The importance of natural habitats as Short-toed Eagle (*Circaetus gallicus*) breeding sites

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ABSTRACT

The biodiversity of native species is diminishing in many regions as natural habitats are being replaced by human settlements and agriculture. Top predators, such as large raptors, are especially sensitive to habitat change, and they present flagship species due to the interest in them by the public. By protecting the raptors' habitats we also protect other species that reside within these habitats. A large population of Short-toed Eagles (*Circaetus gallicus*, hereafter StE) were studied in the Judea region of Israel across a 1,175 km^2 study site during the 2006–2008 breeding seasons, in order to determine whether the different types of habitat affect the number of successful breeding pairs. During the three-year study, we recorded 288 breeding attempts by StE pairs in 156 different nests located mainly on trees. Of the successful StE pairs, 76.9% bred in natural habitats while fewer pairs than expected bred in agricultural areas and human settlements. The mean number of successful StE pairs was positively related to the proportion of natural habitat types and negatively related to the proportion of human settlements and agriculture. Compared to successful pairs breeding in grids with a low density of StE, grids with higher breeding densities of successful pairs comprised more natural habitat types and less agricultural land and human settlement. Even though the population of StE in Israel is large, its future may be at risk as natural habitats are increasingly being destroyed and replaced by human settlements and agriculture. Conservation programs are therefore needed in order to protect as much natural habitat types as possible prior to urban planning and realisation.

Keywords: Short-toed Eagle, conservation, habitat loss, nest sites, top predator, agriculture, human settlements

1. INTRODUCTION

One of the difficulties in preserving natural habitats from habitat loss is that people tend to care more about their own personal requirements and are indifferent to the fate of most plant and animal species (Entwistle and Dunstone, 2000; Ray, 2005). Large raptors such as eagles, however, not only attract the interest of the public but can also be used as a flagship species for conservation because they have large home ranges and the biodiversity is high around these raptors' breeding sites, nests, and home ranges (Sergio *et al.*, 2005). In cases where raptor home range size and habitat composition are known, conservation plans can be drawn up and implemented to preserve both the habitat needed by the birds and the local biodiversity within it (Simberloff, 1998; Ray 2005; Sergio *et al.*, 2006).

Before conservation projects can be drafted, studies are needed in order to better understand the limiting factors of the raptor populations. Raptors are territorial and most have large individual home ranges, low fecundity and avoid human habitation areas (Newton, 1979). Protecting raptors is of particular importance, especially where they are at risk of being electrocuted by power lines, of poisoning by pesticides used in agriculture, of nest-robbing, of illegal trade, and also of being hunted – the latter mainly for sport (Yom-Tov *et al.*, 2012). Habitat loss is specifically problematic to raptors because the two main limiting factors for raptor populations, nest sites and prey, are dependent on the availability of appropriate habitat (Newton, 1979).

The Short-toed Eagle (*Circaetus gallicus*, hereafter StE) is a medium-large raptor with a widespread distribution throughout Europe, North Africa and parts of Asia that hunt mainly reptiles (mostly snakes; Bakaloudis and Vlachos, 2011) in open areas. StE build their nests mainly in trees and raise only one young per year. Even though a large proportion of the StE populations are found throughout the Mediterranean region (López-Iborra *et al.*, 2011), most studies on breeding biology have taken place in Mediterranean Europe (Amores and Franco, 1981; Petretti, 1988; Vlachos and Papageorgiou, 1994; Bakaloudis *et al.*, 2005), with very few in North Africa and the Middle East (Meir, 1986; Friedemann *et al.*, 2013).

Here, in the Middle East, we studied the breeding biology of a large population of StE in Israel, specifically seeking to determine whether this eagle's breeding density is associated with habitat type. The StE eagle population can be used as a model of for other eagles because the StE population is still large enough to study large scale population trends. The number of StE breeding

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pairs was compared to the proportion of natural habitats, agricultural areas, pine forests and human settlements. Since natural habitats, such as steppe and grasslands, are associated with less human disturbances and support higher prey densities (reptiles), we hypothesised that the number of breeding StE pairs would increase with the proportion of natural habitats and decrease with the proportion of agricultural areas, human settlements and pine forests.

2. METHODS

2.1 Study site

The study took place in a 1,175 km^2 area of the Judea region of Israel (Figure 1; 31°44′44.47′N, 34°59′11.93′E) during the 2006–08 breeding seasons. The average yearly rainfall during 2006–08 was 439 mm (N = 3 years, SE = 44.3 mm), with daily minimum temperature of 27.2 °C (N = 3 years, SE = 0.5 °C) and daily maximum temperature of 12.5 °C (N = 3 years, SE = 0.7 °C) from February 15 to July 15 during 2006–08 (data from Israel Meteorological Center). The region is mixed, with natural habitat types (steppe, grasslands and natural deciduous Mediterranean forests, n = 52.2% of the site), interspersed with agriculture (crop fields, vineyards, carob groves, n = 25.8%), human settlements (n = 10.6%), and planted pine tree forests (n = 11.4%).

