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Breeding Success of the Eurasian Kestrel (*Falco tinnunculus*) Nesting on Buildings in Israel

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Urbanization has changed the landscape in many countries in the world, particularly so in Israel since the establishment of the State (Yom-Tov and Mendelssohn 1988, Mendelssohn and Yom-Tov 1999). Urbanized areas have become more widespread, destroying natural habitats, decreasing animal diversity, and to a lesser extent, also creating new habitats for some species. Most raptors live in natural habitats away from humans, but some species, such as Eurasian Kestrels (*Falco tinnunculus*; hereafter ''kestrel'') also inhabit urban areas.

Kestrels are one of the most studied raptors in the world, but research has generally focused on breeding parameters of kestrels inhabiting rural environments in Europe (Cavé 1968, Village 1990, Plesník and Dusík 1994, Kostrzewa and Kostrzewa 1997, Fargallo et al. 2001), and only a few studies have addressed kestrel breeding success in urban habitats (Pikula et al. 1984, Plesník 1985, 1990, 1991, Rejt 2001, Salvati 2002, Kübler et al. 2005). Most of the latter studies found that urban-breeding kestrels have a higher reproductive rates than those in rural areas, with the exception of Kübler et al. (2005), who found no difference. Compared to rural kestrels, urban populations may be ecologically, ethologically, and even genetically different (Rejt et al. 2004). For example, urban pairs use different nest types and prey on more species of birds than do rural pairs (Salvati et al. 1999, Kübler et al. 2005).

Kestrels do not build nests, but, unlike many raptors, they breed in both open-type nests (e.g., abandoned nests of other birds, date palms, cliff edges) and closed-type nests (e.g., cavities in trees and cliffs; Village 1990). In contrast to populations studied in the Czech Republic, Italy, and Poland, where urban kestrels nest primarily in closed-type nests on buildings, the majority of kestrels found breeding in urban sites in Israel used open-type nests, especially flower pots on windowsills (Leshem 1984, Charter et al. 2005).

The higher breeding success reported for urban kestrels (e.g., Pikula et al. 1984, Plesník 1985, 1990, 1991, Rejt 2001, Salvati 2002) may be due to the mainly closed-nest types used by urban birds, in contrast with rural nests, which are located primarily in abandoned corvid nests in trees and, to a lesser extent, in artificial nest boxes (Village 1990). In rural habitats, kestrels breeding in cavity-type nests have higher breeding success than those in open-type nests (Kostrzewa and Kostrzewa 1997, Fargallo et al. 2001, M. Charter unpubl. data), most likely due to decreased predation and increased protection from weather.

In this study we investigated kestrels in Israel, which breed mainly on the windowsills of buildings in cities (urban), towns (suburban), and villages (rural). Because kestrels use the same nest types in the three locations, any differences found in breeding success and reproductive rate would most likely be due to the difference in habitat. We hypothesized that the breeding success of kestrels in rural areas (villages) would be higher than that in both dense urban areas and moderately populated suburban areas, due to the closer proximity of hunting sites and greater mammalian prey availability in the rural areas. In addition, we investigated how nest orientation may affect breeding success in the above-cited different nest habitats.

Methods

Study Area. Our study was conducted throughout the country of Israel. We defined cities, towns, and villages as

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follows. Cities were highly developed and densely populated by humans (>100 000 people), and kestrels there lacked both trees and bushes and open landscape (i.e., favorable hunting territories) near their nests. Towns had smaller human populations (11 000–25 000 people), and smaller buildings that were more widely spaced than in cities but more dense than in villages. Towns also had moderate amounts of trees and bushes, and, due to their comparatively small size, had open landscapes relatively close to the kestrel nests. Villages had very small populations (fewer than 700 people), few buildings, many trees, bushes and fields, and open landscapes (i.e., agricultural areas). In cities, kestrels have to fly great distances in order to hunt in open landscapes, whereas those breeding in villages nest only a few hundred meters from fields.

