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Occupancy rate and habitat variables influencing nest-box use by tawny owls *Strix aluco*

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Abstract - Nest-box use by owls was examined in a large urban park northeast of Milano (northern Italy) from 1997 to 2000. Nest-box features and several micro- and macrohabitat variables were compared among the 89 sites which held a nest box for at least two years consecutively. Sites were classified according to the use of the nest box they held: unused, used for roosting and used for breeding. The percentage of used nest-boxes increased significantly over the four years of study, being on average 44%, but only a small fraction (12%) were used for breeding. Nest-box use was higher during winter than during both summer and autumn, suggesting that thermal benefits might affect nest-site selection by tawny owls. Used nest-boxes were located higher on trees and were settled in younger wood patches than unused nest boxes. Tawny owls appear to prefer natural cavities to artificial nests for breeding in our study area, while out of the breeding season nest-boxes are often used as shelters. The preference for nest-boxes higher than 6 m suggest that Tawny owls might select higher nest-boxes as a part of a protection strategy against human disturbance, which is very high in the Park of Monza.

Riassunto - *Frequenza di occupazione e variabili ambientali che influenzano l'utilizzo delle cassette nido nell'allocco* Strix aluco. Tra il 1997 e il 2000 abbiamo studiato l'utilizzo di nidi artificiali da parte dell'allocco all'interno del Parco di Monza (750ha). Per ciascuno degli 89 siti che hanno ospitato una cassetta nido per due anni consecutivamente sono state rilevate quattro variabili di microhabitat, relative al nido e alla pianta a cui era fissata la cassetta nido, e cinque variabili di macrohabitat, relative alla chiazza di bosco in cui la cassetta nido era collocata. I siti di posizionamento sono stati suddivisi in: siti con cassetta nido non utilizzata, siti con cassetta nido utilizzata come posatoio e siti con cassetta nido utilizzata per la riproduzione. La percentuale di utilizzo delle cassette nido è aumentata significativamente nel corso dei quattro anni di studio, (in media ogni anno il 44% dei nidi è stato utilizzato dagli allocchi), ma solo in 11 casi (12.4%) la cassetta nido è stata utilizzata per la riproduzione. Le cassette nido utilizzate erano quelle rimaste nel sito per un periodo più lungo, erano fissate a maggiori altezze sulle piante ed erano collocate in boschi più giovani rispetto a quelle non utilizzate. Nella nostra area di studio, pertanto, gli allocchi preferiscono le cavità naturali per la riproduzione, mentre le cassette nido sono utilizzate come riparo soprattutto durante il periodo invernale. La preferenza per cassette nido collocate ad altezze superiori ai 6 m potrebbe riflettere la ricerca attiva da parte dei rapaci di siti di nidificazione o riparo meno esposti al disturbo antropico, che nel Parco di Monza è estremamente intenso.

Introduction

Modern forestry reduces the availability of old trees, dead wood and tree cavities (Linder and Östlund 1998; Fridman and Walheim 2000), strongly affecting hole-breeding bird species. Among secondary cavity nesters, medium-sized and large owls may be limited by nest hole availability, particularly species of the genus *Strix*, which are strongly affiliated with and adapted to forest habitats (König *et al.* 1999). The lack of large cavities in managed forests has been suspected to limit the spotted owl *Strix occidentalis* (Forsman *et al.* 1984, Noon and McKelvey 1996), as well as the great grey owl *S. nebulosa* (Duncun 1997), the Ural owl *S. uralensis* (Saurola 1997, Lõhmus 2003), and the barred owl *S. varia* (Postupalsky *et al.* 1997).

The large scale provisioning of nest-boxes in managed forests might prevent owl populations to suffer decline or became extinct because of forestry that removes trees before large cavities are formed (Saurola 1992, 1997). However, since both natural and artificial nest types may differ in their quality, owls might use nest cavities depending on their features rather than on their availability. Nest features may directly affect owl breeding output imposing constraints to clutch size (Korpimäki 1984, 1985), determine the microclimate for both egg incubation

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and nestling growth (Hardy and Morrison 2001, McCafferty *et al.* 2001), and reduce risks of breeding failure because of predation (Sonerud 1985, Belthoff and Ritchinson 1990, Buchanan *et al.* 1995, Hakkarainen *et al.* 2001, Henrioux 2002).

