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Patterns of territory settlement by Eurasian scops-owls (*Otus scops*) in altered semi-arid landscapes

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Abstract

We studied the habitat preferences of Eurasian scops-owls in a semi-arid Mediterranean region undergoing large-scale habitat alteration. Generalized linear models were used to examine patterns of habitat preference at three different spatial scales: core area, home range and landscape, comparing the habitat composition around occupied and unoccupied territories. At the core area scale, owls occupied dry land tree plantations, ephemeral rivers (ramblas) and riverine forests. At the home range and landscape scales, they preferred dry land tree plantations and ramblas, the model stressing the importance of the borders between them. The length of paved roads and the presence of conspecific neighbours were also significant variables in the landscape scale model.

During the study period, the population declined by 52.4%. Territory desertion was probably prompted by the increasing use of dry land plantations, ramblas and riverine forests as building land. Environmental impact studies and assessments continue to disregard the potential of agro-landscape elements for regulating hydrological flows and for hosting fauna. The present study adds to a growing number of papers revealing the importance of traditional agro-landscapes in southeastern Spain, despite whose findings, no long-term, spatially explicit measures have been proposed by environmental authorities.

Keywords: Agro-landscape; Environmental impact; Housing development; Rambla; Traditional agriculture

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1. Introduction

Mediterranean semi-arid landscapes are characterized by a highly diverse mosaic of managed woodlands and shrublands (Shoshany, 2000), large areas of extensive, unirrigated crops (Sánchez-Zapata and Calvo, 1999) and other types of human-altered landscape components, such as ramblas or temporary watercourses (Gómez et al., 2005). Despite a long history of management and exploitation (Blondel and Aronson, 1999), most of these modified, semi-natural ecosystems have the potential to host a higher species richness and diversity than, for instance, large forests, (Ayyad, 2003; Beaufoy, 1998). In fact, the bulk of raptor and owl populations in arid and semi-arid Spain inhabits totally or partially this agro-landscape mosaic (Carrete et al., 2002; Martínez and Calvo, 2000; Martínez and Zuberogoitia, 2004a–c; Martínez et al., 2003b, 2006; Rico et al., 2001; Sánchez-Zapata and Calvo, 1999). Although conservation policies in the semi-arid regions of southeastern Spain are mainly aimed at large birds of prey (e.g. Bonelli's Eagle, *Hieraaeus fasciatus*), such conservationist efforts have not attempted to fully understand their potential as umbrella species (Martínez et al., 2003a), which could well contribute to avoid the loss of large stretches of traditional agro-ecosystems to greenhouse and irrigated fields, housing developments, summer resorts and road networks (Ayyad, 2003; Martínez-Fernández and Esteve, 2005; Martínez-Fernández et al., 2000; Mota et al., 1996). Moreover, a plethora of environmental impact studies and assessments have failed to preserve the networks of traditional agricultural landscapes, especially in coastal areas (Martínez and Zuberogoitia, 2004b). The extent to which the shrinking availability of the agro-pastoral complex will affect the probability of territories being occupied by threatened species remains unknown.

Several studies have approached this problem by means of multi-scale descriptions of the habitat preferences of target species (Martínez et al., 2003b; Penteriani et al., 2001, 2002; Sergio and Bogliani, 2000; Sergio et al., 2003, 2004), an approach largely based on the theoretical framework proposed by Johnson (1980), whose basic postulation is that animals are capable of making decisions regarding resources at consecutively smaller scales. It follows that habitat selection may be considered as a hierarchical process in which, for example, a suitable patch for breeding at a small scale and a suitable area for foraging at a broader scale are selected.

