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Shift in nesting ground of the long-legged buzzard (*Buteo rufinus*) in Judea, Israel – An effect of habitat change

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ABSTRACT

Until the 1980s, at least 31 pairs of long-legged buzzards (*Buteo rufinus*) nested along the streams of the Judean Mountains in Israel, mostly on rocky cliffs, which – according to existing literature – is the common nesting style of this bird. During the past 40 years, however, nesting in these areas has substantially decreased, with many pairs of buzzards now nesting on trees in the Judean Foothills.

We suggest that the geographical shift in nesting area, and with it the dramatic change from nesting on cliffs to nesting on trees, is probably due to the increase in land cover (as a result of afforestation, expansion of human settlements and recovery of the Mediterranean chaparral) that has taken place in the Judean Mountains during the last four decades. Buzzards forage in open habitats and the change in land cover has hindered their ability to locate prey. Since there are no cliffs appropriate for nesting in the Judean Foothills, the buzzards were thus forced to adapt to a new style of nesting. This hypothesis is further supported by our observations that within their new nesting grounds in the Judean Foothills, breeding success was significantly related to the area of the open habitat within the territory.

These findings have important scientific and ecological implications. We recommend that foresters should take into consideration the effect of afforestation on open-landscape raptors, and while planning new forests will consider also their needs, particularly leaving large open swaths of land as foraging grounds for such raptors.

1. Introduction

Habitat change is ranked as the second most serious global threat to biodiversity (Walker and Steffen, 1997). During the course of the 20th century, and especially after the establishment of the State of Israel in 1948, the human population in the former Palestine (present-day Israel and the Palestinian Territories) increased by 15-fold to around 10 million in 2000 (Rupin, 1920; Statistical Abstracts of Israel, 2001). This expansion in human population was accompanied by many changes in land cover (Yom-Tov and Mendelssohn, 1988). Notable among these changes is the turning of formerly open habitats into closed scrubland due to reduced grazing by domestic stock. Further, extensive afforestation replaced large natural open areas, thus affecting raptors population that forage in such habitats (e.g., the griffon vulture *Gyps fulvus*, Egyptian vulture *Neophron percnopterus*, lanner falcon *Falco biarmicus* and long-legged buzzard *Buteo rufinus*; Sela, 1977).

The long-legged buzzard, *B. rufinus* (hereafter LLB) is a medium-size raptor that nests in the southern Palearctic region. Unlike some of its congeners, the common and the rough-legged buzzards (*B. buteo* and *B. lagopus*, respectively), the LLB has been less studied (but see Vatev, 1987; Alivizatos and Goutner, 1997; Alivizatos et al., 1998; Khaleghizadeh et al., 2005). It feeds mainly on small to medium-size mammals, but also on birds and reptiles as well as various invertebrates (Frumkin, 1986; Alivizatos and Goutner, 1997; Khaleghizadeh et al., 2005). LLB are known to nest on cliffs (Frumkin, 1986; Vatev, 1987; Alivizatos et al., 1998; Mullarney et al., 1999) but only occasionally on trees (Cramp and Simmons, 1980; Paz, 1986; Shirihai, 1996). They forage in open country, avoiding dense vegetation where they are apparently unable to locate and pursue their prey. In Israel they were once widespread in the Mediterranean region (Sela, 1975) as well as in the Negev Desert (Frumkin, 1986), but secondary poisoning eliminated much of their population (Mendelssohn and Paz, 1977). Their total population size in Israel during the 1980s was estimated at about 300 pairs (Shirihai, 1996).

Raptor populations are threatened by many changes in their environments, including food availability (Cortés-Avizanda et al., 2009), direct and secondary poisoning (Mendelssohn and Paz,

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1977), and recent climate change may also have some influence on birds numbers (Winkler et al., 2002; Both et al., 2006). However, the effect of habitat change on raptors' population was rarely studied. Conservation efforts should be based on scientific knowledge. Thus, in order to conserve LLB population in Israel and elsewhere more data on the breeding biology of this species are required.

Judea is a mountainous region in central Israel rising to 800 m above sea level and dissected by several streams flowing west to the Mediterranean Sea or east to the Dead Sea. The climax vegetation is Mediterranean chaparral dominated mainly by trees of *Quercus calliprinos* and *Pistacia lentiscus*. Lower stages of the Mediterranean plant succession (garrigue and batha) occur in areas of intense grazing and cutting of trees and bushes. Typical of the latter are bushes of *Calycotome villosa*, *Sarcopoterium spinosum*, and *Cistus* spp. On the west the mountains border the coastal plain or Judean Foothills, a region of undulating low hills ranging in height between 150 and 450 m above sea level. The natural plant community of this region is garrigue and batha, as well as scattered trees (*Q. calliprinos*, *P. lentiscus* and *Ceratonia siliqua*). The valleys between the hills and the more moderate slopes are cultivated.