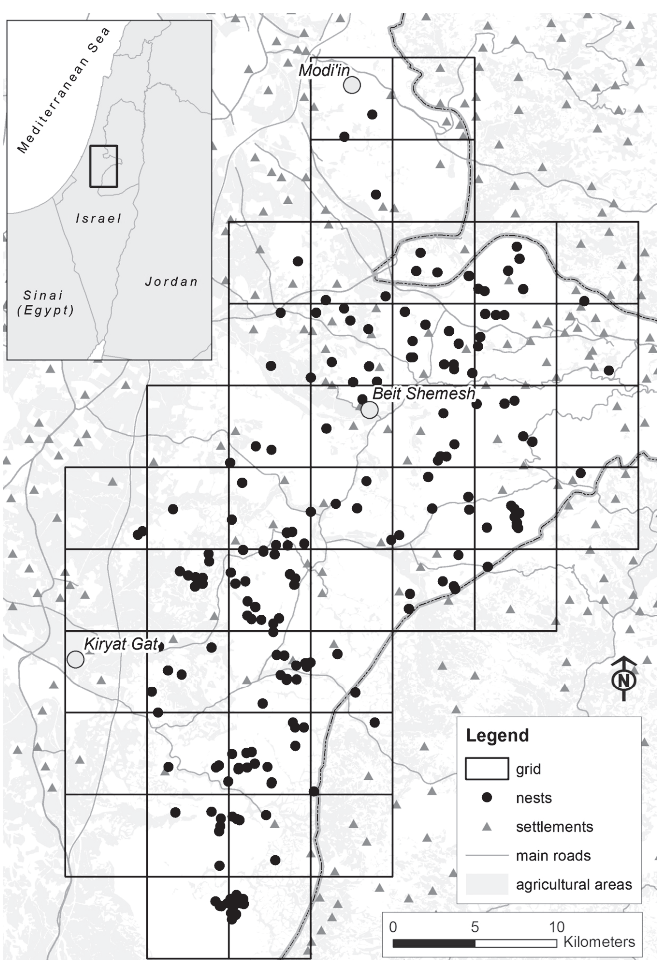

Figure 1 The study site was located in a 1,175-km^2 area of the Judea region of Israel and divided into 47, 25-km^2 grids.

2.2 Data collection

The location of the study was decided after a pilot study during the 2005 breeding season. This preliminary study was conducted by one of the authors (EH) in which he searched the study location during a one month period and found 61 StE breeding pairs. We knew the area was a good site to study StE because of the initial findings of the 61 pairs, but since the preliminary study was conducted sporadically we did not include these findings in the current study. The current study site was visited by EH from March to August 2006 to 2008, once to twice weekly by driving throughout the study site on roads, agriculture paths and forestry paths using a 4 × 4 truck and/or by going foot. Using binoculars (Swarovski 10 × 42), nests were initially found by searching for adults flying with prey, courtship flying, perched adults and territorial behaviour and nests were later revisited on foot in order to determine whether nestlings had fledged. Successful StE nests were those that fledged one young, StE only raise one young per nest.

The coordinates of all the nest sites found during the 2006–08 breeding seasons, habitat type (natural, agricultural, human settlements, planted pine forests) were delineated using existing land-use data from the 2014 Survey of Israel GIS layer (Forrai *et al.*, 2004) and Normalised Difference Vegetation Index (NDVI, Tucker, 1979) of natural habitat types (radiometric corrected data of Landsat 8 satellite, summer 2013) were added into ArcMap GIS software. The difference between the natural habitat and planted pine forest was that the former was made up of native Mediterranean deciduous trees and the latter afforestation areas with monoculture coniferous trees. The proportions of the different habitat types (natural, agricultural, human settlements, and pine forests), located within a 2.5 km radius (estimated StE home range Hadad, unpublished data) around successful StE nests were calculated. Likewise, the distance of each successful nest to each habitat, and to the closest neighbouring successful nest, as well as the mean hill slope (calculated from existing data on the 2014 Survey of Israel GIS layer) on which nests were located were also calculated. In order to determine whether different habitats differentially affect the number of successful breeding pairs, the study area was divided into 47, 25-km^2 grids (5 × 5 km each) (Figure 1). The mean number of successful StE nests during the 2006–08 breeding seasons was calculated for each grid.

