Article

Nocturnal flights lead to collision risk with power lines and wind farms in Lesser Kestrels: a preliminary assessment through GPS tracking

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Abstract

We present here the first report about Lesser Kestrels' flight height behaviour and potential collision risk with wind farms and power lines in two colonies (Gravina in Puglia and Altamura; Apulia, Italy) that present the highest density of Lesser Kestrels worldwide in urban areas. Using accurate GPS data-loggers on nine Lesser Kestrels, we collected data on flight activities during the nestling period. The tracked Lesser Kestrels spent 50% of the monitoring time at heights above ground level (AGL) lower than 41 m, and 75% of time below 98 m AGL. Flight heights resulted not significantly different between the two colonies. Instead, at night Lesser Kestrels resulted to fly at significantly lower altitudes than in the daytime. Our findings, although preliminary, underline the potential collision risk with power lines and wind farms at night in the Lesser Kestrels' colony of Gravina in Puglia. Instead, collision risk resulted negligible during the daytime for both colonies. We conclude that the disappearing of pseudo-steppes in the study area is forcing Lesser Kestrels to flight also at night for foraging purposes during the breading season, which in turn leads to an increased risk of collision with power lines and wind farms.

Keywords Altamura; bio-logging, daytime vs. night-time; *Falco naumanni*; Gravina in Puglia; flight height above ground level.

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1 Introduction

The flight height behaviour of birds has become a focus of applied research, in particular in the context of collision risks with wind farms and power lines (Marques et al., 2014; Costantini et al., 2016). Estimates of birds' collision mortality due to wind farms worldwide range from 0 to almost 40 deaths per turbine per year

(Marques et al., 2014). Rubolini et al. (2005) compiled a list of species that were found among power line victims in Italy, based on over 1,300 reported casualties; overall, 95 species of birds were reported among power line victims (19% of Italy's total species).

A detailed knowledge of flight heights is necessary to assess the potential collision risk of birds with wind farms and power lines. We analyze here the Lesser Kestrels' flight height behaviour and the potential collision risk with these structures in two main colonies in Italy (Altamura and Gravina in Puglia; province of Bari, Apulia region). The Lesser Kestrel *Falco naumanni* is a small falcon that declined considerably in the last decades because of agricultural intensification and use of pesticide which impacted its foraging habitats (BirdLife International, 2004). It is present among Annex I species of EU Wild Birds Directive (2009/147/EEC) and it is classified as SPEC 3 (Species of European Conservation Concern, level 3) according to BirdLife International (2017); it is also a priority species in steppic habitats and arable lands.

The colonies included in this study area are the largest in Italy (in 2013, Gravina in Puglia had about 2600 Lesser Kestrels and Altamura approximately 2500 individuals; Gustin et al., 2013) and have been widely studied so far (Gustin et al., 2014; Gustin et al., 2014b, 2014c; Giglio et al., 2016; Ferrarini et al., 2017; Gustin et al., 2017; Gustin et al., 2017b, 2017c). This area has probably the highest density of Lesser Kestrels in urban areas worldwide. Since wind farms and power lines are present in the study area and Lesser Kestrels show elevated flight activity (Gustin et al., 2017) even at night (Gustin et al., 2014; Gustin et al., 2017b) during the breeding period, it was interesting to estimate, at least preliminarily, the potential collision risk with these infrastructures.

Using accurate GPS data-loggers, we collected data about Lesser Kestrels' flight heights, and made a comparison between the two colonies and between daytime and night-time. We then superimposed the GPS data about Lesser Kestrels' flight activities to the map of detected wind farms and power lines, and commented results in terms of potential collision risk and conservation strategies for the Lesser Kestrels in the study area.

2 Materials and Methods

The study area (Fig. 1) is within the SPA (Special Protection Area) "Murgia Alta" IT9120007, and is included within the IBA (Important Bird Area) "Murge". Nine Lesser Kestrels were surveyed in the period from 15 June to 8 July 2013, corresponding to the most critical part of the chick-rearing period. Daytime started at 6:00 A.M. local time and finished at 9:00 P.M. local time (data from the Meteorological Office of the Apulia Region).