At least 31 pairs of long-legged buzzards (*B. rufinus*) nested until the 1980s along the streams of the Judean Mountains (Rephaim, Sorek, Sansan, Dolev etc.), mostly on rocky cliffs (A. Naor, pers. comm.). During the past 40 years, nesting in these areas has substantially decreased, with many pairs of buzzards now nesting on trees of the Judean Foothills, 10–20 km to the west. This shift in nesting grounds occurred concurrently with a substantial increase in land cover in the Judean Mountains. Change in land cover started after the establishment of the State of Israel in 1948, when Arab villages in the area were abandoned across Judea. In the absence of frequent ecological disturbances such as grazing, uprooting and agricultural processing of the Judean vegetation, the plant succession of the Judean Mountains evolved towards a climax community of the kermes oak (*Q. calliprinos*) and the terebinth (*Pistacia palaestina*). A similar process occurred in the Galilee on Mount Meron (Carmel and Kadmon, 1999). Furthermore, intensive afforestation, mainly with Aleppo and stone pine (*Pinus halepensis* and *P. pinea*, respectively), reduced grazing pressure, while increasing human settlement in the area took place from the 1950s.

We hypothesize that the increased land cover on the Judean Mountains that has occurred during the last 40 years has rendered this area unsuitable for foraging for the long-legged buzzards which usually locate their prey in open fields. As a result, the population that once nested in the Judean Mountains has moved to more open land of the Judean Foothills. Due to the fact that in the latter there are no cliffs suitable for nesting, the buzzards have thus been forced to adopt a new style of nesting – nesting on trees. Furthermore, we also hypothesize that a positive correlation exists between the buzzards' breeding success and the extent of open landscape in their territory. The main aim of our study was to examine these two hypotheses.

2. Methods

Our study was carried out for two years between November 2006 and December 2008 in an area of about 750 km^2 in the western Judean Mountains and adjacent Judean Foothills. In each of the two breeding seasons we located buzzard nests by following buzzards and searching for them by foot. Each nest was visited twice during each breeding season, during the post-hatching period (around the age of 14 days after hatching) and during the chick-rearing period (around the age of 30 days after hatching) and the status of the chicks was noted. Data on past nest locations were kindly provided by A. Naor (pers. comm.), who had surveyed the Judean Mountains during the late 1960s.

In order to determine whether a change in land cover has actually occurred in the Judean Mountains, we compared aerial photographs of the region from 1967 and 2007. We used these photos in order to produce a measure of land cover, defined as the fraction of the area covered by forests, bushes, villages and paved roads. Such a covered area is not suitable for buzzards, which usually forage in open habitats. In particular, we measured past and present land cover over an area of 2 km radius (12.5 km^2) around past and present nests. These data were available for 12 of the abandoned nests in the Judean Mountains, and 32 currently-occupied nests in the Judean Foothills. *t*-tests were used to compare past and present land cover.

In order to study the effect of the extent of open habitat on breeding success, we determined the buzzards' territory size and the proportion of open habitat in it. The buzzards were individually recognized by their appearance, color and shape of their plumage and color rings. Using GPS we marked each buzzard observation on a 1:50,000 map and aerial photographs. Territory size was determined at the end of each breeding season by cross-checking all observations and using the minimum convex polygon method (MCP) based on the peripheral points of each territory observations (Worton, 1995).

We assume that open landscape (fields and shrub land) is the preferable foraging habitat for LLB while forests, chaparral and human settlements are unsuitable for their foraging.

3. Results

Thirty-one long-legged buzzard nests were located on the Judean Mountains during the 1967 breeding season, all of which were built on cliffs along the streams, and all but one of which are now abandoned. During this study we located 52 nests in the Judean Foothills, 24 in 2007 and 28 in 2008, 47 of which were built on trees and only 5 on cliffs. Eight of these nests were used by buzzards in both years of study. Twenty nests were built on Aleppo and stone pines, 13 on funeral cypresses (*Cupressus sempervirens*), 12 on carobs (*C. siliqua*), 1 on tamarisk (*Tamarix aphylla*) and 1 on Christ's-thorn jujube (*Ziziphus spina-christi*). Nineteen of the above nests were built in planted forests (mainly pines and carobs) near the hunting areas. The mean breeding density was 0.5 pairs/10 km^2 ($n = 38$). However, at the central core of our study area there were nine pairs at a density of 1.3 pairs/10 km^2.