2.3 Statistical analysis

Data are presented as means ± SE. All tests were non-parametric and two-tailed since the number of StE pairs breeding in each grid was not distributed normally (Kolmogorov–Smirnov test). We performed Spearman correlation (r_s) to ascertain whether a relationship existed between the density of StE in each grid and the different habitat type; Mann–Whitney *U* test to determine whether habitat type varied between the StE density in each grid; and χ^2-test to compare the aspect of the nest slope and habitat type of nest sites. Standardised adjusted residuals were calculated for each of the cells in order to determine which cell differences contribute to the χ^2-test results. Cells with a standardised residual greater than 1.96 were considered to indicate a significant deviation at the 0.05 level from the expectation (Sheskin, 2003). Statistical analyses were performed using SPSS for Windows version 20.

3. RESULTS

3.1 Overview of breeding pairs

Seventy-five StE breeding pairs were monitored during 2006, 109 pairs in 2007 and 104 pairs in 2008. The number of pairs succeeding to fledge young in 2006 (94.5%), 2007 (96.3%), 2009 (98.1%) did not differ between the years ($\chi^2 = 0.03$, DF = 2, $P = 0.99$, Table 1). The mean distance of nests to the closest neighbouring nests was 1,380.82 + 142.83 m (Min = 58.42, Max = 6362.18) in 2006, 948.52 + 85.67 m (Min = 50.09, Max = 5276.44) in 2007 and 954.96 + 79.74 m (Min = 58.42, Max = 4877.22) in 2008. The mean breeding density was 6.5, 9.3, and 8.9 pairs per 100 km^2, during the 2006, 2007 and 2008 breeding season, respectively. The mean breeding density of the 47, 25-km^2 grids was 1.6 + 2.1 pairs (Min = 0, Max = 8, $N = 47$) in 2006; 2.3 + 2.8 pairs (Min = 0, Max = 11, $N = 47$) in 2007; and 2.2 + 2.8 pairs (Min = 0, Max = 12, $N = 47$) in 2008.

3.2 Effect of habitat on number of breeding pairs

The average number of successful StE pairs of the 47, 25-km^2 grids (Figure 1) during 2006–08 was positively related to the size of the natural habitat types (Figure 2a) and negatively related to the size of the agricultural area (Figure 2b), and human settlements (Figure 2c), but was not related to the size of pine forest cover ($r_s = 0.03$, $N = 47$, $P = 0.84$). The number of successful pairs per grid was also not related to the NDVI of the natural habitats ($r_s = 0.06$, $N = 47$, $P = 0.68$), mean elevation ($r_s = -0.13$, $N = 47$, $P = 0.093$) or the mean slope ($r_s = 0.13$, $N = 47$, $P = 0.39$) of the nests.

Table 1 The number of StE laying pairs, and the percentage of pairs that succeeded to fledge a young during the 2006 to 2008 breeding seasons in the Judea region, Israel

	Number of laying pairs	Percentage of pairs succeeded to fledge young (*N*)
2006	75	94.5 (73)
2007	109	96.3 (108)
2008	104	98.1 (104)

Nest success was unknown for two nests in 2006 and one nest in 2007 were excluded from statistical analysis.

