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Nest site characteristics and habitat preferences of the Kestrel (*Falco tinnunculus*) in a Mediterranean urban area

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The typical habitat of the Eurasian Kestrel (*Falco tinnunculus*) is mainly rocky and farmland areas provided that a quantity of nests is available on quarries or rural buildings. Since Kestrels reach high density also in some European cities, urban habitats represent a model to study the effect of fragmentation, loss of original habitats, and human disturbance on consistent populations of this vulnerable species declining in farmland Europe.

In the historic centre of Rome, nest sites were located 20.5 ± 8.6 m on average from the floor and showed a predominant south-east exposition. Stepwise discriminant function analysis carried out on 25 habitat proportion variables in occupied and random plots provided a model based on proportion of ruderal areas and green areas. No habitat fragmentation variables neither vegetation structure and composition variables entered a discriminant model. Using all the variables, proportion of ruderal areas and green areas provided a discriminant model that correctly classified 82% of cases. Urban Kestrels selected a habitat configuration that includes a quantity of suitable nest sites and open areas suitable for hunting lizards and insects, which are their primary prey in Rome. Protection measures in urban areas should concern nest conservation in old man-made structures and Roman ruins rather than the protection of patches of original landscape.

Key words: Kestrel, *Falco tinnunculus*, nest characteristics, habitat preferences, urban area, Rome.

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1. Introduction

In Europe, birds are largely sensitive to human activities and disturbance (TUCKER & HEATH 1994) which mainly lead to the reduction of forest cover and changes in agricultural practices from traditional to intensive cultivation (SCARASCIA-MUGNOZZA et al. 2000). The development of urban areas causes a further alteration in the original landscape (GILBERT 1989) which promotes habitat loss and fragmentation with a concomitant reduction of green corridors among suitable patches (MORTBERG 2001).

With a range extended across the Palearctic region, the Kestrel (*Falco tinnunculus*) is a typical inhabitant of rocky montane and farmland areas, always with some vertical structures like rock faces, quarries or buildings (VILLAGE 1990, HAGEMEIJER & BLAIR 1997). Foraging open areas typically border the rocky areas or are intermixed with them. The Kestrel is declining in a wide part of its European range, the reasons for the species' decline including agricultural changes and nest site loss (TUCKER & HEATH 1994). More information is needed about the influence of landscape variables such as amount of suitable habitat, habitat patch size, and the effects of fragmentation of habitat patches on territory occupation.

Kestrels were found common in urban areas where they colonise old buildings, ruins, churches, even in the city centre (SALVATI et al. 1999). Urban landscape offers some favourable conditions for breeding (e.g. milder climate, nest availability), but human activities increase disturbance and habitat fragmentation (MORTBERG 2001). Therefore, birds that live in urban habitats allow to study the effect of fragmentation, loss of original habitats, and human disturbance on their breeding populations. I investigated the characteristics of Kestrel nest sites and the composition of areas around them using habitat proportion, fragmentation, vegetation, and wood structure variables in Rome, Italy, and contrasted landscape composition associated with randomly selected sites from the same area. Assessing habitat thresholds in territory occupation may suggest recommendations adequate to create or maintain areas suitable for nesting in highly fragmented landscapes.

2. Methods

I conducted field-work from March 1995 to July 2001 in inner Rome, Latium, in central Italy (41°53' N, 12°28' E). The climate is characterised by three months of summer drought and the annual precipitation averaged 700 mm. The historic centre of Rome (≈17 km²) is an interspersion of ancient and modern built-up areas, small gardens, and ruderal areas. Vegetation of urban gardens includes pines (*Pinus pinea*), cypresses (*Cupressus sempervirens*), cedars (*Cedrus* spec.), and isolated oaks (*Quercus* spp.) (SALVATI et al. 1999).