Land cover around the 12 nests in our sample area in the Judean Mountains has increased significantly during the last 40 years, from an average of 10.8% to 77.7% (Fig. 1a and Table 1).

In comparing the present land cover around the 12 deserted nests of the Judean Mountains with present land cover around 32 active nests in the Judean Foothills, we found a significant excess of total land cover around the former compared to the latter (77.7% *vs.* 19.2%). The differences are also significant in each of the three categories: afforestation, human construction, and chaparral (Fig. 1b and Table 1).

Open territory size was determined for 17 nests in 2007 (5.86 ± 2.31 km^2, mean ± SD) and for 27 nests in 2008 (6.38 ± 2.61 km^2), and ranged between 1.82 km^2 and 10.46 km^2. For each year, a positive correlation was found between the open territory size and the breeding success of a nest, as measured by the number of fledglings: $r = 0.7418$ ($P_{one\text{-}tailed} = 0.0004$) for 2007, and $r = 0.5366$ ($P_{one\text{-}tailed} = 0.0014$) for 2008. Since the number of fledglings does not follow the normal distribution, the P values were estimated by computer simulations, using Mantel's approach. For each year, a random sample of 100,000 permutations was drawn, and the proportion of permutations with a correlation coefficient larger than or equal to the observed correlation coefficient was taken as an estimate of the P value for rejecting the null hypothesis of no

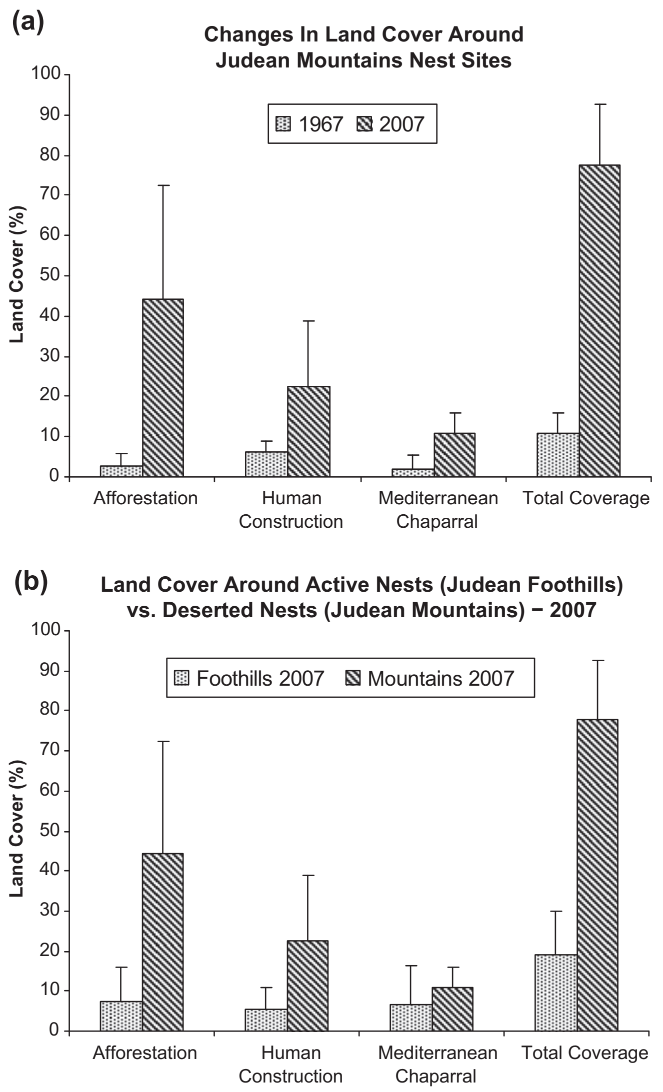

Fig. 1. (a) Change in land cover from 1967 to 2007 around 12 nests in the Judean Mountains. (b) Land cover around 12 deserted nests in the Judean Mountains and around 32 active nests in the Judean Foothills. Land cover was defined as the fraction of the territory covered by forests, bushes, villages and paved roads. (Bars represent standard deviations.)

correlation between the open territory size and the number of fledglings.

