Avifaunal Use of Wooded Streets in an Urban Landscape

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Abstract: *Birds in urban landscapes primarily occupy parks (forest fragments), wooded streets (linear strips connecting fragments), or the urban matrix. I studied the effects of street location in the landscape, vegetation structure, and human disturbance (pedestrian and automobile load) within wooded streets on bird species richness, temporal persistence, and density of feeding and nesting guilds, and on the probability of street occupation by individual species in Madrid during two consecutive breeding seasons. The number of species recorded increased from the least suitable (control streets without vegetation) to the most suitable habitats (urban parks), with wooded streets being intermediate landscape elements. Fourteen species, belonging to four of the eight guilds identified in this system, were recorded in wooded streets in both years. Streets that connected urban parks, along with vegetation structure, positively influenced the number of species within wooded streets, species persistence, guild density, and probability of occupation of streets by individual species. Human disturbance exerted a negative influence on the same variables. Wooded streets potentially could function as corridors, allowing certain species—particularly those feeding on the ground and breeding in trees or tree holes—to fare well by supporting alternative habitat for feeding and nesting. Local improvements in corridor quality, through increased vegetation complexity and reduced human disturbance, could exert a positive influence on the regional connectivity of the system. Because of differential use of corridors by species with different habitat requirements, however, corridor implementation should also take into account the target species of management.*

Uso de Calles con Vegetación por Aves en un Paisaje Urbano

Resumen: *En paisajes urbanos, las aves ocupan preferentemente parques urbanos (fragmentos forestales), calles arboladas (corredores que conectan fragmentos), o la matriz urbana. Este trabajo pretende determinar los efectos de la ubicación de las calles en el paisaje, la estructura de la vegetación y el disturbio humano (tasa de peatones y tráfico automovilístico) en calles arboladas sobre la riqueza de especies, la persistencia temporal de dichas especies, la densidad de gremios de aves, y la probabilidad de ocupación de especies individuales de calles arboladas en la ciudad de Madrid (España) durante dos temporadas reproductivas consecutivas. El número de especies siguió un gradiente ascendente desde el elemento menos adecuado (matriz urbana) al más adecuado (parques urbanos), siendo las calles arboladas elementos intermedios. Catorce especies pertenecientes a cuatro de los ocho gremios identificados en este sistema fueron registradas en las calles arboladas durante los dos años. Las calles que conectaban los parques urbanos, junto con la estructura de la vegetación, afectaron positivamente el número de especies en las calles arboladas, la persistencia temporal de las mismas, las densidades de los gremios y las probabilidades de ocupación de calles por especies individuales. El disturbio urbano produjo un influencia negativa sobre las mismas variables. Las calles arboladas de una ciudad podrían considerarse como corredores potenciales, permitiendo que ciertas especies sobrevivan o se reproduzcan (particularmente aquéllas que se alimentan en el suelo y crían en árboles o huecos de árboles). El mejoramiento local de la calidad de estos corredores (mediante un incremento de la complejidad de la vegetación y una reducción del disturbio humano) podría ejercer una influencia positiva*

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sobre la conectividad regional del sistema. Sin embargo, la implementación de corredores deberá también tomar en cuenta las especies que son el objetivo de las medidas de manejo, debido al uso diferencial de los corredores por especies con diferentes requerimientos de hábitat.

Introduction

Landscape connectivity—the degree to which landscape features enhance or restrain movement among fragments—could play a major role in dispersal, home range movement, colonization, and extinction of biota (Harris & Scheck 1991; Taylor et al. 1993; Machtans et al. 1996). The proportion of suitable habitat in the landscape appears to determine a connectivity threshold (Keitt et al. 1997; Metzger & Décamps 1997) below which populations become more fragmented and isolated (Fahrig 1988; McEuen 1993; Andrén 1994). Connectivity elements, mainly corridors, are thought to counter the effects of habitat fragmentation by connecting otherwise isolated patches and thereby enhancing ecological fluxes such as species interactions and gene flow (Saunders & Hobbs 1989; Dunning et al. 1992; Harrison 1992; Rich et al. 1994). Corridors have been proposed as valuable tools for implementing conservation strategies to lessen the loss of native species diversity, particularly in urban landscapes (Adams & Dove 1989).