The Eurasian scops-owl (*Otus scops*) is a small, insectivorous, trans-Saharan migrant nocturnal raptor which inhabits agro-pastoral mosaics in many parts of their European range (del Hoyo et al., 1999). Its highly endangered conservation status in Europe (BirdLife International, 2004) makes it a good target species for assesing the potential repercussions of the habitat-changes occurring in Mediterranean areas. Several authors (Alonso et al., 2003; Marchesi and Sergio, 2005) have suggested that changes in traditional land uses may affect the abundance of this species. While some studies report stability in local populations (Marchesi and Sergio, 2005), others give grounds for serious concern if modern agricultural practices continue their advance (Galeotti and Sacchi, 2001; Tucker and Heath, 1994; Zuberogoitia, 2002). Besides the interest in the Eurasian scops-owl as a species dependant on increasingly scarcer habitats, a recent study has shown that it can also be considered a reliable biodiversity indicator (Sergio et al., 2005); this suggests that identification of the configuration of its preferred habitat could be of great value not just for this species but also for many other target species. Accordingly, the aim of the present study is (1) to identify the most relevant environmental features affecting site occupancy of

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the Eurasian scops-owl in Mediterranean ecosystems and (2) to evaluate how the use of three biologically meaningful spatial scales may contribute to the description of such features. Although the Eurasian scops-owl also inhabits cities in Spain, since our main interest was to assess the conservation value of traditional agro-landscape mosaics and so the study only focuses on countryside owls.

2. Methods

2.1. Study area

The study was carried in the province of Alicante, a territory of 5863 km^2 located in southeastern Spain. Elevation ranges from 0 to 1558 m a.s.l., and the climate varies from semi-arid meso-Mediterranean to sub-humid Mediterranean, with a predominance of the semi-arid (Grove and Rackham, 2001). Average annual rainfall is about 400 mm, and annual mean temperature is about 19 °C. The landscape is dominated by extensive agro-ecosystems (carob, almond, olive trees, vineyards, cereals), scrublands, pine woodlands and medium-sized cities, although housing and irrigated agricultural fields are rapidly expanding throughout the study area (Martínez and Zuberogoitia, 2004b). Temporary and ephemeral watercourses (ramblas, small creeks) crisscross the landscape, where riverine forests are scarce and largely degraded (Agencia del Medi Ambient, 1997).

2.2. Survey methods

The study was conducted between 1997 and 2001. Owl territories were located using the following methods: (1) listening to spontaneous vocalizations, (2) using playback of conspecifics and (3) looking for nests and food remains (Galeotti and Sacchi, 2001; Zuberogoitia, 2002). A territory was considered to be occupied if a calling male was heard in two visits performed between early March and the end of June on the condition that the male was heard again at least one month after it was first detected. Since not all the nests were found every year, we assumed the centre of activity to be the place from where owls delivered their first spontaneous calls at dusk during the breeding season (March–June), because this is considered a good predictor of the location of owls' nests (Martínez et al., 2003b). Throughout the study period, we found 61 territories occupied at least 1 year.

2.3. Selection of scales and habitat variables

In order to assess the habitat preferences of the Eurasian scops-owl, we compared the habitat composition around the 61 occupied territories with the habitat composition around 61 non-occupied spots located at random, but a minimum distance of 5 km from each other or from occupied sites. All the non-occupied random sites remained empty throughout the study period. We selected a set of environmental variables related to topography, human influence and land use from aerial photographs and 1:2000 maps (Table 1). Three biological meaningful spatial scales were considered:

(a) *Core area scale*: The size of the core area was described as a 10.5 ha circular plot around the nests or the centres of activity (35.0% of the home range, 183 m radius) (Cramp and Simmons, 1985; Mikkola, 1983).

Table 1
Description of the variables used to characterize the habitat around territories

Type	Variable description
Physiography	Relief, number of 100-m contours cut by four lines starting from the centre of the area in directions N, S, E and W
Human disturbance	Paved roads, length in m Housing developments, % of area
Land use	Forest, % of area Scrubland, % of area Dry land tree plantation[a], % of area Citric plantation, % of area
Edges	Forest–scrubland, length in m Forest–dry land tree plantation, length in m Scrubland–dry land tree plantation, length in m Dry land tree plantation–rambla, length in m
Nesting/roosting requirements	Rambla, length in m Riverine forest, length in m

[a]Includes almond, carob and olive trees.