Nesting Survey. A nationwide survey on the breeding biology of kestrels in Israel was conducted from 2003–2006. A standardized questionnaire on kestrel breeding success was placed on the website of the International Center for Study of Bird Migration (Latrun), and the Israel Ornithology Center (www.birds.org.il). Participants were asked to fill in as many of the following fields as possible: participant's name, address, telephone number; laying date of kestrel's first egg, laying date of last egg, clutch size, total number of young hatched (i.e., brood size during first week), date that the first young fledged, number of young that died, number of young that fledged (approx. 23–27 d old), and the nest orientation, grouped in four categories: N-NE, E-SE, S-SW, W-NW. All participants were contacted by phone at least three times to verify data reliability. Questionnaires with no contact information were eliminated from the survey. During the study, about 40% of participants sent pictures, and a third of the homes were visited at least twice yearly.

Reproductive Parameters. At nests for which the time of laying was unknown, the date was estimated by subtracting the incubation period (28 d; Cramp 1985) from the hatching date. Breeding data were recorded for each laying pair and for each successful nest. We defined (1) hatching success as the percentage of eggs that hatched within each clutch, (2) the percentage of young that fledged from each brood as the percentage of hatched young that reached fledging age, (3) egg productivity as the percentage of eggs per nest that hatched, (4) brood size as the number of young hatched, and (5) a successful nest as one that fledged at least one young. Egg laying date ($N = 9$) and hatching interval order ($N = 12$) were provided by participants who observed the nest in their home daily. Partial nest failure was recorded when a pair fledged some but not all of their hatched young. Eight nests were used for more than one breeding season; for these nests with multiple records, we randomly selected one year of data, to avoid pseudoreplication. Data from two pairs breeding in cities and one pair in a village that laid second clutches after successfully raising first broods during the 2004 breeding season (Charter at al. 2005) were not included in this analysis.

Statistical Analyses. All statistical tests were two-tailed and all tests were nonparametric. Descriptive breeding data were analyzed using Kruskal-Wallis ANOVA and Kruskal-Wallis Multiple Comparisons. Spearman test was used to analyze correlations among breeding parameters, and chi-square and Fisher's Exact Test were used for comparing nest success between locations. Levels of significance were set at $P < 0.05$. Statistical analyses were performed using Statistica 7.1 software.

RESULTS

One hundred and twenty-four pairs of laying kestrels were monitored during the 2003–2006 breeding seasons. No differences in breeding parameters were found among the four years (24 Kruskal-Wallis tests, $P > 0.05$) and the data were therefore pooled. Seventy-nine pairs nested in cities (Tel Aviv region, Netanya, and Haifa), 19 pairs in towns (11 towns, mostly located in the West Bank), and 26 pairs in villages (13 villages). The mean floor number on which the kestrels nested was higher in cities (6th floor; range = 1–14 floors) than in towns (2nd floor; range = 1–5 floors) and in villages (2nd floor; range = 1–2 floors; Kruskal-Wallis$_{2,110}$ = 56.17, $P < 0.001$). Mean egg-laying interval for kestrels breeding in cities was 2.1 d ($N = 9$) and hatching order was as follows: 62% of eggs hatched the first day, 18% on the second, 12% on the third, and 8% on the fourth day ($N = 12$). There were no differences in laying date for nests in the three locations (Table 1). Laying date was inversely related to clutch size in pairs breeding in cities ($r = -0.42$, $N = 40$, $P < 0.01$), but not in towns ($r = -0.31$, $N = 11$, $P = 0.35$) or in villages ($r = -0.14$, $N = 10$, $P = 0.69$).

Kestrels breeding in villages fledged more young per laying pair than pairs in cites (Kruskal-Wallis Multiple Comparisons, $P < 0.05$; Table 1). No differences were found between clutch size, brood size, percentage hatching success, percentage nestlings fledged, and egg productivity between kestrels breeding in the three locations (Table 1).

Of the laying pairs, 18% ($N = 22$) were unsuccessful, failing to fledge at least one young, with slightly more failures in cities ($N = 17$) than in villages ($N = 2$; Fisher's Exact Test, $P < 0.06$). No differences were found between towns and the other two locations (Fisher's Exact Test, n.s.). Most (20 of 22; 92%) failures occurred during the incubation period, with the remaining (8%) during the nestling stage. Of the failures, 8 (36%) of the nests simply failed to hatch, 9 (41%) failed due to human interference, 3 (14%) because of nest desertion, and 2 (9%) because of predation. Human disturbance included people removing clutches, opening and closing windows, and watering flower pots occupied by incubating kestrels. During the nestling stage, one pair was predated by crows and one was removed by nest robbers. There were no differences in the number of pairs failing partially (cities: 54.2%; towns: 61.1%; villages: 59.1%; $\chi^2 = 0.42$, df = 2, $P = 0.42$).