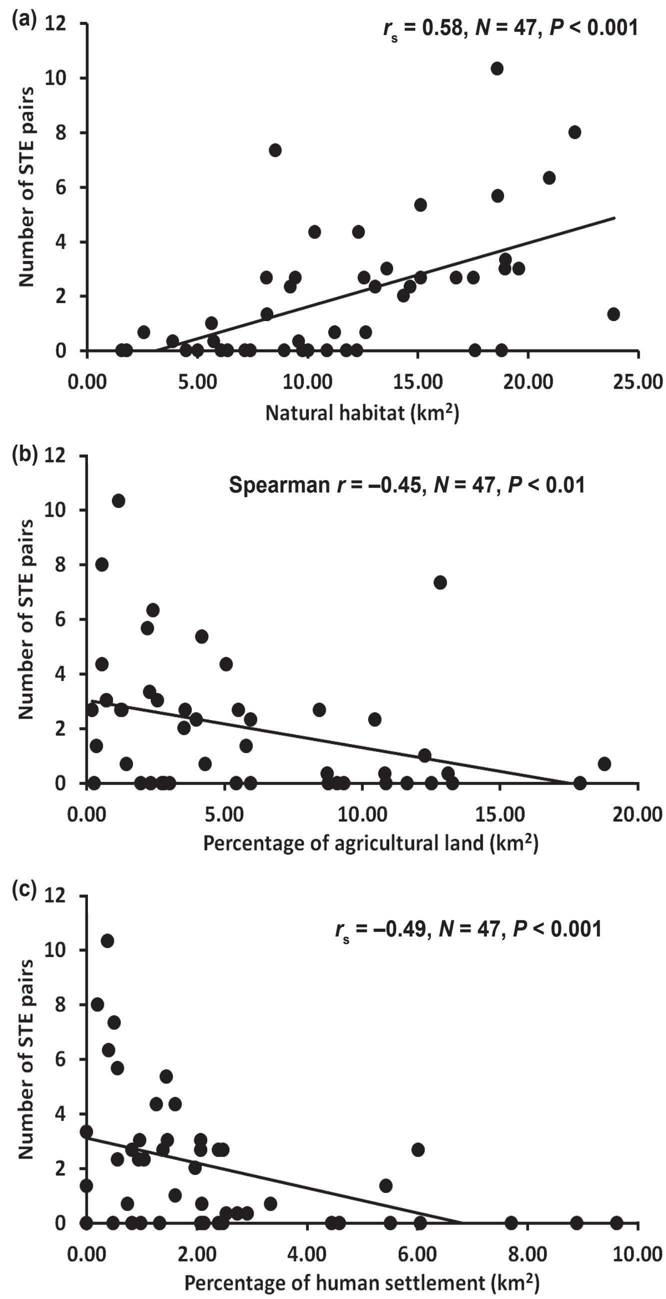

Figure 2 Relationship between the percentage of different habitats: (a) natural habitat, (b) human settlements, (c) agricultural area, and mean number of StE successful pairs breeding in the 25-km^2 grids ($N = 47$) during the 2006–08 breeding seasons.

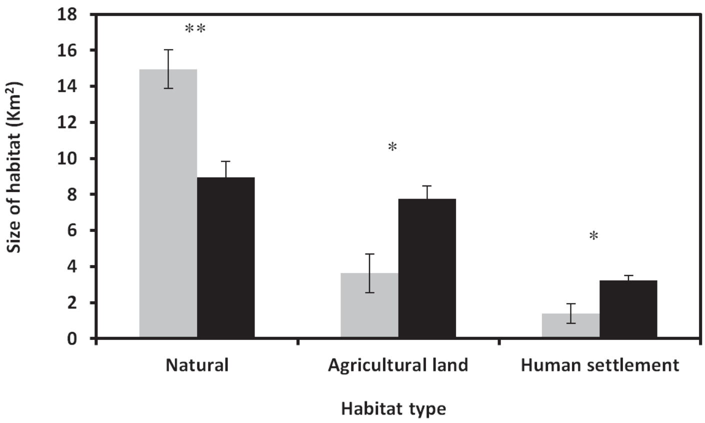

Figure 3 Comparison between the size of natural habitat types, agricultural area, and human settlements in grids with high ($N = 22$, grey) and low density ($N = 25$, black) of StE eagles. (significant difference at $*P < 0.01$, $**P < 0.001$). Means $\pm$ SE.

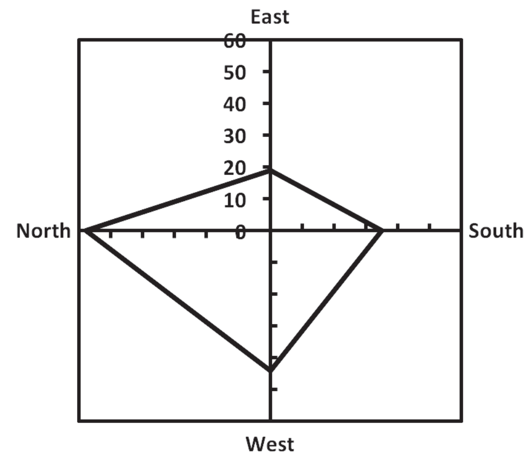

Figure 4 The slope aspect of hills on which the 156 StE nests were located during the 2006–08 breeding seasons.

By dividing the grids into two groups of either high ($N = 22$) or low ($N = 25$) StE density, based on the median number of successful breeding pairs during 2006–08 in grids (1.33 pairs), we found that grids with high StE densities occupied a larger area of natural habitat types (15.0 + 0.9 km^2 *versus* 8.9 + 1.1 km^2; Mann–Whitney test, $U = 96.0$, $P < 0.001$) and less agricultural area (3.6 + 0.7 km^2 *versus* 7.8 + 1.1 km^2; Mann–Whitney test, $U = 143.00$, $P < 0.01$) and human settlement area (1.4 + 0.3 km^2 *versus* 3.2 + 0.5 km^2; Mann–Whitney test, $U = 139.00$, $P < 0.01$); whereas there was no difference between density level and area of pine forest occupied (2.8 + 0.6 km^2 *versus* 2.4 + 0.6 km^2; Mann–Whitney test, $U = 241.00$, $P = 0.48$) (Figure 3).