Although several authors have suggested benefits and costs of corridor implementation, its utility has yet to be fully assessed (Noss 1987; Simberloff & Cox 1987; Hobbs 1992; Simberloff et al. 1992). Most of the empirical knowledge about corridors focuses on patterns that seem situation-specific, depending as much on landscape features as on the target species (Saunders & Hobbs 1989; Merriam & Lanoue 1990; Rich et al. 1994; Downes et al. 1997). Species may differ in their probability of movement along corridors; for instance, species with short natal and breeding dispersal distances could face high mortality rates while moving through corridors relative to the amount of time spent within the corridor (Tischendorf & Wissel 1997). Thus, any management undertaking ought to evaluate the requirements and abilities of individual species to survive in a fragmented landscape supported by corridors (Saunders & de Rebeira 1991; Saunders & Hobbs 1991).

In urban landscapes, wooded streets could be regarded as structurally similar to corridors because they are vegetative linear strips connecting urban parks. For two consecutive years, I studied avian use of wooded streets in Madrid, analyzing the effects of street placement, vegetation structure, and human disturbance (people and traffic load). I expected an increase in the probability of wooded street use when the location of these linear strips augmented the connection between parks, when vegetation complexity increased, and when human disturbance declined.

At the community level, I determined if bird species occupied urban landscape elements (matrix, wooded streets, and parks) differentially and assessed the factors related to the temporal persistence in occupation of wooded streets and the variability in overall densities. Temporal variability in corridor use could be a relevant indicator of habitat suitability for management purposes (Wiens 1989). I also analyzed how wooded street features could affect the density of different species groupings (guilds), classified in relation to food and breeding requirements. Certain guilds might be more adept at inhabiting corridors because they can make use of a broader range of resources, ensuring their spatial and temporal persistence (Tellería & Santos 1997). Finally, I determined the factors that affected the probabilities of occupation of wooded streets by individual species. Even though these streets might offer sufficient resources, the biological characteristics of individual species (i.e., high sensitivity to human disturbance) may prevent them from occupying apparently suitable linear strips.

Methods

Study Area

I conducted my study in Madrid, Spain, during 1997 and 1998 (May to August). Madrid has an extensive network of urban parks, many of which are connected by wooded streets. I established a sampling design that took into account three landscape elements: urban parks, wooded streets, and urban matrix (Fig. 1). Fifteen parks ranging from 0.4 to 118 ha were censused (Fig. 1). All parks were representative of the urban parks of this city, with deciduous and coniferous trees and large areas of watered grass. Wooded streets were covered with a mix of deciduous and coniferous trees at least 4 m high. These trees were arranged linearly on sidewalks 2–3 m apart, giving the appearance of continuous green cover on both sides of the sampled streets. Most old trees had holes that offered potential nesting sites. Thirty wooded streets were selected with different levels of connectivity, vegetation structure, and human disturbance (pedestrian rate and traffic load; Fig. 1). The length of these wooded streets ranged from 150 to 400 m. I analyzed length differences among wooded streets in a prelimi-

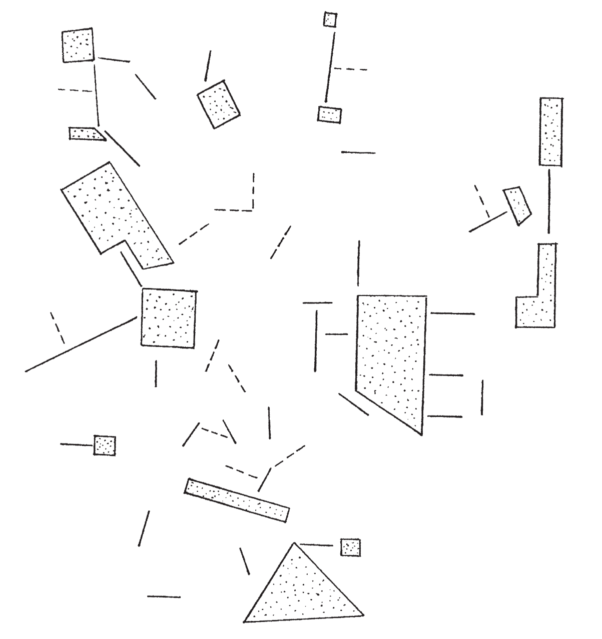

Figure 1. Schematic representation of the sampling design in the city of Madrid (Spain). Thirty wooded streets, 15 urban parks, and 13 streets without vegetation (controls) were selected.