Differences in used and unused cavities support the hypothesis that forest owls are actually selective for certain nest characteristics related to antipredator and thermoregulatory benefits, which may both influence individual fitness. Belthoff and Ritchinson (1990) showed that Eastern screech owls *Otus asio* select nest sites based on the depth of the cavity and, to a lesser extent, on cavity height and entrance size, and suggested that these features increased protection from predators. Postupalsky *et al.* (1997) showed that barred owls produce fewer young per clutch in old stick nests than in cavities or nest-boxes, while Franklin (1988) reported higher breeding successes of great grey owls in broken-top snag of Douglas-fir *Pseudostuga* spp. and spruce *Picea* spp. than in stick and snag nests in lodgepole-pine *Pinus contorta*. Korpimäki (1984, 1985) reported that clutch size in Tengmalm's owl *Aegolius funereus* was larger in nest-boxes than in natural cavities, and that clutch size and breeding success were related to box size. Finally, Hardy and Morrison (2001) found that the elf owl *Micrathene whitnei* preferred north-facing nest cavities because they are cooler than south-facing ones in the Sonorahn desert (Hardy and Morrison 2001), while Goad and Mannan (1987) found no preference in the Saguaro National Park, 200-500 m higher in elevation and 2-4 °C cooler.

The tawny owl is a secondary-cavity nester, which readily adopts nest-boxes (Dambiermont *et al.* 1967, Southern 1970, Delmée *et al.* 1978, Plesnik and Dusik 1994, Sasvári *et al.* 2000), suggesting that availability of natural nest sites may limit breeding populations of this species (Dambiermont *et al.* 1967, Petty *et al.* 1994). Only a previous study has examined descriptively the nest site selection by tawny owls (Dambiermont *et al.* 1967), and it reported that preferred nest-boxes were settled in wood edges or clearances. However, in that study nest-boxes were placed randomly, without taking into account the territory boundaries, and therefore, nest-boxes may have been deserted simply because owls did not find them. In this study, we measured several micro- and macrohabitat characteristics surrounding nest-boxes located within territories of 45 tawny owl pairs living in the Park of Monza, and related these characteristics to nest-box use. Our specific aims were: (1) to study the occupation frequency of nest-boxes by tawny owls during a 4-year period, and (2) to compare micro- and macrohabitat characteristics of used and unused nest-boxes.

Methods

Study area

The study was carried out from 1997 to 2000 in the Park of Monza, Northern Italy (45.35N, 9.16E). The study area (750 ha) is a large urban park completely surrounded by building areas. Woods, both young and mature, are highly fragmented and occupy 50% of the study area, while open grasslands cover 32% of the Park. The remaining 18% is represented by the river Lambro and by many historical buildings and farm-houses, the National Autodrome of Monza and a Golf Club. Human disturbance is very high, particularly during week-ends and sporting events of the Autodrome, when more than 100.000 people may invade the Park.

The mean population density of tawny owl in the Park of Monza was 5.9 territories/Km^2, and did not change during the four years of the study, ranging from 5.6 territory/Km^2 ($N = 42$) in 1997 to 6.1 territory/Km^2 ($N = 46$) in 1998.

Definition of territory boundaries

Territories were located and mapped accurately using the playback method (Johnson *et al.* 1981) from fixed spots along the road network. Territory boundaries were obtained by Minimum Convex Polygon method (Mcdonald *et al.* 1980) using all territorial responses that were unambiguously assigned to each male tawny owl by individual acoustic recognition of their hoots (Galeotti and Pavan 1991, Appleby and Redpath 1997).

Nest-box characteristics and positioning

Timber nest-boxes (20x20x80 cm; entrance hole 20x20 cm) were fastened directly to the trunk or to a branch (height range: 4.5-8.5 m). Starting from 1997, 51 nest-boxes were placed inside the boundaries of 42 owl territories. During winter 1998-1999, 16 new boxes were added and 22 nest-boxes were relocated in others territories. Therefore, from 1999 onward there were 67 nest boxes in 45 territories (all territories settled in the Park but one) and we could collect data on environmental features surrounding 89 (67+22) different sites holding a nest-box for at least two consecutive breeding seasons. Nest-boxes were checked once for each season to find signs of use by owls such as pellets, feathers and prey remains, adult owls, eggs or nestlings. All signs of use (but not eggs or nestlings) were systematically removed at the end of each checking.