Kestrel pairs breed regularly in scaffolding holes and eaves of old buildings, churches, and Roman ruins (SALVATI et al. 1999). I performed visits during winter to map suitable nests using 1:1000 and 1.10,000 maps, aerial photographs and photos taken from panoramic spots. I searched cavities in man-made structures, including modern and ancient buildings and roman ruins. Active nests were checked searching for adults seen incubating or carrying food and young seen or heard at the nest. Observation of adults entering or leaving nests, nuptial displays, territorial flights, and collection of pellets, prey remains, and feathers, often confirmed nest occupation. Owing to their architectural complexity all facades of ancient buildings and roman ruins were examined from many points of view using more panoramic sites and visiting courtyards and terraces to locate nests also on the internal facades. Suitable cavities near the occupied ones were checked to reveal possible close nesting with the contemporary occurrence at the nest of adults and young of two or more neighbouring pairs (SALVATI et al. 1999). Broadcasting of the calls of adult male and female allowed me to confirm the occupation of some secretive cavities especially in close nesting (SALVATI et al. 2000). Distribution of pairs is scattered throughout the historic centre, with density ranging from ~ 3 territories/km² in the archaeological park to ~ 0.5 territories/km² in modern districts (SALVATI et al. 1999, SALVATI 2001). The size of measurement plots (~ 30 ha) was therefore chosen as resembling the minimum available area per territory, calculated as 1/maximum territory density (see below).

I regarded as potential nests those holes having an external opening larger than 100 cm² (length x breadth) and more than 20 cm deep. Due to the impossibility to reach and measure many nests located at the top of old buildings, I prefer to classify holes into four categories, according to the approximate measure of their width and depth: (i) holes with opening < 400 cm² and deep < 30 cm; (ii) holes with opening < 400 cm² and deep > 30 cm; (iii) holes with opening > 400 cm² and deep < 30 cm; (iv) holes with opening > 400 cm² and deep > 30 cm. I measured hole height and maximum height of each nest building by using a clinometer, a compass, and 1:1000 photographic maps of the historic centre of Rome. The orientation of the opening was measured as well. Wind direction and speed were obtained from the meteorological station of „Ufficio Centrale di Ecologia Agraria – Collegio Romano" which is in the centre of the study area. Nest availability was obtained in 15 man made structures of different size by counting all available scaffolding holes (e.g. COLOMBO & GALEOTTI 1993). These buildings were chosen because their holes have about the same opening dimension. A Spearman rank correlation test was used to correlate the number of available cavities and the number of Kestrel nests in each building sampled.

To describe habitat conditions at occupied nesting areas and random sites, I chose stable nests with occupation ≥ 3 years located in the historic centre of Rome. Overall, I identified thirteen occupied nesting areas where I sampled habitat conditions within a 300 m radius circle (28.8 ha) centred over each nest. I generated twenty-one identical circular plots around randomly chosen locations in the remaining part of the historic centre to estimate available habitats. None of the random plots overlapped with occupied nesting areas.

I described territory characteristics using 25 variables (see Table 2). Surface areas covered by different habitat types in each plot were identified on aerial photographs and with field verification were drawn on a 1:1000 map and measured by dot grid in hectares. Habitat and tree species diversity were calculated using the Shannon-Weaver index. Patchiness was calculated as the total number of patches divided by the number of habitats in each plot. Vegetation structure and composition were measured in both occupied and control plots by means of circular plots located at random but always placed at least 10 m inside a boundary for a total of 53 vegetation plots. The number of vegetation plots in each territory or random area was chosen according to their total surface of wooded area; multiple plots were used when the wooded area exceeded 1 ha. I sampled vegetation using a modification of the circular sample-plot method (JAMES & SHUGART 1970). I recorded tree number, height (using a clinometer), and diameter at breast height (using a dbh measuring tape) of all woody plants more than 5 m tall within a 20 m radius circular plot.

The mean values of all variables measured in occupied plots and in random sites were compared by means of two-tailed t-tests. Stepwise discriminant function analysis (DFA) was used to identify the subset of variables that best discriminated among occupied and random plots. I performed the analysis on each data sample using different subsets of variables: (a) habitat cover variables; (b) habitat fragmentation variables; (c) vegetation structure variables; (d) vegetation composition variables; and (e) all the above variables together. Minimum value of F to allow a variable entered model was 4. Logarithmic transformation was performed on habitat structure and fragmentation variables. Arcsin square root transformations were used on habitat proportions and tree species frequencies. All statistical analyses were performed using STATISTICA package.

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3. Results

On average, nest holes were located 20.5 ± 8.6 m from the floor. Kestrels tended to occupy nests located near to top of man-made structures (Table 1). Nest openings have a prevalent south-east orientation (Fig. 1). The number of Kestrel breeding pairs is strictly correlated with the number of cavities available in each building ($r_S = 0.65$, $P < 0.01$, $n = 15$).