Kestrel pairs mostly used flowerpots located on windowsills as nesting sites (75%), followed by windowsill ledges (10%), utility porches (6%), and others (9%). There was no difference in the distribution of nest orientation among the three locations (Kruskal- Wallis$_{2,109}$ = 3.21, $P = 0.20$), or within any of the three locations (cities, $\chi^2 = 0.02$, df = 3, $P = 0.99$; towns, $\chi^2 = 0.16$, df = 3, $P = 0.98$; villages, $\chi^2 = 0.37$, df = 3, $P = 0.95$). In the cities, a signif-

Table 1. A comparison of breeding parameters (means ± SE) of Eurasian Kestrels breeding in cities, towns, and villages in Israel, 2003–2006.

				KRUSKAL-WALLIS	
	CITY (*N*)	TOWN (*N*)	VILLAGE (*N*)	ANOVA	*P*
Laying date	30 March ± 2.4 (11)	28 March ± 6.0 (11)	21 March ± 4.8 (11)	3.17	0.20
Clutch size	4.9 ± 0.1 (63)	5.1 ± 0.2 (18)	5.2 ± 0.1 (20)	2.72	0.26
Brood size	3.3 ± 0.3 (69)	3.9 ± 0.4 (18)	4.3 ± 0.3 (21)	2.51	0.29
Number of young fledged per laying pair	2.9 ± 0.2 (79)	3.4 ± 0.4 (19)	4.0 ± 0.3 (26)	6.92	<0.05
Percentage hatching success	67.1% ± 0.1 (65)	75.0% ± 0.1 (18)	78.6% ± 0.1 (20)	0.67	0.72
Percentage of young fledged	90.2% ± 0.0 (54)	84.9% ± 0.1 (16)	88.3% ± 0.1 (21)	0.22	0.90
Percentage egg productivity	58.6% ± 0.1 (63)	64.6% ± 0.1 (18)	71.5% ± 0.1 (20)	1.48	0.48

icant difference was found in the number of fledged young per laying pair depending on the orientation of nests (Kruskal- Wallis$_{3,75}$ = 9.56, $P < 0.05$), with the pairs breeding in nests facing south having the greatest number of young. The number of pairs breeding in nests facing east was lower than in nests facing south ($P < 0.05$; Kruskal-Wallis Multiple Comparisons), whereas no differences were detected in towns (Kruskal-Wallis$_{3,19}$ = 1.62, P = 0.65) and villages (Kruskal-Wallis$_{3,15}$ = 0.70, P = 0.70).

DISCUSSION

Kestrel reproductive rate was lowest in cities. Both the number of young fledged per laying pair and the percentage of pairs successfully fledging at least one young were lower in cities than in villages. This could be due to a lower abundance of small mammalian prey in the cities. Unlike kestrels in towns and villages, kestrels breeding in cities in Israel feed their nestlings primarily birds and rarely small mammals, insects or reptiles (M. Charter unpubl. data). Nevertheless, Mediterranean kestrels have been observed to successfully raise young on alternative prey (Gil-Delgado et al. 1995).

Our results contradict those found in the Czech Republic, Poland, and Italy (Pikula et al. 1984, Plesník 1990, Rejt 2001, Salvati 2002), where the urban kestrel populations had higher reproductive rates than rural ones. However, the comparison between urban and rural kestrels in those studies did not consider the potential effect of different nest types on breeding success, a possible confounding factor, as the majority of rural nests were open-type natural nests and the urban pairs bred in buildings (i.e., more protected cavity-like nests). In one study that compared similar nest types between locations (Kübler et al. 2005), there were no differences in reproductive rates between kestrels breeding in nest boxes in the center and suburbs of Berlin. Therefore, the higher breeding success found in urban kestrels in Europe might be due to the different nest types, not to the locations. For example, kestrel breeding success has been found to be lower in open natural nest sites than in cavity nest sites (Kostrzewa and Kostrzewa 1997, M. Charter unpubl. data). In another study of kestrels breeding in nest boxes (i.e., cavity) and date palms (i.e., open-type nests) in agricultural areas of Israel, clutch size (4.9 and 4.1, respectively) and number of young fledged (3.1 and 2.1, respectively) differed, with cavity-nesting birds having greater reproductive success than those in open nests. (M. Charter unpubl. data). Thus, the reproductive success of kestrels nesting in open-type nests on buildings in all three locations in this study was more similar to that of cavity-nesting birds than that of birds nesting in open-type nests in rural areas.

