BR	WA
1	F	1	29	0	8	0	1	0	0	0	0
2	F	0	23	1	5	0	1	0	0	0	0
3	F	1	28	0	7	0	0	1	0	0	0
4	F	1	24	0	8	0	1	0	0	1	0
5	F	0	29	1	6	1	0	0	1	0	0
6	M	0	21	0	12	0	1	0	0	0	0
7	M	1	21	0	19	0	0	0	1	0	1
8	M	0	20	0	18	0	0	0	0	0	0
9	M	0	19	0	14	0	1	0	0	0	1

Considering all the individuals under study, 7 land codes were used in proportion to their availability (HS, AL, NG, SV, TR, BR, WA; Table 4), while breeding kestrels positively selected PS ($P < 0.001$), and significantly avoided LC ($P < 0.05$) and FO ($P < 0.05$). When considering only female Lesser Kestrels, 8 land codes were used in proportion to their availability (HS, AL, PS, NG, SV, TR, BR, WA; Table 4), while LC ($P < 0.05$) and FO ($P < 0.05$) were significantly avoided. When considering only male Lesser Kestrels, 5 land codes were significantly avoided ($P < 0.05$; HS, AL, LC, FO, BR; Table 4), PS were positively selected ($P < 0.001$) while the remaining codes were used in proportion to their availability.

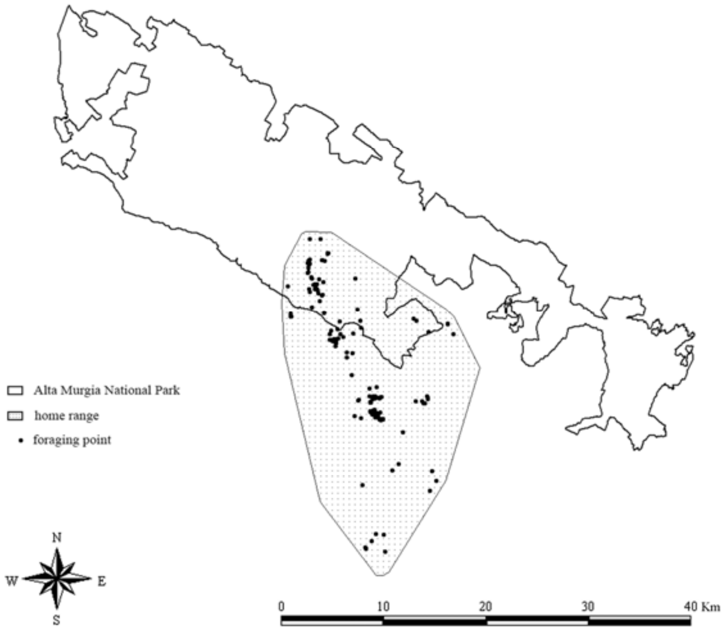

Fig. 2 The Lesser Kestrel's home range (95% isopleth; 35,503.07 hectares) and the detected 329 foraging points are shown. A design II study (i.e., the use is measured for each animal, however the availability is measured at the scale of population) resulted most appropriate for our case study.

Table 4 Foraging land code selection measured through Bonferroni simultaneous confidence intervals for: a) all individuals, b) only females, c) only males.

All	**Land code**	**Lower**	**Upper**	**Available**	**Selection**	**df**	**Prob**
	HS	0.000	0.034	0.029			
	AL	0.574	0.721	0.700			
	LC	0.000	0.018	0.051	avoid	9	$P < 0.05$
	PS	0.224	0.365	0.111	prefer	9	$P < 0.001$
	FO	0.000	0.012	0.088	avoid	9	$P < 0.05$
	NG	0.000	0.034	0.009			
	SV	0.000	0.018	0.001			
	TR	0.000	0.018	0.008			
	BR	0.000	0.012	0.002			
	WA	0.000	0.012	0.000			