Ruderal areas covered on average 7 % and 0.1 % of the total surface in occupied and random plots. Gardens comprised on average 5 % of the area of occupied nesting areas and 10 % of the total area in random plots. Both proportion of open areas and habitat diversity were slightly higher in

Table 1: Characteristics of nest sites occupied by Kestrels in the historic centre of Rome. Data are reported as mean ± SD. For the average dimension of small, medium, and large cavities, see methods.

Tab. 1: Merkmale der Turmfalken-Brutplätze im historischen Zentrum von Rom, angegeben sind jeweils Durchschnittswerte ± Standardabweichung (Angaben zu den Ausmaßen „kleiner", „mittelgroßer", bzw. „großer" Höhle in Abschnitt „Methods").

Nest location	Exposure (°)	Nest height (m)	Building height (m)	Sample size
Eaves	193 ± 88	24.4 ± 11.0	36.5 ± 11.8	5
Small cavities	155 ± 100	21.5 ± 8.6	27.0 ± 8.6	25
Medium cavities	160 ± 42	13.8 ± 5.6	23.8 ± 8.1	5
Large cavities	225 ± 88	18.7 ± 7.3	29.7 ± 8.3	7
All nests	172 ± 93	20.5 ± 8.6	28.2 ± 9.2	42

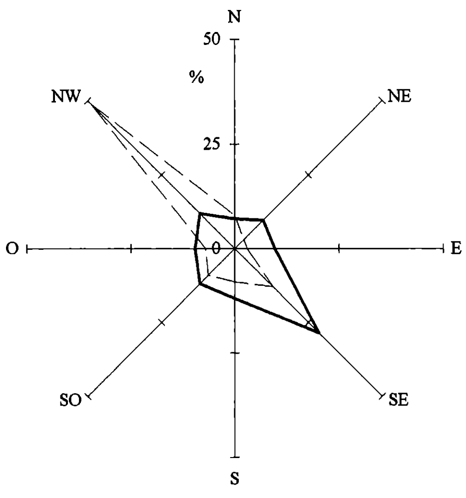

Fig.:
Distribution (%) of entrance exposures of Kestrel holes (n = 42) in the historic centre of Rome in the horizontal plane (continuous line), and direction (%) of wind during late winter in the same area (lineated line).

Abb.:
Häufigkeitsverteilung in % a) zur Ausrichtung der Höhlenöffnung von Turmfalken-Brutplätzen (n = 42) im historischen Zentrum von Rom (durchgezogene Linie), b) zur Windrichtung während des späten Winters im selben Gebiet (gestrichelte Linie).

occupied nesting areas than in random plots. The mean size of green areas and street tree patches did not vary between occupied and random plots. Tree density and height were similar in occupied and random plots. There were no significant differences between occupied and random plots in the occurrence of any other tree species or tree species diversity.

The stepwise discriminant analysis carried out on habitat cover variables in occupied and control plots provided a model based on the proportion of ruderal areas (RUD) and vegetable gardens (GAR) (Wilks' Lambda = 0.60, $F_{1,32}$ = 10.30, P = 0.0004), thus confirming the results of the mean comparisons (see Table 2). No habitat fragmentation variables neither vegetation structure and composition variables entered a discriminant model. Using all the variables, only RUD and GAR entered a discriminant model (Wilks' Lambda = 0.60; RUD: $F_{1,32}$ = 12.25, P = 0.0014; GAR: $F_{1,32}$ = 12.10, P = 0.0015). Twenty-eight cases (82.3 %) were correctly classified.

Table 2: Habitat characteristics of Kestrel nesting areas and random plots in the historic centre of Rome. Each variable is given as mean ± SD and range. Land cover variables were given as percentage of the total plot surface. Tree species variables were given as percentage of the total number of trees surveyed in each vegetation plot (see methods for details).

Tab. 2: Habitat-Merkmale typischer Nistgebiete des Turmfalken (Brutnachweise aus ≥ 3 Jahren) und entsprechend großer zufällig ausgewählter Flächen (jeweils historisches Zentrum von Rom). Für jede Variable ist jeweils der Mittelwert ± Standardabweichung und die Spannbreite angegeben (Flächenangaben jeweils in % zur gesamten Flächengröße, Angaben zu Baumarten jeweils in % zur Gesamtzahl aller Bäume in der betreffenden Fläche; zu weiteren Details s. den Abschnitt „Methods").