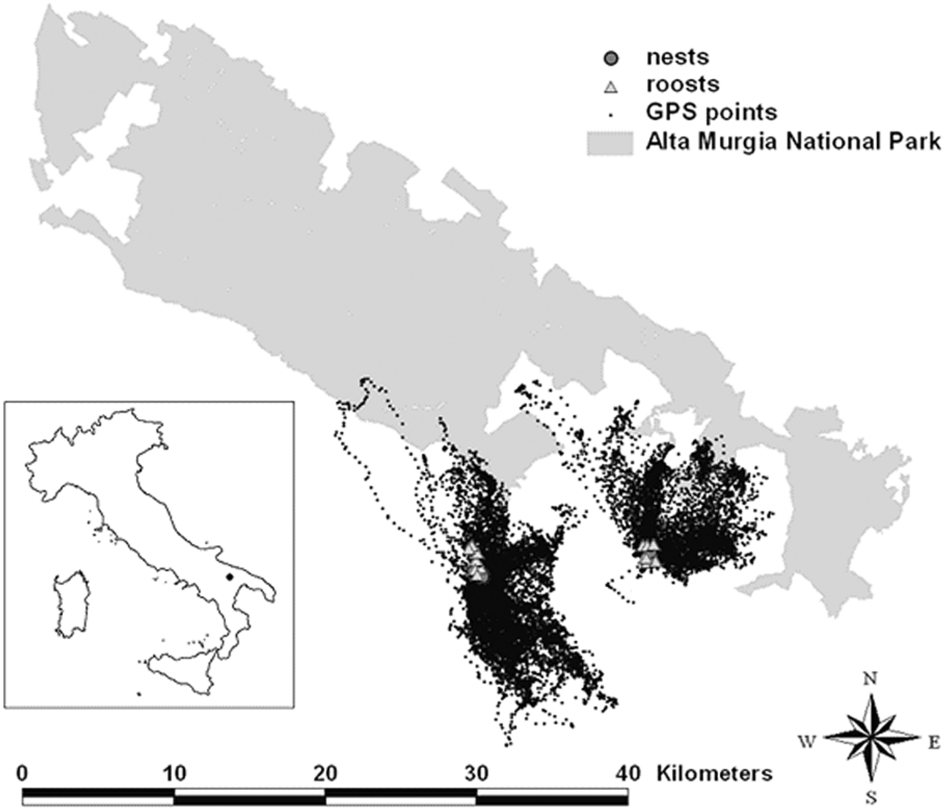

Fig. 1 Colonies (Gravina in Puglia on the left and Altamura on the right; Apulia region, Italy). Alta Murgia National Park, nests, roosts and GPS points of the tracked Lesser Kestrels are shown.

We used TechnoSmart GiPSy-4 data-loggers (23×15×6 mm, 5 g weight), that provided information about date, time, latitude, longitude, altitude and instantaneous speed. Birds were captured and fitted with data loggers at their nest boxes while they were feeding their chicks. We carefully selected only adult Lesser Kestrels in fit health conditions. The ratio of logger weight to body weight was less than 4% for all of the individuals, which is consistent with the widely accepted 3-5% rule. All devices were tied dorsally to the base of two central tail feathers (Fig. 2). The deployment of transmitters did not take more than 15 minutes. On average, battery duration was 3-4 days using 1-minute fix. To download the data from the data-loggers, birds were recaptured at their nest boxes after batteries were exhausted.

During the tracking period, almost 93% of GPS points were linked to 6-8 satellites. In these favorable conditions, errors associated to the measurement of flight heights were in the order of ± 4-6 m (Giacomo Dell’omo, TechnoSmart; personal communication). About 6% of GPS fixes received signals from 5 satellites. Only about 400 GPS points, linked to less than 5 satellites, were discarded because measurement errors of flight heights were in the order of ± 20-25 m (Giacomo Dell’omo, TechnoSmart; personal communication).

Fig. 2 We used TechnoSmart GiPSy-4 data-loggers (23×15×6 mm, 5 g weight) that provided information about date, time, latitude, longitude, altitude and instantaneous speed.