Females	**Land code**	**Lower**	**Upper**	**Available**	**Selection**	**df**	**Prob**
	HS	0.000	0.044	0.029			
	AL	0.651	0.835	0.700			
	LC	0.000	0.033	0.051	avoid	9	$P < 0.05$
	PS	0.108	0.272	0.111			
	FO	0.000	0.021	0.088	avoid	9	$P < 0.05$
	NG	0.000	0.044	0.009			
	SV	0.000	0.021	0.001			
	TR	0.000	0.021	0.008			
	BR	0.000	0.021	0.002			
	WA	0.000	0.000	0.000			

Males	**Land code**	**Lower**	**Upper**	**Available**	**Selection**	**df**	**Prob**
	HS	0.000	0.025	0.029	avoid	9	$P < 0.05$
	AL	0.426	0.654	0.700	avoid	9	$P < 0.05$
	LC	0.000	0.000	0.051	avoid	9	$P < 0.05$
	PS	0.307	0.533	0.111	prefer	9	$P < 0.001$
	FO	0.000	0.000	0.088	avoid	9	$P < 0.05$
	NG	0.000	0.040	0.009			
	SV	0.000	0.025	0.001			
	TR	0.000	0.025	0.008			
	BR	0.000	0.000	0.002	avoid	9	$P < 0.05$
	WA	0.000	0.025	0.000			

The two most important cover types for Lesser Kestrels' foraging requirements (PS and AL) have a different spatial configuration within HR95 (Fig. 3). AL present fewer patches (274 vs. 346) with larger extension (mean ± SD: 90.70 ha ± 938.56 vs. 11.37 ha ± 66.21, $t = 2.160$, $P < 0.05$) and lower distance from the colony (mean ± SD: 7245 m ± 3200 vs. 11,278 m ± 3350, $t = -15.182$, $P < 0.001$).

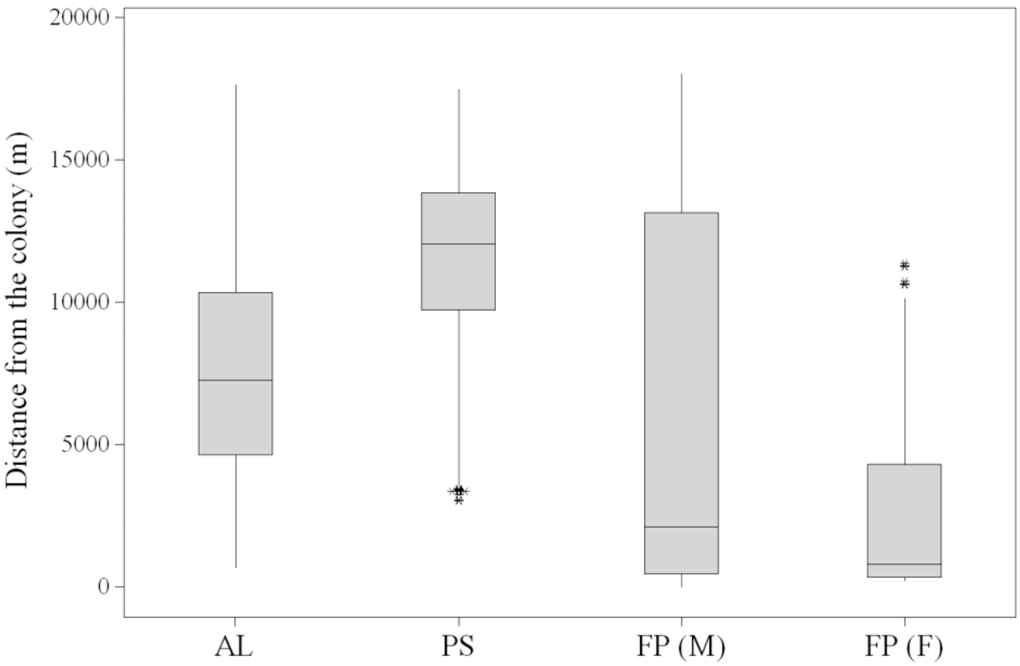

Fig. 3 Boxplots of distances (in m) from Lesser Kestrels' colony of: a) patches (GIS polygons) of non-irrigated arable land (AL), b) patches of pseudo-steppes (PS), c) male foraging points FP (M), d) female foraging points FP (F).