	Occupied plots (n = 13)	Random plots (n = 21)	*p*-level[a]
Deciduous woods (%) [DEW]	0.84 ± 2.58 (0.0–9.28)	1.21 ± 2.04 (0.0–6.52)	0.39
Pine woods (%) [PIN]	0.49 ± 1.15 (0.0–4.02)	0.29 ± 0.83 (0.0–3.48)	0.54
Vegetable gardens (%) [GAR]	5.29 ± 5.60 (0.0–27.52)	10.42 ± 7.90 (1.34–27.52)	0.02*
Street trees (%) [STR]	4.95 ± 2.75 (0.70–9.73)	4.85 ± 2.85 (0.72–11.11)	0.90
Meadows (%) [MEA]	3.66 ± 5.84 (0.0–20.11)	1.65 ± 2.26 (0.0–6.91)	0.37
Waterbodies (%) [WAT]	2.17 ± 4.53 (0.0–13.31)	1.54 ± 4.03 (0.0–14.81)	0.61
Ruderal areas (%) [RUD]	6.52 ± 16.27 (0.0–59.31)	0.31 ± 0.62 (0.0–1.99)	0.02*
Old built-up areas (%) [ADE]	54.37 ± 42.01 (0.0–95.87)	41.18 ± 38.22 (0.0–92.04)	0.31
Modern developed areas (%) [MDE]	21.70 ± 31.43 (0.0–73.43)	38.51 ± 42.06 (0.0–95.86)	0.35
Habitat diversity (Shannon-Weaver) [H_{hab}]	0.77 ± 0.44 (0.22–1.51)	0.71 ± 0.28 (0.19–1.33)	0.96
Surface of green areas (ha) [TGA]	3.10 ± 2.46 (0.0–8.75)	4.72 ± 2.51 (1.17–11.45)	0.11
Mean size of green area patches (ha) [MSG]	0.58 ± 0.76 (0.0–2.94)	0.82 ± 0.46 (0.25–1.56)	0.06
Mean size of street trees patches (ha) [MST]	0.22 ± 0.16 (0.05–0.69)	0.21 ± 0.09 (0.06–0.40)	0.82
Patchiness [PAT]	3.58 ± 1.84 (1.25–8.0)	3.27 ± 1.34 (2.0–7.67)	0.55
Mean tree density (trees ha^{-2}) [TDE]	67.64 ± 39.42 (24.0–148.0)	78.13 ± 48.42 (32.0–168.0)	0.30
Mean tree height (m) [THE]	12.01 ± 1.81 (8.25–14.60)	13.56 ± 2.68 (9.17–19.46)	0.07
Mean diameter at the breast height (m) [DBH]	0.53 ± 0.13 (0.30–0.75)	0.57 ± 0.11 (0.36–0.74)	0.09
Conifers (%) [CON]	49.27 ± 41.90 (0.0–100.0)	32.24 ± 31.51 (0.0–100.0)	0.38
Quercus ilex (%) [QIT]	18.24 ± 25.73 (0.0–81.10)	18.88 ± 26.12 (0.0–84.20)	0.96
Pinus pinea (%) [PPT]	24.56 ± 25.84 (0.0–71.43)	15.87 ± 18.31 (0.0–63.60)	0.37
Cedrus sp. (%) [CET]	7.75 ± 24.89 (0.0–90.0)	9.04 ± 22.44 (0.0–100.0)	0.59
Cupressus sempervirens (%) [CST]	16.96 ± 26.06 (0.0–90.0)	7.32 ± 14.64 (0.0–61.90)	0.17
Platanus sp. (%) [PLT]	15.79 ± 16.01 (0.0–66.67)	18.39 ± 30.54 (0.0–100.0)	0.60
Other species (%) [OTH]	16.70 ± 19.72 (0.0–50.0)	29.87 ± 32.04 (0.0–100.0)	0.23
Tree diversity (Shannon-Weaver) [H_{trees}]	0.86 ± 0.37 (0.32–1.53)	0.99 ± 0.54 (0.0–2.11)	0.55

[a] *t*-test comparisons with df = 32 performed on transformed data (see methods for details). Asterisks indicate significance at $p < 0.05$.