GPS data (Fig. 1) were imported into GIS and superimposed on the terrain elevation of the study area digitized at 1:2,000 scale by the authors from the available topographic maps of Apulia Region. For each GPS point, flight height above ground level (in meters; H AGL hereafter) was calculated by subtracting terrain elevation a.s.l. from flight height a.s.l. (provided by data-loggers). In order to delimitate the study area, we also estimated the two colony home-ranges. As individual home-ranges in the two colonies were highly overlapping, we pooled data from all individuals (n_1= 4 for Altamura, n_2= 5 for Gravina in Puglia). We used fixed kernel estimators at 99% isopleth calculated with least-squares cross-validation (Worton, 1989). Kernel estimators are popular home-range analysis tools because they are non-parametric and robust to autocorrelation. Positions and heights AGL of wind farms and power lines in the study area were detected during field work.

GPS data were analyzed using a repeated measure ANOVA with H AGL as response variable, individual Lesser Kestrels as (random) subject variable, colonies as (fixed) between factor variables and time as (fixed) within factor. We used the Mauchly's statistic to test the assumption of sphericity in order to avoid Type I error, i.e. the likelihood of detecting a statistically significant result when there isn't one. Tests were considered significant for $P < 0.05$.

3 Results

The monitoring effort for the nine individuals amounted to about 686 hours, 261.6 hours for the 4 Lesser Kestrels of Altamura and 423.8 hours for the 5 individuals of Gravina in Puglia.

Table 1 Summary statistics of Lesser Kestrels' flight heights (in meters above ground level) with respect to between (colonies) and within (time) factors. Flight height equal to 0 indicates Lesser Kestrels at ground. In order to avoid possible outliers, we chose the 95th percentile as maximum flight height.

	Altamura	**Gravina in Puglia**	**Day-time**	**Night-time**
N. of tracked individuals	4	5	9	9
N. of GPS points	15,699	25,405	27,684	13,420
Mean	112	95	126	50
Std. Dev.	307	210	279	172
Minimum	0	0	0	0
5th percentile	0	0	0	0
10th percentile	0	0	0	0
25th percentile	18	15	20	9
50th percentile	41	41	58	28
75th percentile	94	98	133	50
90th percentile	250	224	299	87
95th percentile	448	349	465	124

Descriptive statistics (Table 1) show that in both colonies Lesser Kestrels spent 50% of the monitoring time below 41 m AGL and 75% below 98 m AGL. The 95th percentile of H AGL was less than 450 m AGL in both colonies. Descriptive statistics show dissimilar flight height behaviors between daytime and night-time. At night (13,420 GPS points), Lesser Kestrels spent 50% of the monitoring time below 29 m AGL and 90% below 87 m AGL. The highest H AGL recorded at night was 124 m AGL (Table 1). The median H AGL during the daytime (27,684 GPS points) resulted about twice as the H AGL at night (58 m vs. 28 m; Table 1).

Mauchly's test proved that the sphericity assumption could be held in repeated measures ANOVA (Table 2). The comparison between the two colonies showed no significant differences (Table 2). Instead, time (daytime vs. night-time) resulted significant (P = 0.011). We found no significant interaction among time and colonies (Table 2).

Table 2 Inferential statistics (repeated measures ANOVA) of Lesser Kestrels' flight heights with respect to between (colonies) and within (time) factors and interaction term.

Source term	DF	Sum of Squares	Mean Square	F-Ratio	Prob. Level
BETWEEN					
Colony (Altamura vs. Gravina)	1	2.86E-06	2.86E-06	0	1.000
WITHIN					
Time (day vs. night)	1	3.29E+07	3.29E+07	15.85	0.011*
INTERACTION TERM					
Colony x Time	1	538430.2	538430.2	0.26	0.632

* $P < 0.05$
Mauchly's test of sphericity: $P > 0.10$

The most elevated H AGL (i.e. 30 m AGL) between power lines' and wind farms' heights present in the two home-ranges was retained as safety H AGL for the species in the study area. At night Lesser Kestrels spent 50.9% of the monitoring time (6841 GPS points out of 13,420) at H AGL below this safety H AGL. If we only consider the colony of Gravina in Puglia at night, this value increases to 54.6% (4468 GPS points out of 8182). Instead, in the daytime Lesser Kestrels spent 67.8% of time (18,774 GPS points out of 27,684) above this safety H AGL.