Habitat variables

For each site, we recorded the following features of the nest-box: nest height on the tree, slope (sorted as upright or bended), exposition (N, S, E, W) and nest permanence (i.e. number of days that a nest-box

stayed on the tree). The features recorded for the tree holding the nest (hereafter "microhabitat" features) were: tree species (oaks, hornbeams, maples, and other trees), trunk circumference, and distance from the nearest forest edge. The characteristics of the wood patch containing the nest-box (hereafter "macrohabitat" features) included: wood patch area, mean trunk diameter, mean tree height, wood maturity calculated as the ratio between large (diameter > 50 cm) and small (diameter ≤ 50 cm) trees, and density of undercover (young trees ≤ 2 m). These data were obtained from the forestry management plan of the Park of Monza (Cereda 1998), reporting in detail the measures of all trees for each wood patch of the Park.

Statistical analyses

We used Log-linear analysis to test if nest-box use varied according to season and year by using data on all installed nest-boxes. We checked if nest-box use increased with permanence using the Q-cochram test for categorical repeated measures on a sample of 29 nest-boxes which stayed on the same trees for four consecutive years. For these analyses, nest-boxes were divided in two categories: used and unused by owls.

To test if micro- and macro habitat variables affected nest site selection, the 89 sites in which a nest-box was set up for two breeding season were assigned to three categories according to nest-box use by owls: unused sites (boxes did not show signs of owl presence in all control-visits), roost sites (presence of pellets, feathers, prey remains or roosting adults), and breeding sites (nest, eggs or nestlings inside). We compared micro- and macrohabitat variables among site categories with a MANOVA; variables were log-transformed to meet the assumption of homogeneity of variance and covariance matrices. Categorical variables such as exposition, slope, and tree species were excluded from this analysis, and their effect was assessed using a χ^2 test. All statistics were performed with SPSS 10.0.

Results

Occupancy rates of nest-boxes

The annual percentage of nest-boxes used by owls increased (Fig. 1) from 31.4% in 1997 (16 out 51 nest boxes) to 47.1% (24 out 51) and 47.8% (32 out 67) during 1998 and 1999 respectively, and reached 52.2 % in 2000 (35 out 67), being on average 44.6%. Log-linear analysis showed that the increase in nest-box use over time was significant ($\chi^2_2 = 11.43$, $P = 0.0033$), and the use by owls varied according to season ($\chi^2_3 = 17.34$, $P = 0.0006$), nest-boxes being more visited during winter and spring (35.2% and 27.2% respectively) than during summer and autumn (18.8% and 20% respectively).

By contrast, the nest-box occupancy of the 29 nests which stayed on the same trees for the whole study period significantly increased only in the second year

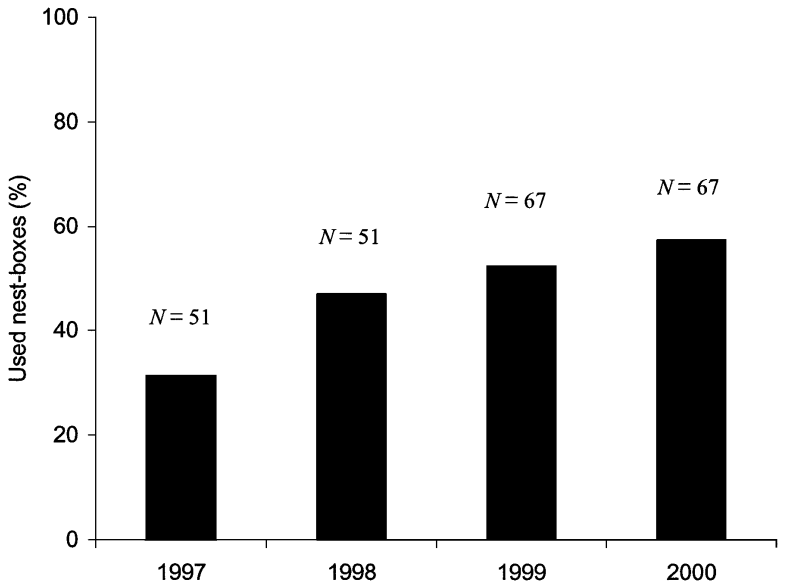

Figure 1. Nest-box use by tawny owls in the Park of Monza from 1997 to 2000. *N* = Numbers of nest-boxes available each year.