4. Discussion

Land cover is an important component in determining hunting success of several species of raptors (Sela, 1977; Vatev, 1987; Austin et al., 1996; Alivizatos and Goutner, 1997; Sergio et al., 2005). In Bulgaria, long-legged buzzards forage in areas covered with weeds and scattered bushes which are constantly grazed by sheep and cattle (Vatev, 1987). Alivizatos and Goutner (1997) found a significant negative relationship between the number of fledglings and vegetation cover, and concluded that the decisive factor for determining the hunting success for LLB is vegetation cover. In Israel, scrubland and Mediterranean garrigue and even agricultural fields are the optimal hunting spaces for LLB (Sela, 1977).

At least 31 pairs of LLB nested until the 1980s along the streams of the Judean Mountains in Israel, where they found rocky ledges and caves for nesting and open landscape to search for prey. At that time, land cover of the mountains was almost entirely open, characterized by low vegetation of Mediterranean garrigue and batha. Such land cover made the Judean Mountains an optimal habitat for the raptor populations that nested there, such as the griffon vulture (*G. fulvus*), Egyptian vulture (*N. percnopterus*), golden eagle (*Aquila chrysaetos*), Bonelli's eagle (*Hieraaetus fasciatus*) and long-legged buzzard (Sela, 1975).

During the past 40 years, LLB nesting in the Judean Mountains has almost ceased, while many pairs have started to nest on trees in the Judean Foothills. This change was concurrent with an average 7-fold increase in vegetation cover in the Judean Mountains from the past. The main factors responsible for the change in land cover were afforestation (responsible for about 59% of the total change), followed by expansion of human settlement (about 27%) and by recovery of the Mediterranean chaparral (about 14%).

We suggest that this change rendered most of the Judean Mountains unsuitable for foraging by LLB, hindering the detection of their prey and forcing these raptors to move to the open fields of the foothills. Indeed, we found that in both years of our study (2007 and 2008), open territory size was significantly correlated with breeding success.

Long-legged buzzards are accustomed to building their nests on cliffs (Heinzel et al., 1972; Frumkin, 1986; Vatev, 1987; Paz, 1992; Alivizatos et al., 1998; Mullarney et al., 1999) and only rarely do so on trees (Cramp and Simmons, 1980; Paz, 1986; Shirihai, 1996). As there are no cliffs appropriate for nesting in the Judean Foothills, the buzzards adapted to a new style of nesting – nesting on trees. New scattered pine and carob plantations in the Judean Foothills provide safe, concealed and potentially suitable nesting places for these buzzards, some of which have occupied old nests of the short-toed eagle (*Circaetus gallicus*). The proximity of these trees to Mediterranean scrubland and garigue potentially allow the LLB close and comfortable access to their hunting areas. Consequently, the Judean Foothills now provide an optimal habitat for the LLB population, which has moved to it from their former nesting area in the mountains. In doing so, they have adopted a new nesting style for this species.

Potentially, the above changes may have occurred due to other factors, such as competition with other raptors that replaced the buzzards in their original habitat, predation on buzzards or non-biological effects, such as global warming. We do not find evidence for any such effects. No other raptor replaced the buzzard in its former habitat, and as far as it is known no predators threaten this species in Israel, and global warming affected both past (the Judean Mountains) and present (the Judean Foothills) areas similarly. Hence, we consider habitat change as the key factor responsible for the above changes.

A similar effect of habitat change on a raptor population has already been documented by Sergio et al. (2009): Alpine populations of scops owl (*Otus scops*) depend on traditional, extensive agro-pastoralism, and a decrease in this agricultural system and the consequent forest expansion are threatening the owls' population. Greenberg (1990) stated that there are intrinsic differences within and between species in their ecological plasticity. He also proposed that the degree of plasticity influences the degree of a species' colonizing ability and its ability to occupy new habitats. An example for nest site plasticity of a raptor is the griffon vulture *G. fulvus*, that nests in colonies of up to 100 pairs on large cliffs, walls of ravines and precipices, whereas in some areas of the western Iberian Peninsula, it nests on trees, in old nests of cinereous vultures *Aegypius monachus* (Traverso, 2001). Similarly, as pointed out by one of the reviewers, the booted eagle *Hieraaetus pennatus* nests on cliffs in the Balearic Islands (even though the availability there for trees is high, as proven by the high densities of red kites), whereas it nests on trees in the rest of its distribution in mainland Europe. The fact that the LLB adapted to new conditions and started to nest on trees instead of cliffs, proves that it has the

Table 1
Land cover (in %) around 12 nests in the Judean Mountains in 1967, around the same, but then deserted nests in 2007, and around 32 active nests in the Judean Foothills in 2007. Comparisons between the Judean Mountains nests in 1967 and 2007 were done by paired samples *t*-tests. Comparisons between the Judean Mountains deserted nests in 2007 and the Judean Foothills in 2007 were done by independent samples *t*-tests, assuming unequal variances. *P* values are two-tailed.