3.3 Nest characteristics

The mean slope of the hills on which the 156 nests were located during 2006 to 2008 was 9.1% (SE = 0.5, $N = 156$) and the mean elevation of nests was 326.5 m.a.s.l (metres above sea level) (SE = 8.6, $N = 156$, Min = 107.4, Max = 625). More StE pairs bred in north-facing slopes and fewer in east-facing slopes than expected from random ($\chi^2 = 20.6$, DF = 3, $P < 0.001$) (Figure 4). The average distance $\pm$ SE from the nests to the closest pine forests was 713 $\pm$ 63.0 m; 680.33 $\pm$ 42.1 to agricultural land; 1613.68 $\pm$ 82.9 m to human settlements; and 12.3 $\pm$ 3.1 m to natural habitats. 84.7% of the StE nests were built on *Ceratonia siliqua* (38.3%), *Pinus halepensis* (32.0%), and *Quercus calliprinos* (14.4%) followed by *Ziziphus spina–christi*, *Pistacia palaestina*, *Rhamnus palaestina*, *Styrax officinalis*, *Eucalyptus camaldulensis rostrata*, *Tamarix aphylla*, *Cupressus sempervirens*, and *Olea europaea*, while one pair built a nest on a cliff (Table 2).

The most common habitat type found within 2.5 km around nest sites was natural habitat types (68.5% of the total habitats, SE = 1.5, $N = 156$), followed by agricultural fields (14.5%, SE = 1.0, $N = 156$), pine forests (12.1%, SE = 0.8, $N = 156$), and human settlements (4.9%, SE = 0.3, $N = 156$). Significantly more StE nests were located in natural habitats (76.9% of total pairs) and fewer nests in agricultural fields and settlements than expected (Figure 5).

Table 2 The number of different tree species on which the StE built their nests during the 2006–08 breeding seasons

	2006		2007		2008	
Carob tree *Ceratonia siliqua*	32	(42.7%)	40	(36.7%)	37	(35.6%)
Aleppo Pine *Pinus halepensis*	17	(22.7%)	38	(34.9%)	40	(38.5%)
Palestine oak *Quercus calliprinos*	12	(16.0%)	14	(12.8%)	15	(14.4%)
Christ's Thorn Jujube *Ziziphus spina–Christi*	5	(6.7%)	3	(2.8%)	2	(1.9%)
Terebinth *Pistacia palaestina*	3	(4.0%)	4	(3.7%)	4	(3.8%)
Palestinian buckthorn *Rhamnus palaestina*	2	(2.7%)	2	(1.8%)	2	(1.9%)
Official Storax *Styrax officinalis*	1	(1.3%)	2	(1.8%)	1	(1.0%)
River Red Gum Eucalyptus camaldulensis rostrata	1	(1.3%)	1	(0.9%)	1	(1.0%)
Cliff	1	(1.3%)	1	(0.9%)	1	(1.0%)
Athel pine *Tamarix aphylla*	1	(1.3%)	0	(0.0%)	0	(0.0%)
Mediterranean Cypress *Cupressus sempervirens*	0	(0.0%)	3	(2.8%)	1	(1.0%)
African olive *Olea europaea*	0	(0.0%)	1	(0.9%)	0	(0.0%)
	75		109		104	

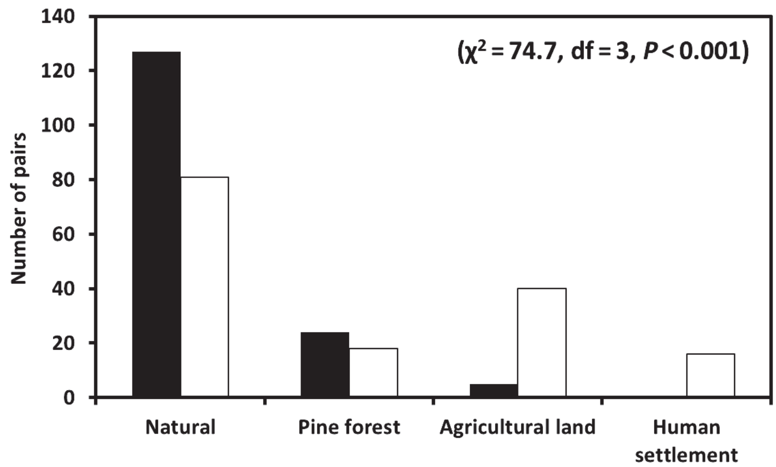

Figure 5 Comparison of the observed number (black) ($N = 156$) and the expected number (white) of StE nests located in different habitats in the Judea region of Israel during the 2006–08 breeding seasons.