During the monitoring period, distance from nest (measured on 2337 GPS points for males and on 1389 GPS points for females, using a repeated measures ANOVA) resulted significantly higher for males than for females (mean ± SD: 6.209 km ± 5.085 vs. 2.752 km ± 3.234, $F = 21.674$, $P < 0.01$). When considering only the 329 FP (150 for males and 179 for females), using a repeated measures ANOVA distance from nest resulted significantly higher for males than for females (mean ± SD: 6.972 km ± 6.522 vs. 2.496 km ± 3.328, $F = 7.837$, $P < 0.01$; Fig. 3).

4 Discussion

4.1 Sexual divergences in Lesser Kestrels' movements

Comparisons between home-ranges and distances travelled by female and male Lesser Kestrels are present in other studies as well (Catry et al., 2013; Tella et al., 1998). These studies have presented contradictory findings, in some cases females showed smaller home-ranges but not in all cases.

We have found clear sexual divergences in Lesser Kestrels' movements during the monitoring period. Distance from nest was about 2.25 times higher for male than for females. When considering only foraging points, distance from nest was about 2.8 higher for males than for females. GPS data also revealed a higher amount of total movements for males (2707.7 km vs. 966.5 km). Hence, male movements have been more frequent and more long-range than female ones. This is likely due to the fact that we focussed our study on the hatching period, and not on the whole nestling one.

Owing to budgetary requirements of time and energy for reproduction and parental care, an upper limit to female flight activities during the hatching period was expected as a consequence of two necessities: a) spending as much time as possible in parental care, b) limiting energy requirements for resource acquisition. In fact, although among Lesser Kestrels males and females both feed the chicks along the chick rearing period until chick emancipation, in the first days after hatching the female stays longer periods with the chicks.

During 2012, in the study area 77 nests surveyed by the authors had a clutch of 3.79 ± 0.82 eggs. We might expect that any sex divergence in Lesser Kestrel's foraging behaviour was the product of their respective ways to optimize the relationship between resource acquisition and reproductive activity (Emlen and Oring, 1977). Sexual divergences in reproductive role were expected to translate into significant divergences in movements patterns and resource use between males and females, at least during the hatching period.

The distances travelled by Lesser Kestrels also suggest that in the study area the foraging habitat is not good. In fact, several authors have found values of less than 3 km away from colony when agriculture in the surround of the colony of Lesser Kestrel was non-intensive (Bustamante, 1997; Tella et al., 1998). When favourable habitat is available in the surroundings of the colony, foraging distances are small and males and females may probably use the same fields to hunt (Catry et al., 2013; Tella et al., 1998). If the preferred habitat around the colony is scarce, birds are expected to move further distances, and this is the case when differences between males and females arise.

4.2 Lesser Kestrel's foraging habitat selection

In our study area, Lesser Kestrels seem to prefer PS for foraging activities, suggesting that preys are more accessible or more frequent in this land-use category. In the study area, these dry grasslands with scant trees and flat relief present extensive cereal crop cultivation with harvested field that remain uncultivated for one or more years (short-medium fallow), and are grazed by livestock herds. Livestock produces optimal conditions for Lesser Kestrels' breeding activity by making vegetation shorter and less dense, hence facilitating the access to prey for Lesser Kestrels.

We also found that AL (cereals to a great extent, but also legumes, fodder crops, root crops and fallow land) were used in proportion to their availability by Lesser Kestrels, and avoided by males. Avoidance of cereals was also found by Ursúa et al. (2005) in the Ebro valley (North-East Spain). Therefore, our results confirm this behaviour as a general pattern in the species. One possible explanation is that vegetation structure of cereals makes foraging in this habitat complex at this time of year, since AL are denser and taller than PS, and they might offer shelter to prey and/or obstruct hunting manoeuvres (Shrubb, 1980; Toland, 1987) hence reducing access to prey for kestrels. In addition, in our study area, the use of biocides and fertilizers within AL is common, which could have a negative affect on the abundance of insect prey, making this habitat less suitable as hunting grounds for kestrels (BirdLife International, 2004; BirdLife International, 2013).