Region and Year	Total land cover			Afforestation			Construction			Chaparral		
	Mountains 1967	Mountains 2007	Foothills 2007	Mountains 1967	Mountains 2007	Foothills 2007	Mountains 1967	Mountains 2007	Foothills 2007	Mountains 1967	Mountains 2007	Foothills 2007
Cover (mean ± SD)	10.8 ± 5.1	77.7 ± 14.9	19.2 ± 10.6	2.8 ± 3.2	44.2 ± 28.4	7.2 ± 8.9	6.3 ± 2.7	22.5 ± 16.4	5.4 ± 5.5	1.8 ± 3.5	11.0 ± 5.0	6.8 ± 9.4
Mountains 1967 *vs.* Mountains 2007	$t_{11} = 14.88$	$P < 0.0001$		$t_{11} = 5.17$	$P = 0.0003$		$t_{11} = 3.47$	$P = 0.0052$		$t_{11} = 10.95$	$P < 0.0001$	
Mountains 2007 *vs.* Foothills 2007		$t_{15} = 12.45$	$P < 0.0001$		$t_{12} = 4.43$	$P = 0.0008$		$t_{12} = 3.53$	$P = 0.0042$		$t_{37} = 1.93$	$P = 0.0610$

ecological plasticity to adapt to a new environment and acquire novel nesting habits. This is in contrast to some reified conservation ideas believing that birds have a limited ecological plasticity. However, such plasticity of changing nesting habits is not rare. For example, in Israel, the spur-winged plover *Vanellus spinosus* used to nest only in wet habitats such as meadows and banks of ponds and other water bodies. During the 1970s it started to breed in cow sheds and fields, and since the 1990s some pairs nest on roofs, from which the fledglings have to jump several meters down in order to feed (Yogev and Yom-Tov, 1997).

Newton (1979) suggested that habitat productivity determines nesting density. Indeed, the present nesting density of the buzzard in the Judean Foothills is 0.5 pairs/10 km^2, an unusually high density and probably the highest reported for this species. A much lower density was documented in Greece – 15–25 pairs in an area of 4242 km^2 (~0.05 pairs/10 km^2; Alivizatos and Goutner, 1997); in Bulgaria four pairs were studied in an area of 2000 km^2 (~0.02 pairs/10 km^2; Vatev, 1987); in Russia – 28–33 pairs in an area of 1079 km^2 (~0.3 pairs/10 km^2; Zavyalov et al., 2001); in southern Israel (Negev Desert) – 27 pairs in an area of 9000 km^2 (~0.03 pairs/10 km^2; Frumkin, 1986), and also in northern Israel – 49 pairs in an area of 4755 km^2 (0.1 pairs/10 km^2; Sela, 1975; the Israel Nature and Parks Authority).

Our findings have broad implications for landscape planning and policy. Increased land cover is aimed for in several countries where extensive tree cutting and overgrazing laid large areas bare, thus increasing soil erosion. In addition, the rise of standard of living in western countries is accompanied by more free time that many people prefer to spend in shaded forests. Hence, in Israel and elsewhere, afforestation is seen as a positive step towards more sustainable land use. Our findings show that afforestation has also a negative implication, by decreasing suitable habitat essential for some raptors. We suggest that foresters should take this factor into consideration, and while planning new forests will consider also the needs of these raptors. Afforestation should be planned in such as way that large, open swaths of land will be left as foraging grounds for such raptors, which can use trees in the forest edge for nesting and the open areas for foraging. Leaving such open landscape has another benefit: In Israel, as well as in other Mediterranean countries, such open landscapes have much richer animal and plant biodiversity (Lehman and Perevolotzky, 1992; Levanony, 2005; Manor et al., 2008).

In conclusion, we report here on a shift of breeding grounds of the long-legged buzzard from the Judean Mountains to the Judean Foothills, and provide evidence supporting the hypothesis that this shift was a consequence of the drastic change in land cover that has taken place during the last four decades. This is also the first report of a long-legged buzzard population having changed its traditional nesting style, and moved to nesting on trees as opposed to its usual cliff habitat.

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