(b) *Home range scale*: We described scops-owls' home ranges as a 30 ha circular plot around the nests or the centres of activity (309 m radius) (Cramp and Simmons, 1985; Mikkola, 1983).
(c) *Landscape scale*: Since landscape ecology addresses the relationships between animal distribution and mosaics of ecosystems (Forman and Gordon, 1986), we tested for a possible response of scops-owls to habitat composition at a broad landscape level. Thus, we chose an area of 100 km^2 around each nest (5642 m radius) because substantial changes in landscape composition were likely to be found within this radius in the study area (Agencia del Medi Ambient, 1997). Furthermore, other studies have reported the responses of birds of prey and owls to this landscape scale (e. g., Martínez and Zuberogoitia, 2004c; Sánchez-Zapata and Calvo, 1999).

2.4. Statistical analyses

Generalized linear models (GLMs) were used to obtain the mathematical descriptions of habitat preferences. Such models allow the use of appropriate error formulations, hence avoiding some of the limitations of conventional regression models. The territory occupation by owls was measured as a binary response variable (presence = 1, absence = 0), and we used a logit link function with binomial error structure. Each variable in turn was tested for significance, and only those variables that contributed to significant changes in deviance were retained. Only variables significant at the 1% level were included in the models (Nicholls, 1989). The final models were selected by likelihood ratio tests for type I analysis (SAS Institute, 1996).

The κ statistics was used to assess whether model discrimination significantly improved chance classifications (Martínez et al., 2003b). κ-values of prediction success of 0–40% are considered to indicate slight to fair model performance, values of 40–60% moderate, 60–80% substantial and 80–100% almost perfect (Landis and Koch, 1977).

3. Results

3.1. Habitat preferences at the core area scale

The habitat model at this spatial scale explained 61.3% of the original deviance. This model showed that the probability of finding an occupied territory increased with the amount of dry land tree plantations, ramblas and riverine forest (Table 2), the three types of habitat where territories were found. This model classified correctly 82.0% of the occupied territories and 90.0% of the unoccupied territories. This classification was 66.8% better than chance (κ-test: $Z = 6.34$, $p < 0.001$).

3.2. Habitat preferences at the home range scale

The probability of finding an occupied territory at this scale accounted for 69.6% of the original deviance. This model predicted the high probability of finding Eurasian scops-owls in areas with high percentages of dry land tree plantations, ramblas and edges between them (Table 2). This model classified correctly 71.0% of the occupied territories and 77% of the unoccupied territories. This classification is 71.6% better than chance (κ-test: $Z = 7.9$, $p < 0.001$).

3.3. Habitat preferences at the landscape scale

The model for this scale accounted for 44.3% of the original deviance. Owls showed a positive response to the surface of dry land tree plantations, ramblas, edges between them and the presence of neighbours (Table 2). However, we found a negative response to the length of paved roads. The model at this scale correctly classified 62.2% of occupied territories and 65.5% of unoccupied territories, this classification being 61.2% better than chance (κ-test: $Z = 5.9$, $p < 0.001$).

Table 2
Summary of the generalized linear models for the probability of presence of Eurasian scops-owls (comparing occupied vs. non-occupied territories) in southeastern Spain

Factor	Core area scale			Home range scale			Landscape scale		
	b	SE	χ^2	b	SE	χ^2	b	SE	χ^2
Paved roads							−0.890	0.026	17.5***
Ramblas	0.641	0.021	51.0***	0.277	0.005	80.1***	0.333	0.005	21.6***
Riverine forest	0.351	0.030	23.6***						
Conspecific neighbours							0.550	0.002	10.1***
Dry land tree plantations	0.775	0.000	67.8***	0.919	0.047	76.8***	0.766	0.072	24.0***
Dry land tree plantations/ramblas edges				0.990	0.022	88.0***	0.984	0.006	18.4***
Residual deviance	33.7			30.6			55.8		

***$p < 0.001$.

3.4. Population trends

Throughout the study period, we observed a clear decrease in the number of occupied territories in the study area, from 54 (88.5% of occupancy) in 1997 and 1998 to 22 (36.1% of occupancy) in 2001. This decline affected the three types of nesting habitat equally: ramblas, dry land tree plantations and riverine forest (Fig. 1).