nary study and found that they did not affect the probabilities of street occupation. Thirteen streets without vegetation cover (urban matrix) were chosen as controls and were located in old and modern sectors of the city, with buildings delimiting streets without trees.

Bird Surveys

Four parks and five wooded streets were randomly selected and visited (15 visits in 1997 and 13 visits in 1998) to determine the minimum number of visits necessary for thorough sampling. With cumulative curves, I concluded that three visits for urban parks and four for wooded streets were necessary to detect the bird species present in the landscape elements.

Parks were surveyed 4–5 times per year in the morning (0700 to 1100 hours) to determine species richness and the density of individual bird species (number birds/10 ha). I recorded the number of individuals seen and vocalizing in 100 × 50 m fixed line transects in large parks; in small ones I surveyed with thorough searches (Tellería & Santos 1997).

I surveyed each street weekly (6–7 visits per year) to determine the number and density of bird species. Each survey lasted at least 20 minutes. As I walked across sidewalks at a steady pace, I recorded only those birds seen or heard up to 20 m from the ground just below the uppermost canopy layer to make sure individuals were using trees within streets. When individuals were detected on the ground, I tallied them as using wooded streets only if they landed (after fleeing) in nearby trees located within the street. On control streets, I recorded individuals on the ground or flying 20 m off the ground. My analysis included only individuals belonging to species observed within wooded streets when they were (1) present during at least 25% of the visits, (2) observed on at least two consecutive visits, and (3) recorded when singing, building a nest, or carrying food. Thus, what I assessed is bird use of wooded streets. This sampling procedure proved useful in correctly recording species within these linear strips, given that most of the species in the urban matrix were rarely detected.

The concept of corridor width (Saunders & de Rebeira 1991) is not applicable to this urban landscape, mainly because wooded street width does not reflect the availability of different amounts of vegetation cover but rather the amount of cement cover. Besides, vegetation is concentrated on sidewalks of approximately equal widths (±3 m). Therefore, to avoid bias from correlated factors such as disturbance or width, I calculated wooded street density as the number of individuals per street length.

Species belonging to the Anatidae and Apodidae families were not considered in the analysis because their distribution is determined mainly by water sources and availability of breeding sites in buildings, respectively (Bernis 1988). Such resources were not homogeneously distributed over the urban landscape and could have biased my results. House Sparrows (*Passer domesticus*) and Rock Doves (*Columba livia*) were also excluded because they are widespread species in urban habitats and have been recorded in all the parks and wooded and control streets studied.

Species were assigned to different categories based on their food and nesting requirements (Table 1), as described by Cramp (1992) and Tellería et al. (1999). This classification was preferred over others that take into account edge and interior forest requirements (Moller 1987; van Dorp & Opdam 1987; Harms & Opdam 1990; McCollin 1993) because many species have conflicting classification criteria (McCollin 1998), and reliance on forest edges could vary greatly in harsh boundary landscapes such as this urban setting. Food substrates were classified into three categories: ground, tree, and bush. Nest substrates included holes in tree, tree, ground, bush, and rock. Combining preferences produced nine groups of species which could be regarded as guilds because they share similar requirements during the breeding season (Table 1). Blackbirds were considered a ground/tree species (the first word indicating food and the second, nesting requirements) in the analyses, whereas the only ground/rock species (White Wagtail) was not included due to low sample size.

Table 1. Species found in the urban landscape in Madrid, their food and nesting requirements,[a] the number of wooded streets in which they were present in each year, and the variability in wooded street occupation (Var^2).