4. DISCUSSION

In this study, natural habitat types were found to be of high importance to the StE breeding pairs. First, the number of successful StE pairs was positively related to the proportion of natural habitat types and negatively related to the proportion of agricultural land and human settlement. Second, areas with successful high StE densities were composed of more natural habitat types and less agriculture and human settlements than areas with low StE densities. Finally more successful StE bred in the natural habitat types than expected. From a conservation point of view it is of considerable concern that the StE bred mainly in the natural habitats and avoided breeding in human settlements and agricultural land, since the two latter habitats are gradually encroaching upon the natural habitats as the human population continues to increase throughout Israel and other regions of the Middle East.

Human settlements and human activities were also found to negatively affect StE numbers in Spain (López-Iborra *et al*., 2011), but in comparison to the present study, forests were the best predictor for StE breeding numbers in Spain (López-Iborra *et al*., 2011). A reduction in breeding numbers in areas with increased urbanisation has also been found in other species (Chace and Walsh, 2006; Palomino and Carrascal, 2007). In Greece, open habitats were found not only to be important for StE breeding, as found in this study, but also as hunting sites (Bakaloudis, 2009). Snake populations may be abundant in natural habitats in Israel, similar to those in Spain, where it was found that StE population size is related to snake species richness (Moreno-Rueda and Pizarro, 2007). Since habitat loss due to population growth and human/agricultural development, is also one of the main causes of snake population decrease worldwide (Reading *et al*., 2010), as well a leading factor in the reduction of biodiversity (Savard *et al*., 2000; McKinney, 2006), if no preventative measures are taken to stop habitat destruction, the eagle's food sources, in addition to those of other species living in eagle territories, may also become severely limited. The loss of nest locations is another factor of concern. A further concern regarding habitat loss is that as agriculture and human settlements increase so too do interspecific predatory pressure (Shapira and Shanas, 2008) and competition (Gutiérrez *et al*., 2007) increase on species living in natural habitats, exerted by opportunistic animal species associated with human settlement. These species, which take advantage of anthropogenic resources, reach high numbers that then invade and exploit the natural habitats.

In this study, no relationship was found between NDVI of the natural habitat types and the number of successfully breeding StE pairs. NDVI is probably more important in raptor species breeding in temperate rather than in semi-arid environments with low annual rainfall, such as found in this study. Specifically, this is most likely the case for species such as StE whose main prey are reptiles (mainly snakes), which are better adapted to the sparse low vegetation in the dry habitats.

The average elevation of the nest sites (326.5 m.a.s.l.) in this study was within the range of that found in studies in Europe (Petretti, 1988; Bocca 1989; Bakaloudis *et al*., 2001; Velevski and Grubač, 2008); whereas the breeding density (8.3 pairs per 100 km^2) was higher than that found in Greece (5.9 pairs/100 km^2, Bakaloudis *et al*., 2005; 7.3 pairs/100 km^2, Vlachos and Papageorgiou, 1994), Former Yugoslav Republic of Macedonia (4.9 km, Velevski and Grubač, 2008), Italy (2.1 pairs/100 km^2, Petretti, 1988), and Serbia (1.1 pairs/100 km^2, Vučanović, 2008), and lower only than that found in Spain (11.8 pairs/100 km^2, Amores and Franco, 1981). The small study site of the latter (51 km^2) was most probably the reason for the very high population density. When monitoring breeding populations, we typically choose to study species in areas with high population numbers and avoid areas with low numbers. In the present study, some areas had very high breeding densities. For example the StE breeding density of the 25-km^2 grids of this study was as high as 12 pairs per grid (48 pairs/100 km^2), with pairs breeding as close as 50 m from one another.

The mean distance of the closest neighbouring successful nest of this study (1.1 km) was closer than that found in Greece (2.7 km, Bakaloudis *et al.*, 2005; 2.2 km Vlachos and Papageorgiou, 1994), Italy (4.4 km, Petretti, 1988; 13–24 km, Bocca, 1989), Former Yugoslav Republic of Macedonia (5 km, Velevski and Grubač, 2008), Serbia (5 km, Vučanović, 2008), and Belarus (6 km, Ivanovsky,1992). In addition to high breeding densities of successful nests, StE have been found to roost (Muñoz *et al.*, 2010) and hunt in large numbers (Darawshi, 2011). In Israel, StE aggregate in large flocks of over 119 (mixed adults and juveniles) individuals to hunt in cultivated fields after the breeding seasons, where the eagles follow tractors to hunt snakes and also rodents when the fields are being ploughed at the end of the year (Hadad, 2007).