4 Discussion

In the daytime the Lesser Kestrels can respond to a possible collision risk adapting their behaviour, and thus mitigating risks thanks to the favorable visibility conditions. The elevated flight heights AGL detected during the daytime further suggest that Lesser Kestrels' collision risk with existing wind farms and power lines is negligible. In the daytime the Lesser Kestrels can also make advantageous use of power lines for both perching and catching preys ("sitting-and-waiting" strategy). In addition, distances between wires generally prevent electrocution risk for Lesser Kestrels, in fact it is much more common for long-winged species (Bevanger, 1998) which can make contact with two phases simultaneously.

On the contrary, our results show that at night Lesser Kestrels spent about 50% of the tracking time (approximately 32% in the daytime) at H AGL below the detected safety H AGL. They are used to make widespread nocturnal flights in the study area in both low light (i.e. close to sunset and close to sunrise) and no light conditions (Gustin et al., 2014; Gustin et al., 2017b) and, as shown in this study, they fly at significantly lower altitudes than in the daytime, probably because the nocturnal hunting of beetles, myriapods and grasshoppers is more difficult than in the daytime when visibility is much more elevated. The study area at night is almost completely unlighted with the exception of the two towns of Gravina and Altamura and few farmhouses in the countryside, thus Lesser Kestrels' collision risk at night is further increased by low visibility conditions. The different collision risk at night between the two colonies is only due to the different density (higher for the Lesser Kestrels' colony of Gravina) of wind farms and power lines, and not to different flight height behaviors, as shown in this study.

Our findings underline the potential collision risk with power lines and wind farms at night for the Lesser Kestrels' colony of Gravina in Puglia. These results might be useful to the local administrations for good early planning of future infrastructures in order to minimize Lesser Kestrels' collision risk in this area. Optimal sitting of new wind farms and power lines outside the detected home-ranges of the two colonies seems a feasible choice. Placement of a small number of larger wind farms and power lines, rather than numerous small ones, is a further feasible option (Marques et al., 2014).

The disappearing of pseudo-steppes in the study area is forcing Lesser Kestrels to flight also at night during the breading season for foraging purposes (Gustin et al., 2014; Gustin et al., 2017b). In fact, pseudo-steppes are the most important habitat for the maintenance of this species (Gustin et al., 2014c). In the study area, pseudo-steppes are almost exclusively within the boundaries of the Alta Murgia National Park (Gustin et al., 2014c), i.e. more than 6 km distant from the two colonies. In the remaining portion of the study area, pseudo-steppes have been almost completely replaced in the recent past by non-irrigated arable lands, broad-leaved forests, coniferous forests, mixed forests and ligneous crops. In addition, in the neighbourhood of the two colonies, intensive agriculture made harvested patches a short-lived habitat, as cereals are converted into low-quality stubbles with consequent decline in prey abundance. The reduction in both the extent and quality of foraging habitats is most likely to force Lesser Kestrels to flight long distances even at night during the breeding season (Gustin et al., 2017b). This, in turn, has led to an increased collision risk with power lines and wind farms. A better conservation of pseudo-steppe habitats is thus a necessary step to lower Lesser Kestrels' collision risk in the study area.

Our findings are only preliminary. They are limited to the municipalities of Gravina in Puglia and Altamura, but a higher density of wind farms in the study area is present in the municipality of Minervino, which lies several km north of Gravina in Puglia. A detailed study of Lesser Kestrels' flight behaviour through GPS data and the assessment of collision risk in this municipality is necessary. In addition, in this study we have adopted a cost-effective approach based on GPS data, where we have studied collision risk as a result of Lesser Kestrels' flight behaviour and infrastructure positions and heights. A step forward is required to compute collision probability based on mathematical modelling using many variables in input for each power line and wind farm like, for instance, tower heights, blade length and number of birds flying close to infrastructures (Band et al., 2007).

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