Common names	*Genus and species*	*Food*[b]	*Nesting*[c]	*1997*	*1998*	*Var*^{2}
Coal Tit	*Parus ater*	tree	tree hole	4	7	0.07
Blue Tit	*Parus caeruleus*	tree	tree hole	2	3	0.04
Great Tit	*Parus major*	tree	tree hole	5	2	0.18
Treecreeper	*Certhia brachydactyla*	tree	tree hole			
Blackcap	*Sylvia atricapilla*	tree	tree			
Long-tailed Tit	*Aegithalos caudatus*	tree	tree			
Bonelli's Warbler	*Phylloscopus bonelli*	tree	ground			
Hoopoe	*Upupa epops*	ground	tree hole	1	1	0.00
Green Woodpecker	*Picus viridis*	ground	tree hole	1	1	0.00
Starling	*Sturnus vulgaris*	ground	tree hole	7	8	0.01
Tree Sparrow	*Passer montanus*	ground	tree hole	1	1	0.00
Jackdaw	*Corvus monedula*	ground	tree hole	1	2	0.11
Stock Dove	*Columba oenas*	ground	tree hole			
Ring-necked Parakeet	*Psittacula krameri*	ground	tree			
Blackbird	*Turdus merula*	ground	tree/bush	10	15	0.04
Serin	*Serinus serinus*	ground	tree	7	13	0.09
Greenfinch	*Carduelis chloris*	ground	tree	9	7	0.02
Magpie	*Pica pica*	ground	tree	14	21	0.04
Woodpigeon	*Columba palumbus*	ground	tree	12	13	0.01
White Wagtail	*Motacilla alba*	ground	rock	1	2	0.11
Robin	*Erithacus rubecula*	ground	ground			
Wren	*Troglodytes troglodytes*	bush	bush			
Sardinian Warbler	*Sylvia melanocephala*	bush	bush			

[a] *Food and nesting requirements based on Cramp (1992) and Tellería et al. (1999).*
[b] *Food substrates were classified as ground, tree, and bush.*
[c] *Nesting substrates were classified as holes in tree, tree, ground, bush, and rock.*

Corridor Placement, Vegetation Structure, and Human Disturbance

My predictions depended on three types of variables that would explain how species used wooded streets: street location in the landscape, vegetation cover, and human disturbance within streets (Table 2). Street location indicated the degree of connectivity of a single street, ranging from 0 to 2, for cases in which a wooded street did not connect any urban park (0) or it connected one (1) or two (2) parks (Henein & Merriam 1990).

Vegetation structure included several measures of vegetation cover: grass, shrub, and forest (Table 2). The selection of variables followed that of Tellería and Santos (1997). Measures were taken in 25 × 30 m rectangular plots (base oriented toward the sidewalks) uniformly located at 50-m intervals. Cover variables were visually estimated (Prodon & Lebreton 1981). To reduce the number of original variables (Table 3), I performed a principal component analysis on the averaged vegetation features of each wooded street. Four factors were selected from the analysis, with eigenvalues >1 as the criterion for factor selection.

Human disturbance has been reported to adversely influence bird survival and reproduction (Foppen & Reijnen 1994; Reijnen & Foppen 1994). To determine the pedestrian and automobile traffic load, I chose two random points along a wooded street, and at each point I recorded the number of pedestrians and cars passing by in 3-minute intervals in the morning (0800–0900 hours) and at midday (1300–1400 hours). I repeated this procedure four times at each wooded street immediately after census sessions in each year, turning final values into rates of pedestrians and cars per minute. The number of cars can be considered a good estimator of traffic load (Reijnen et al. 1997).

Statistical Analysis

I used the following dependent variables: number of species, density of guilds, and presence or absence of individual species within wooded streets. The number of

Table 2. Variables measured in 30 wooded streets of Madrid and their classification scheme.