4. Discussion

The Eurasian scops-owl showed a scale-dependent response to habitat features (Table 2). Different sets of variables entered the spatial-explicit model, which supports the view of Johnson (1980) that animals perceive space at several levels and each level reflects different ecological requirements, such as nesting or foraging areas. Spatial-explicit works on settlement patterns or habitat use, better reflecting habitat features that determine the continuity of animal populations, should enhance the efficiency of management decisions concerning the preservation of breeding populations. For instance, the GLM model at core area scale reflected the nesting habitat preferences of the population studied. The owl territories were mainly located in ramblas, dry land tree plantations and riverine forests, where they bred and roosted in bank tunnels, dilapidated rural houses and hollow trees (mainly carobs in dry land plantations and poplars in riverine forests). Only ramblas and dry land tree plantations also appeared as significant in the home range and landscape scale models. The small extent of riverine forest in the study area may explain why this variable was not included in the models constructed for the less detailed scales.

At the home range scale, the regression models showed that the main factor determining the presence of territories was the length of edges between dry land tree plantations and

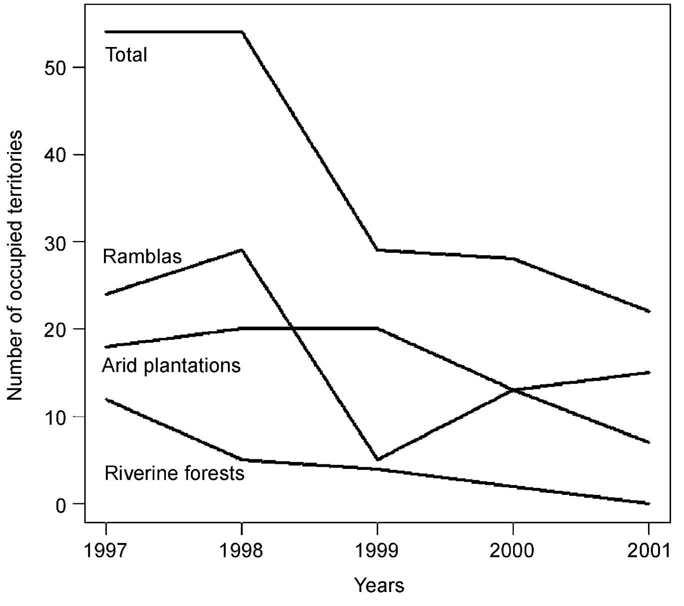

Fig. 1. Inter-annual variations in the Eurasian scops-owl population studied.

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ramblas. Edges between habitats are usually structurally complex features which have notable and equally complex effects on bird populations (Flaspohler et al., 2001). The design of our study did not allow us to incorporate the fine-grained structure of edges in the models, and so we propose a parsimonious hypothesis to explain why the presence of edges is an important factor in determining the settlement pattern of the Eurasian scops-owl in our study area. This hypothesis depends on a number of factors, from hydrology to prey abundance. In semi-arid Spain, edge areas are characterized by a two-phase mosaic of bare ground and vegetated patches (Puigdefábregas and Sánchez, 1996). From a hydrological point of view, bare patches act as water-contributing areas while vegetated patches act as water-receiving areas. This particular combination of source–sink patches may result in a banded vegetation pattern parallel to the slope contours clearly visible at the top of the bank (i.e., the edge between patches of different habitat types), optimizing the use and soil storage of superficial water. Our models suggest that Eurasian scops-owls forage in such bands of vegetation which characterize the margins between ramblas and dry land tree plantations, probably because they are insect-rich areas. Moreover, during moderately or severely dry spells, water is retained by the source–sink system of vegetation bands, preventing the collapse of productivity in these areas (Puigdefábregas and Sánchez, 1996). This helps to maintain favourable habitats for *Orthoptera*, *Miriapoda* and *Coleoptera* (David et al., 1999), which were frequently found in scops-owl pellets in the study area (authors' unpublished data). A review of previous studies on Eurasian scops-owl (Marchesi and Sergio, 2005) showed that the most common prey are Tettigoniid grasshoppers, which typically occur in good numbers in edge habitats (F. Sergio, personal communication).