Even though the StE in this study bred on slopes facing all directions, more pairs bred on north-facing slopes than on east-facing slopes than expected. In the hot semi-arid climate of this study, winds are westerly and may assist in cooling the nests; whereas nests located on eastern slopes may be avoided by the birds due to the lack of wind. Furthermore, northern slopes do not receive direct sunlight, whereas eastern slopes do, which may be detrimental to StE breeding. Our results differ from those found in Greece (Bakaloudis *et al.*, 2001) and France (Choussy, 1973), where StE mainly bred on southern slopes in order to avoid the cold conditions of northerly winds. Our findings also differ from the findings of two studies on StE in Italy, one of which showed that the eagles avoided south-facing slopes (Bocca, 1989) and the other that the population showed no specific orientation of slopes (Petretti, 1988). The reason why more nests were found on the northern slope in the present study was probably due a combination of the lower exposure to sun and the benefit received from westerly winds.

The large population of StE in this study may be an important breeding source of the species regionally in the Middle East because eagles are endangered in most of the neighbouring countries, mainly due to hunting, illegal trade, and nest robbing. Even though Israel has laws protecting the eagles from such negative impacts, their breeding numbers will nonetheless decrease if the natural habitat types continues to be lost to human expansion. Such loss of natural habitat types will also affect the biodiversity of the region, which warrants further urgent studies and the implementation of conservation protocols.

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6. REFERENCES

Amores, F. and Franco, A.M. (1981) Alimentation et écologie du Circaète Jean-le-Blanc dans le sud de l'Espagne. *Alauda*, **49**, 59–64.

Bakaloudis, D.E. (2009) Implications for conservation of foraging sites selected by short-toed eagles (*Circaetus gallicus*) in Greece. *Ornis. Fenn.*, **86**, 89–96.

Bakaloudis, D.E. and Vlachos, C.G. (2011) Feeding habits and provisioning rate of breeding short-toed eagles *Circaetus gallicus* in northeastern Greece. *J. Biol. Res.*, **16**, 166–177.

Bakaloudis, D.E., Vlachos, C.G. and Holloway, G.J. (2005) Nest spacing and breeding performance in Short-toed Eagle *Circaetus gallicus* in northeast Greece. *Bird Study*, **52**, 330–338.

Bakaloudis, D.E., Vlachos, C.G., Papageorgiou, N. and Holloway, G.J. (2001) Nest-site habitat selected by Short-toed Eagles *Circaetus gallicus* in Dadia Forest (north-eastern Greece). *Ibis*, **143**, 391–401.

Bocca, M. (1989) Status del Biancone (*Circaetus gallicus*), dell'Aquila reale (*Aquila chrysaetos*) e del Pellegrino (*Falco peregrinus*) in Valle d'Aosta. *Boll. Mus. Reg. Sci. Nat. Torino*, **7**, 163–183.

Chace, J.F. and Walsh, J.J. (2006) Urban effects on native avifauna: a review. *Landsc. Urban Plan.*, **74**, 46–69.

Choussy, D. (1973) Observations sur le Circaete Jean-le-Blanc. *Nos. Oiseaux*, **32**, 83–89.

Darawshi, S. (2011) Effect of agriculture on the ecology of the Short-toed Eagle (*Circaetus gallicus*) in Israel. MSc thesis. The Hebrew University, Israel.

Entwistle, A. and Dunstone, N. (2000) *Priorities for the conservation of mammalian diversity: has the panda had its day?* Cambridge University Press.

Forrai, J., Murkes, S., Voznesensky, L. and Klebanov, M. (2004) Development of a better cadastral practice at the survey of Israel. In: *Proceedings of FIG working week*, pp. 22–27. Athens, Greece.

Friedemann, G., Izhaki, I., Leshem, Y. and Mumcuoglu, K.Y. (2013) Alternative nest-building behaviour of the Long-legged Buzzard (*Buteo rufinus*) and the Short-toed Eagle (*Circaetus gallicus*) in the Judean Foothills, and the parasitic and non-parasitic arthropod fauna in their nests. *Israel J. Entomol.*, **43**, 11–19.

Gutiérrez, R.J., Cody, M., Courtney, S. and Franklin, A.B. (2007) The invasion of barred owls and its potential effect on the spotted owl: a conservation conundrum. *Biol. Invas.*, **9**, 181–196.