Code	*Variable*	*Characteristic*
STPL	placement of wooded streets in the urban landscape	0, no connection 1, connection at one end 2, connection at both ends
PC1	grass and shrub cover, number of shrub and tree species	see Table 3
PC2	tree height and number stems 30–50 and >50 cm dbh	see Table 3
PC3	shrub height and coniferous cover	see Table 3
PC4	number of stems 10–30 cm dbh	see Table 3
CAR	car traffic rate within streets	number of cars per minute
PEOPLE	pedestrian traffic rate within streets	number of pedestrians per minute

species could yield general trends indicating how species used different landscape elements. The density of species (in this case classified according to food and breeding requirements) is considered a good estimator of the probability of corridor use (Downes et al. 1997; Henein et al. 1998). I employed such distinct dependent variables analyzed at different scales to obtain a more meaningful picture of the role of wooded streets as potential corridors in this urban setting. Each street (with and without vegetation) was regarded as a sample unit. Certain variables were log-transformed ($\log_{x+1}$) to meet the requirements of normality and homoscedasticity (Underwood 1997).

Species richness and overall densities were correlated in both years by means of Pearson product-moment correlations. Rarefaction analyses were applied to standardize species richness in parks and on wooded and control streets to similar levels of census intensity (Wiens 1989). I used a one-way analysis of variance to compare species richness in the three landscape elements. The variability in the occupation of wooded streets per species was calculated as (number of occupied wooded streets in 1997 − number of occupied wooded streets in 1998 / total number of occupied wooded streets in both years)^2. Interannual persistence in wooded street use was assessed as the number of species occupying a wooded street in both years divided by the total number of species recorded in both years. The availability in overall densities was calculated as (1997 total corridor density − 1998 total corridor density)^2. I used multiple stepwise regression analyses to test the effect of street placement, vegetation structure, and human disturbance on interannual persistence, density variability, overall species richness, and density of tree/tree-hole, ground/tree-hole, and ground/tree species. The analyzed models were obtained with forward selection procedures. To analyze the factors affecting the patterns of species occupation (presence vs. absence) in wooded streets, I employed a stepwise logistic regression, which estimates the dependency of a dichotomous variable from a set of independent traits either discrete or continuous (Hosmer & Lemeshow 1989). All species occurring in <5 wooded streets were not included in the individual species analysis.

Table 3. Factor loadings of individual variables obtained by a principal component analysis on the vegetation structure of 30 wooded streets in Madrid.

*Variable**	*PC 1*	*PC 2*	*PC 3*	*PC 4*
GRASSC	0.77	—	—	—
SHRUBC	0.87	—	—	—
SPSHRUB	0.89	—	—	—
SHRUBHE	—	—	0.76	—
CONIFTC	—	—	0.77	—
DECIDTC	—	—	—	—
SPTREE	0.81	—	—	—
TREEHE	—	0.78	—	—
SDBH<10	—	—	—	—
SDBH10–30	—	—	—	0.88
SDBH30–50	—	0.76	—	—
SDBH>50	—	0.80	—	—
Eigenvalue	3.29	2.39	1.76	1.41
Variance	0.27	0.20	0.15	0.12
Cumulative variance	0.27	0.47	0.62	0.74

**Abbreviations: GRASSC, grass cover; SHRUBC, shrub cover; SPSHRUB, number of shrub species; SHRUBHE, shrub height; CONIFTC, coniferous cover; DECIDTC, deciduous cover; SPTREE, number of tree species; TREEHE, tree height; SDBH<10, stems <10 cm dbh; SDBH10–30, stems 10–30 cm dbh; SDBH30–50, stems 30–50 cm dbh; and SDBH>50, stems >50 cm dbh.*

Results

During two consecutive springs, the number of species found in Madrid followed a gradient from the least to the most suitable habitats (Fig. 2). The number of species in wooded streets was intermediate between those of control areas and urban parks. Fourteen species were recorded in wooded streets, and 24 species were encountered in urban parks (Table 1). Of all the species found in this urban system, 3 of 4 tree/tree-hole species, 5 of 6 ground/tree-hole species, 5 of 6 ground/tree species, and only 1 ground/rock species were recorded within wooded streets. None of tree/tree, tree/ground, ground/ground, and bush/bush species was detected in wooded