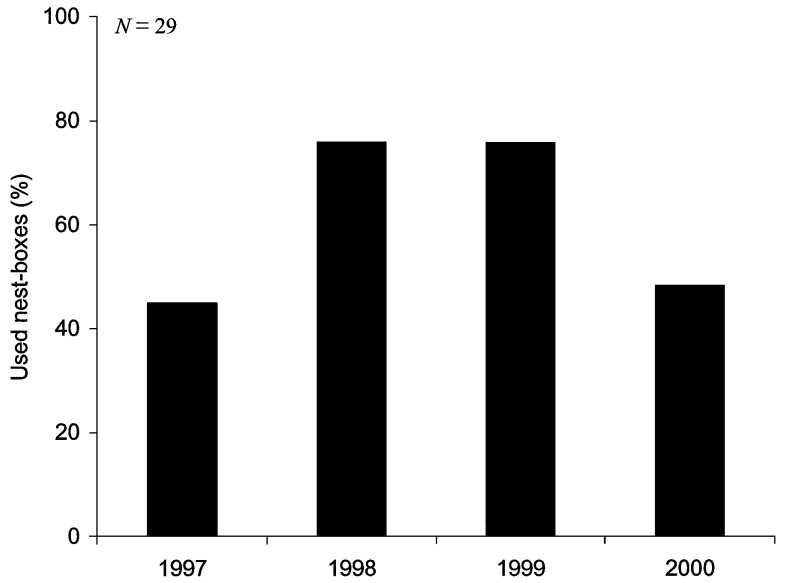

Figure 2. Nest-box use in relation to year for the 29 nest-boxes which stayed on the same tree all over the study period.

of permanence (Q_3 = 11.96, N = 29, P = 0.008), since the percentage of visited nest-boxes rose from 44.8% to 75.9% from 1997 to 1998, but it remained unchanged in the third year, and decreased to 48.3% in the fourth year (Fig. 2). Therefore many nest-boxes were abandoned by resident owls after three years.

Nest box and nest site selection

Most positioning sites (55 out 89, 61.8%) were visited by tawny owls at least once during the four years of study. However, only 11 nest-boxes were occupied for breeding (i.e., 12.3% of positioning sites), while others were used for roosting, since we found only pellets, feathers and prey remains inside.

Nest height, nest permanence, and wood patch maturity differed significantly among site categories (MANOVA: Pillai's Trace = 0.577, $F_{9,78}$ = 3.563, P < 0.001, Tab. 1). Nest boxes used for roosting and breeding were located higher on trees, and within younger wood patches than unused nest boxes. Moreover, the nest box permanence in roosting and breeding sites was much longer than in deserted sites. Nest-box

Table 1. Differences (± SE) in micro- and macrohabitat variables (untrasformed data) among unused, roosting, and breeding nest-box sites in the Park of Monza from 1997 to 2000 (MANOVA). (See Methods for details on habitat variables considered).

Variables	Nest site categories			MANOVA			
	Unused (N=34)	Roosting (N=44)	Breeding (N=11)	Sum of squares	df	F	P
Nest-box							
Nest height (m)	5.68 ± 0.13	6.10 ± 0.13	6.18 ± 0.19	0.02	2	3.36	0.039
Nest permanence (days)	632 ± 24	927 ± 57	1253 ± 93	0.837	2	16.86	<0.001
Microhabitat							
Trunk circumference (cm)	168.2 ± 24.3	152.4 ± 9.6	155.4 ± 13.7	0.03	2	0.46	0.63
Distance from the edge (m)	31.8 ± 5.6	41.5 ± 5.8	38.0 ± 9.3	0.28	2	0.69	0.50
Macrohabitat							
Wood patch area (ha)	8.99 ± 1.69	8.58 ± 1.35	12.16 ± 4.14	0.02	2	0.04	0.95
Mean trunk diameter (cm)	34.3 ± 1.3	33.4 ± 0.8	32.5 ± 1.0	0.002	2	0.12	0.89
Mean tree high (m)	24.9 ± 0.6	24.8 ± 0.4	25.7 ± 0.8	0.002	2	0.37	0.69
Wood maturity	0.21 ± 0.03	0.14 ± 0.02	0.07 ± 0.02	18.5	2	14.75	<0.001
Undercover density	9722 ± 3492	10190 ± 2191	28718 ± 15386	11.18	2	1.52	0.22
MANOVA model (Pillai's Trace)					9, 78	3.563	<0.001

slope did not differ among site categories ($\chi^2_2 = 2.63$, $P = 0.27$), nor the exposition ($\chi^2_6 = 2.31$, $P = 0.88$) or the tree species holding the nest ($\chi^2_6 = 6.47$, $P = 0.37$).