4. Discussion

Many predators, including Kestrels, have benefited from habitats and food supply associated with human settlements (e.g. GALEOTTI 1990, SODHI et al. 1992, GEHLBACH 1996, SALVATI et al. 1999). Urbanisation increases climate and resource stability, which in turn affect reproductive traits and population features, and provide in some cases adequate conditions for urban populations of birds (GEHLBACH 1996). However, the clustered distribution of Kestrel territories in the historic centre of Rome (see SALVATI et al. 1999), where both original habitats and exotic vegetation are scattered in many small patches, suggests that this species is able to find suitable habitats only in territories with specific nest and habitat characteristics.

Kestrels strongly depend on the abundance of cavities (VILLAGE 1983) which is generally high in towns. The increasing number of close nesting pairs in the historic centre of Rome reflects the local availability of scaffolding holes in old buildings. Kestrels occupy prevalently the higher holes in buildings and this may represent a mechanism to avoid predation (e.g. ANTIKAINEN 1987, PLESNIK 1991, COLOMBO & GALEOTTI 1993, NEGRO & HIRALDO 1993). In addition, the prevalent south-east exposition of nest openings could reflect a strategy to avoid cold winds which mainly blow from north-west direction during the period that encompass Kestrel laying.

Kestrel nesting areas differ from random plots based only on the proportion of ruderal areas and garden areas. Territory occupation was not affected either by habitat diversity or vegetation types, as it was expected for a typical farmland species (VILLAGE 1990). Proportion of both modern and old built-up habitats did not show significant differences among occupied territories and random plots, indicating that Kestrels use both habitats for nesting. A high degree of patchiness was generally tolerated. Areas with an interspersion of ruderal, old built-up, open areas, and small green areas seem to represent an optimal habitat configuration for urban Kestrels. These wide habitat preferences may account for the high density of Kestrels in urban areas, even in city centres (SALVATI 2001).

Kestrels seem more sensitive to the reduction of nest sites due to building repairing or reconstruction (e.g. RAMSDEN 1998) than to fragmentation or loss of habitat. Therefore, protection measures in cities should mainly concentrate on the conservation of cavities in old buildings and Roman ruins (SALVATI et al. 1999).

5. Zusammenfassung

Brutplatz-Merkmale und Habitat-Präferenzen von Turmfalken (*Falco tinnunculus*) eines mediterranen Stadtgebietes.

Turmfalken nutzen in Europa als Bruthabitat vor allem bergige und ländliche Gebiete, vorausgesetzt dass adäquate Nistmöglichkeiten (z.B. in Steinbrüchen oder an Gebäuden) vorhanden sind. Doch erreicht *F. tinnunculus* oft auch in Städten hohe Dichten. Deshalb eignen sich städtische Habitate für modellhafte Untersuchungen an dieser in weiten Bereichen Europas an Bestand abnehmenden Art über Auswirkungen von Landschaftsfragmentation, Verlust urspünglicher Habitate und Störungen durch den Menschen.

Nistplätze des Turmfalken befanden sich im historischen Zentrum von Rom in einer durchschnittlichen Höhe von 20,5 ± 8,6 m, und es wurden vor allem Nischen besiedelt, die nach Südosten hin offen waren. Ein Vergleich mit Hilfe der Diskriminanzanalyse für 25 verschiedene Habitatmerkmale zwischen 13 Turmfalkenrevieren und 21 zufällig ausgewählten Flächen in Rom ohne Turmfalken-Besiedlung zeigte, dass allein durch den Anteil an Ruderalgelände und Grünflachen 82 % aller Flächen richtig zugeordnet werden konnten. Die in der Stadt lebenden Turmfalken hatten ihre Reviere bevorzugt in solchen Gebieten, die ausreichend freie Flächen zur Jagd auf Eidechsen und Insekten (in Rom die primäre Beute dieser Art) aufwiesen und genügend geeignete Nistmöglichkeiten hatten. Deshalb sollten sich Hilfsmaßnahmen für den Turmfalken in Rom eher auf die Erhaltung seiner Niststätten an Gebäuden und Ruinen als auf den Schutz einzelner Landschaftsbereiche beziehen.

6. References

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