Avoidance of LC (olive groves, vineyards and fruit trees) and FO by foraging birds could be easily expected for an open-habitat raptor such us the Lesser Kestrel, as it has been previously shown (e.g., Tella et al., 1998). The 4 FP detected in HS were due to agricultural farms, as we were able to control on the digital orthophotos of the study area provided by the Apulia Region.

The spatial distribution of PS and AL around the colony of Gravina is very dissimilar, with AL patches significantly closer that PS ones. Although PS represent about 11% of HR95, they are almost exclusively within the boundaries of the Alta Murgia National Park (2876.7 hectares out of 3936.1; Fig. 4) that is more than 5 km distant from the colony.

In the remaining portion of the Lesser Kestrel's HR95, PS have been almost completely replaced by AL, FO and LC in the recent past. Agricultural expansion, that determined the increase of AL and LC, both with the abandonment of marginally cultivated areas, that led to the progressive colonization by natural vegetation (NG, SV and TR firstly, and FO secondly), have strongly reduced PS in the study area.

This has influenced the foraging selection by females (Fig. 3), since PS are almost completely absent, or at least rather rare, in the smaller area surveyed by females (Fig. 4). In fact, 50% of female FP are less than 650 m distant from the colony, and only 19 female FP have been detected at a distance greater than 5 km. This suggests that females, because of their greater effort in hatching activities, must be content with the kind of foraging habitat they can accomplish within a reasonable distance from the colony. Males, instead, are less limited in their foraging efforts during the hatching period, thus they can select more distant habitats. Hence male Lesser Kestrels reveal the kind of more suitable habitat for foraging, independently of further limitations.

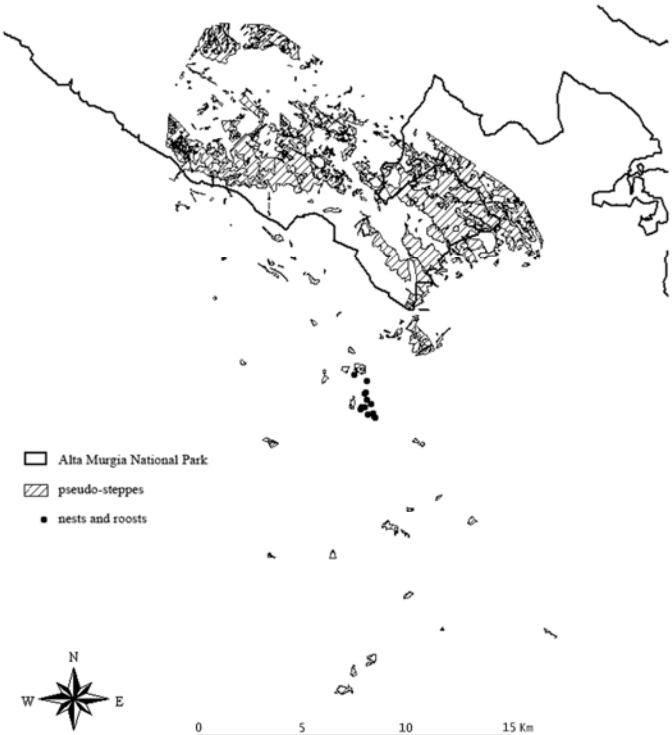

Fig. 4 Spatial configuration of the pseudo-steppes in the lesser kestrel's home range. Although pseudo-steppes represent about 11% of the home-range, they are almost exclusively within the boundaries of the Alta Murgia National Park (2876.7 hectares out of 3936.1) that is more than 5 km distant from the colony. In the remaining portion of lesser kestrel's home-range, pseudo-steppes have been almost completely replaced by arable lands, forests and ligneous crops in the recent past.