Discussion

Nest-box use

Although nest box adoption by owls increased throug the years, nevertheless no more than 44 % of installed nests were used on average by birds, and only a small fraction (12%) was used for breeding. The low frequency by which tawny owls used nest-boxes for breeding might be due to the fact that boxes were located in long-established territories, and pairs resident there would already own a suitable nest cavity for breeding. In short, suitable natural cavities might be available in excess in our study area, and preferred to nest boxes for breeding.

The pattern of use of the 29 nest-boxes which stayed consecutively on the same tree for four years suggested that not all nest-boxes were immediately located by owls, and some individuals passed one year before adopting the nest-box settled in their territory. The nest-box use observed in the second and third year suggested that all suitable nest-boxes had been located and adopted at that time, while remaining nest-boxes were avoided by owls. Finally, the decline observed in the last year revealed that some nest-boxes were abandoned, probably because of human disturbance or nest-box decay. For this reason, relocation of old nest-boxes and the addition of new ones during 1998 favoured nest-box adoption by tawny owls. Indeed, the yearly percentage of used nest-boxes increased significantly over the 4 years of the study, particularly between the first and second year (from 31.2% to 47.1%), and between the third and fourth year (from 47.8% to 52.2%).

The use of nest-boxes varied among seasons, suggesting that nest-boxes may have been used by tawny owls as roost sites to protect themselves during winter. Therefore, tawny owls may use nest boxes for thermoregulatory benefits.

Habitat variables affecting nest-box use

Nest-box permanence on tree, nest box height, and wood maturity appeared to affect nest-box adoption by tawny owls.

Used nest-boxes stayed on the same tree for longer periods than unused nest boxes. This result confirmed that tawny owls living in the Park of Monza need some time before adopting nest-boxes settled into their territory.

Used nest-boxes were located higher on trees than unused. A taller nest protects against terrestrial predators and human disturbance. Predator avoidance is an important factor for nest-site selection of spotted owls (Buchanan *et al.* 1995) and long-eared owls (Hieroux 2002). In both the two species taller nests suffer low predation risk from terrestrial predators, which often cause nest failure. Similarly, tawny owls may select taller nest-sites to avoid predation. However, in our study area potential predators are few, whereas human disturbance is continuous and very high, since up to 100.000 people may enter the Park during spring and summer week-ends. Therefore, protection against human disturbance might drive the tawny owls to select higher nest-boxes in the Park of Monza.

Used nest-boxes were found in younger wood patches. The availability of natural cavities is directly related to tree age and species, with mature and ancient oak woods providing the best opportunities for breeding to tawny owls (Southern 1970). By contrast, both natural young woods and plantations offer no suitable cavities for this species. Therefore, the greater use of nest-boxes located in young wood patches may be related to the lower availability of natural cavity there.

Finally, we did not find any evidence that slope, exposition or tree species affected nest-box selection by tawny owls. Dambiermont *et al.* (1967) found that tawny owls apparently prefer nest-boxes settled on edges or in clearances, and suggested that they accomplished the function of both free admittance to nest and direct access to hunting areas. However, we found that distances from wood edge did not differ significantly between used and unused nest-boxes.

The results of this study suggest that nest-boxes would be fastened higher than 6 m, within young wood patches. Moreover, since nest-box use by tawny owls increased after the second year it stayed on the tree and decreased onward, it would be useful to relocate nest-boxes that were never used by owls over a period of 2-3 years.

A correct forest management maintaining older and larger trees can preserve and improve tawny owl populations; in fact, nest-boxes are quite ignored by tawny owls in woodlands with good availability of suitable nest holes. Similarly, nest-boxes fail to attract tawny owls in urban areas, particularly in ancient towns: actually, all nest-boxes we set up in the historical centre of Pavia (Northern Italy, Galeotti P., unpubl. data) were deserted by owls, which preferred other cavities such as abandoned chimneys or holes in the monuments. Therefore, nest-boxes may be useful in woods where natural holes are rare because of their age, species composition or human timber harvesting, such as young wood and tree plantations (poplar groves or spruce and pinewood). For example, in the Kielder forest (UK), an extensive man-made conifer forest with timber being harvested by clear-cutting

every 40-60 years, tawny owls rapidly adopted artificial nests, and most pairs bred in nest-boxes (Petty and Peace 1992).

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