In this study, the percentage of pairs failing to fledge any young was higher in cities than villages (21.8% and 7.7%, respectively). In comparison, only 1% and 4% of city pairs failed in Italy (Salvati 2002) and the Czech Republic (Plesník 1985), respectively. The study in Italy may have underestimated pair failure due to the difficulty of checking the nests located in building cavities at greater heights. (Nests in Israel were located on windowsills.)

The mean percentage of pairs failing to raise young in the three locations in the current study were within the range reported in nine studies of rural kestrels in Europe (average = 24%, range = 3–42%; Pikula et al. 1984, Bonin and Strenna 1986, Village 1986, Village 1990, Plesník and Dusík 1994, Kostrzewa and Kostrzewa 1997, Village 1998, Avilés et al. 2000). In our study, human disturbance accounted for 41% of total nest failures, which was high compared to other studies and was probably due to the close proximity of humans to the nests. Pairs breeding in urban environments may thus experience increased human disturbance.

Although kestrels breeding in cities in Israel had a random distribution of nest orientation, the number of young fledged per laying pair was significantly correlated to nest orientation, possibly because of energetic benefits from differences in sunlight and wind from specific directions. Plesník (1991) found that 75% of nests faced south or southeast, and, in rural Israel (M. Charter unpubl. data), 62% of nests in date palms faced east.

The majority of urban kestrels in Israel were reported breeding in flowerpots on windowsills, whereas in the three European studies the birds bred mainly in cavity nests, such as in vent-holes, cracks in walls, and attics, and only occasionally on windowsills. Flowerpots are very common in many households in cities, towns, and villages in Israel because plants can be grown year round. The flowerpots provide a soft substrate and are large enough for egg laying and for raising a full brood.

This is the first study to show that breeding success of kestrel pairs breeding in buildings in rural villages was higher than that of pairs nesting in cities. As in other studies (Kostrzewa and Kostrzewa 1997, Fargallo et al. 2001, M. Charter unpub. data) where pairs nesting in artificial nest boxes had higher breeding success than those in natural nest sites, the breeding success of pairs on buildings in Israel also seemed to be higher in all three locations than in natural sites elsewhere in Israel (M. Charter unpubl. data) probably due to increased protection from predators, which seldom hunt on buildings. Future studies comparing diets of kestrels breeding in similar nest types but in different types of locations are necessary to improve our understanding of how food availability may affect breeding success. Finally, we suggest that any studies of breeding success of pairs nesting in different areas should also consider the nest types.

ÉXITO REPRODUCTIVO DE *FALCO TINNUNCULUS* AL NIDIFICAR EN EDIFICIOS EN ISRAEL

RESUMEN.—Medimos el éxito reproductivo de individuos de la especie *Falco tinnunculus* que nidificaron en edificios en tres localidades: ciudades grandes, ciudades pequeñas y pueblos pequeños. Debido a que estos halcones cazan principalmente en campos abiertos y alimentan a sus polluelos principalmente con pequeños mamíferos, el éxito reproductivo de las parejas que nidifican en las ciudades puede ser reducido ya que la abundancia de presas es menor en áreas urbanas. Encontramos que tanto el número de volantones por pareja como el porcentaje de parejas que fueron exitosas produciendo por lo menos un volantón, fueron menores en las ciudades que en los pueblos. Los nidos en edificios en los tres tipos de localidades pueden proveer mayor protección ante depredadores incluso en áreas rurales, debido a que la mayoría de los depredadores evita los edificios habitados por humanos. Nuestro hallazgo de que el éxito reproductivo de halcones que se reproducen en el mismo tipo de nido (un edificio) difiere entre hábitats, resalta la necesidad de estudios futuros que distingan entre tipos de nido y hábitats al comparar el éxito reproductivo de las aves rapaces en un área de estudio determinada.

[Traducción del equipo editorial]

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