4.3 Implications for conservation

The first consequence of our results for management is that, during the hatching period, females are more vulnerable than males, due to time-consuming parental care to offspring. Thus, conservation policies in the study area should prevalently boost females rather than males. Since 50% of the FP for females were found within 650 meters from the colony of Gravina (hence outside the Alta Murgia National Park), it follows that conservation measures need to be more restrictive within that radius, and must consist of two main actions: a) preserving all the patches at PS present, b) maintain non-intensive agriculture in AL as much as possible. The first objective can be achieved by purchasing the few land parcels at PS using funds from the Apulia Regional Plan for Rural Development 2014-2020. The cost of land parcels at PS is very low in the study area (about 1700 EURs per hectare; source: Apulia Regional Plan for Rural Development 2007-2013), therefore this management policy is highly feasible. The second objective is less easy to accomplish, but it can be achieved using incentives to farmers through funds from the Apulia Regional Plan for Rural Development 2014-2020 or from the European Union.

The second implication is that PS are the most important habitat for the maintenance of the species in the study area. PS can be found almost exclusively within the National Park, this demonstrating the importance of this institution for the preservation of the Lesser Kestrel. However, many other patches at PS are within a radius of few hundred meters from the boundary of the National Park. Hence, few small enlargements of the park’s boundaries would result in the automatic preservation of hundreds of hectares at PS included in colony’s HR95. This management option has already been indicated by the authors to the managers of the Alta Murgia National Park, who in turn are discussing this topic with the municipality of Gravina and the Apulia Region. It's clear that a further action is required to fully preserve the existing PS outside the park, and in particular in the home range of the species.

The third implication for conservation planning is that Lesser Kestrels are forced to fly even 17 km away from the colony to find food. This reveals that in the neighbourhood of the colony, intensive agriculture is present that makes AL less attractive for foraging, as confirmed by our field surveys. As it seems unfeasible from an economic viewpoint the distribution of incentives to maintain traditional agriculture over all the home range (about 35,000 ha), the only feasible solution seems to be the creation of an ecological network of small patches at PS in the Lesser Kestrel’s home range, in order to maintain suitable areas for foraging at distances not too prohibitive for females, and energetically favourable for males. The most suitable land codes for this kind of conversion to PS are NG and SV, which together total around 380 hectares, and whose acquisition cost in the study area is rather low (about 1000 EURs per hectare; source: Apulia Regional Plan for Rural Development 2007-2013). Furthermore, about 25 hectares out of 380 are within 650 m from the colony, hence being of particular interest for the conservation of female Lesser Kestrels. A further useful conservation action is the provision of suitable nesting sites near the higher quality areas (i.e. PS) individuated in this study (Pérez et al., 2011).

Last, the pattern of cereal rotation means that the landscape around the colony is modified every breeding season, influencing individual foraging decisions and patch use. Several authors (Donázar et al., 1993; Catry et al., 2011) have highlighted the differences in foraging opportunities presented by each of the three cereal stages (cereal, fields being harvested and stubble) and its impact on breeding success. During harvest, cereals become a quality foraging habitat owing to an increase in prey accessibility caused by the sudden removal of vegetation cover. The sequence in which patches are harvested influences the total amount of food delivered to chicks and annual breeding success. The considerable impact of the timing in which cereal patches are harvested highlights the interacting effect of spatial and temporal resource dynamics, which are likely to affect the foraging and breeding success of Lesser Kestrels. Thus, ideally the cereals in the study area should be harvested on a rotation covering the period of chick growth to maximise food abundance.

5 Concluding Remarks

In this study, focussed on the hatching period, we detected: a) the preferred foraging habitats for the Lesser Kestrel within and outside the Alta Murgia National Park in Italy, b) the sexual divergences in foraging movements and in c) foraging habitat selection, d) the relationship between foraging movements and the spatial arrangement of habitats in the study area.

Although the detected Lesser Kestrel's behaviour resulted rather clear, it was achieved in a specific period (i.e., 20 days of the hatching period when the species is particularly vulnerable) when female Lesser Kestrels remain a long time brooding the chicks, thus this could not be representative of the whole nestling period. For this reason, in accord with the Alta Murgia National park we have already planned to extend our monitoring efforts to the whole nestling period in 2014 and 2015. In order to detect if sexual divergences in foraging selection of Lesser Kestrels are a prerogative of the reproductive period, we are planning to extend our surveys to the pre-reproductive period as well.

Despite these limitations, our study is the first contribution to the assessment of the foraging strategies and the necessary conservation policies for the Lesser Kestrel in Southern Italy.

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