The GLM model for the landscape scale shows similar habitat responses to those observed at the home range scale. However, two new significant variables are included: the presence of conspecific neighbours and the length of paved roads. In the first case, the presence of Eurasian scops-owl pairs was positively correlated with the presence of other conspecific neighbours, a circumstance which could be explained in two ways. First, the aggregation of breeding territories could result from the clumped distribution of suitable areas for breeding or foraging. Second, scops-owls may be cuing in on local environmental quality, the presence of conspecifics being a useful way of indirectly assessing habitat suitability (Martínez et al., 2003b). The Eurasian spcops-owl has frequently been described as colonial or loosely colonial (Marchesi and Sergio, 2005), which agrees with our finding of a clumped distribution.

On the other hand, the loss of agro-pastoral habitats through the development of road networks has been shown to constrain the presence of occupied territories of most birds of prey or owls (Bautista et al., 2004; Martínez and Zuberogoitia, 2004a–c; Martínez et al., 2003b; Taylor, 1994) and to alter densities of raptors at long distances through diffuse habitat alteration (Forman, 2000; Reijnen et al., 1996; van der Zande et al., 1980). Although grassy road margins are usually prey-rich corridors attracting foraging owls, roads have a negative effect on owls both through road kills and habitat degradation at different spatial scales (Martínez and Zuberogoitia, 2004c; Shawyer, 1987; Taylor, 1994).

It is noteworthy that two variables enter the model at the three spatial scales, namely ramblas and dry land tree plantations (Table 2), which suggests that they play an important role in explaining the pattern of settlement of the Eurasian scops-owl. Housing developments in our study area destroy such ramblas and cultivations, creating a true sea of concrete where only a few isolated, exotic, squalid, shadow-less trees remain in extremely sunny promenades (Martínez and Zuberogoitia, 2004b). Fumigation and lack of herbs, bushes or trees prevents insects from thriving in such places. Suitable trees for Eurasian scops-owls and other owls, Passeriformes and small-sized carnivores, mainly aged carobs, are simply removed, mainly to private firms. It will be important for managers to take into account the results of studies showing the importance of the agro-pastoral landscape for listed fauna, and to generate predictions as to the effects of this invasive form of urban development, examples of which can be found all along the coast of the study area, and increasingly in interior areas (Martínez and Zuberogoitia, 2004b). Managers need not expect a negative response from members of the public if policies aimed at the preservation of traditional land-uses are implemented, because opinion polls show that the dwellers of newly-built housing states in the study area possess a suitably developed state of social awareness that prefers a network of dry land plantations among buildings and bungalows to long promenades with exotic trees.

During the study period, the Eurasian scops-owl population studied decreased by 52.4%. Our results suggest that the reported decline can be mainly attributed to the loss and alteration of the semi-natural habitats where the scops-owls breeds. The territories found in the few remaining stretches of riverine forests, one of the most endangered habitat types in the Iberian peninsula (SEO/BirdLife, 1999), are especially illustrative. The construction of channels, roads and urban developments have strongly affected watercourses all over Spain, with only a few vestigial non-altered patches remaining in the Mediterranean semi-arid regions. Riverine forests have been reduced in extent to a remnant of what they originally were, and undergrowth is frequently cleared to create recreational areas. Also worrying is the loss or decay of abandoned rural houses and the mounting shortage of old trees (carobs, olive, almond) resulting from the conversion of cultivated lands into urbanized areas. Dry land tree plantations and ramblas have been shown to be lacking in ecological value in environmental impact studies and assessments (Martínez and Zuberogoitia, 2004b), and therefore designated as fit for urbanization (the former) and canalization (the latter). However, environmental impact assessment committees must consider evidence that fragmentation of the agro-pastoral mosaics and the resulting reduction in the availability of edges between patches not only upsets hydrological flows but also reduces the likelihood of having territories being occupied by a large number of species of conservation concern.

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