Hadad, E. (2007) Short-toed Eagle in the land of Judah. *Teva Advarim.*, **145**, 84–98.

Ivanovsky, V.V. (1992) Ecology of Short-Toed Eagle nesting in Byelorussian Poozerje. In: Kurochkin, E.N. (eds), *Modern ornithology*, pp. 69–77. Nauka, Moscow.

López-Iborra, G.M., Limiñana, R., Pavón, D. and Martínez-Pérez, J.E. (2011) Modelling the distribution of short-toed eagle (*Circaetus gallicus*) in semi-arid Mediterranean landscapes: Identifying important explanatory variables and their implications for its conservation. *Eur. J. Wildlife*. Res., **57**, 83–93.

McKinney, M.L. (2006) Urbanization as a major cause of biotic homogenization. *Biol. Conserv.*, **127**, 247–260.

Moreno-Rueda, G., and Pizarro, M. (2007) Snake species richness and shrubland correlate with the short-toed eagle (*Circaetus gallicus*) distribution in southeastern Spain. *Annls. Zool. Fennici*, **44**, 314–320.

Meir, B. (1986) The Biology and Population Ecology of the Short-toed Eagle (*Circaetus gallicus gallicus*) in the Judean hills, Israel. MSc thesis, Tel-Aviv University, Israel.

Muñoz, A.R., Toxopeus, B., Elorriaga, J., Gonzalez, J.M. and Yáñez, B. (2010) First record of a communal roost of Short-toed Eagles *Circaetus gallicus*. *Ibis*, **152**, 173–175.

Newton, I. (1979) *Population ecology of raptors*. Poyser, Berkhamsted.

Palomino, D. and Carrascal, L.M. (2007) Habitat associations of a raptor community in a mosaic landscape of central Spain under urban development. *Landscape Urban Plan.*, **83**, 268–274.

Petretti, F. (1988) Notes on the behaviour and the ecology of the Short-toed Eagle in Italy. *Le. Gerfaut.*, **78**, 261–286.

Ray, J.C. (2005) Large carnivorous animals as tools for conserving biodiversity: assumptions and uncertainties. In: Ray, J.C., Redford, K.H., Steneck, R.S. and Berger, J. (eds), *Large carnivores and the conservation of biodiversity*, pp. 34–56. Washington, DC, Island Press.

Reading, C.J., Luiselli, L.M., Akani, G.C., Bonnet, X., Amori, G., Ballouard, J.M., Filippi, E., Naulleau, G., Pearson, D. and Rugiero, L. (2010) Are snake populations in widespread decline? *Biol. Lett.*, **6**, 777–780.

Savard, J.L., Clergau, P. and Mennechez, G. (2000) Biodiversity concepts and urban ecosystems. *Landscape Urban Plan.*, **48**, 131–142.

Sergio, F., Newton, I. and Marchesi, L. (2005) Top predators and biodiversity. *Nature*, **236**, 192.

Sergio, F., Newton, I., Marchesi, L. and Pedrini, P. (2006) Ecologically justified charisma: preservation of top predators delivers biodiversity conservation. *J. Appl. Ecol.*, **43**, 1049–1055.

Shapira, I., Sultan, H. and Shanas, U. (2008) Agricultural farming alters predator–prey interactions in nearby natural habitats. *Anim. Conserv.*, **11**, 1–8.

Sheskin, D.J. (2003) *Handbook of parametric and nonparametric statistical procedures*. crc Press, Abingdon.

Simberloff, D. (1998) Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? *Biol. Conserv.*, **83**, 247–57.

Tucker, C.J. (1979) Red and Photographic Infrared Linear Combinations for Monitoring Vegetation. *Remote Sens. Environ.*, **8**, 127–150.

Vlachos, C. and Papageorgiou, N. (1994) Diet, breeding success, and nest-site selection of the Short-Toed Eagle (*Circaetus gallicus*) in Northeastern Greece. *J. Raptor Res.*, **28**, 39–42.

Velevski, M. and Grubač, M. (2008) Distribution and estimation of the population size of the Short-toed Snake-eagle *Circaetus gallicus* in Macedonia. In: *Proc. 3rd congress of the Ecologists of Macedonia, with international participation*. pp 22–24. Macedonian Ecological Society.

Vučanović, M. (2008) Podaci o biologiji gnežđenja zmijara *Circaetus gallicus* na Vršačkim planinama. *Ciconia*, **17**, 38–43.

Yom-Tov, Y., Hatzofe, O. and Geffen, E. (2012) Israel's breeding avifauna: a century of dramatic change. *Biol. Conserv.*, **147**, 13–21.