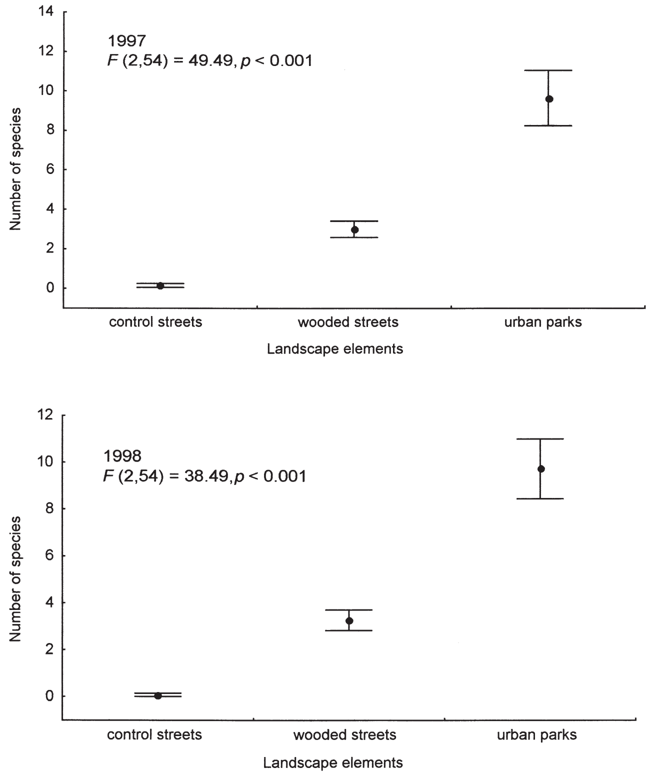

Figure 2. Species richness in the three elements of the urban landscape sampled during 1997 and 1998: control streets (without vegetation cover), wooded streets, and urban parks. (Results from an analysis of variance.)

streets. Of the 14 species found within wooded streets, 5 were ground/tree-hole, 5 were ground/tree, 3 were tree/tree-hole, and 1 was ground/rock. In both years, the same species were detected in wooded streets, despite variations in the number of streets occupied (Table 1). Excluding the White Wagtail, such variability in occupation was greater on tree/tree-hole species (mean var^2 = 0.09 ± 0.08) than on ground/tree-hole (mean var^2 = 0.02 ± 0.05) and ground/tree species (mean var^2 = 0.04 ± 0.04).

The overall number of species in wooded streets increased in both years (Table 4) when streets connected parks at both ends, as the rate of pedestrian use decreased, and as the number of stems of 10–30 cm diameter at breast height (dbh) (PC4) increased. In 1998 species richness was also positively influenced by shrub height and the amount of coniferous cover (PC3).

Regarding the temporal dynamics in wooded street use, species richness and overall abundance were significantly correlated between years (species richness, r^2 = 0.92, $p < 0.001$; abundance, $r^2 = 0.68$, $p < 0.001$). Mean persistence in wooded streets was low and highly variable (mean persistence = 0.35 ± 0.33, CV = 94.3%). Species persistence in wooded streets was influenced positively by tree structure (PC2, tree height and number of stems >30 cm dbh) and negatively by the rate of pedestrian use (Table 4). In much the same way, the variability in overall density was high between 1997 and 1998 (CV = 313%) and was accounted for by another structural variable, shrub height and coniferous cover (PC3; Table 4).

The probabilities of wooded street use based on guilds showed consistent patterns between years. In 1997 and 1998, densities of tree/tree-hole species were affected mainly by street location. In 1997, tree structure (PC2, tree height and number of stems >30 cm dbh) also augmented the probabilities of wooded street use, whereas traffic load exerted a negative influence (Table 4). Densities of ground/tree-hole species were positively influenced by vegetation structure in both years: tree structure (PC2) and shrub height and coniferous cover (PC3). Moreover, traffic load decreased the density of ground/tree-hole species in wooded streets. Finally, densities of ground/tree species increased with vegetation structure (PC1, grass and shrub cover, number of shrub and tree species) in 1997 and 1998. Human disturbance also affected this guild, with decreasing densities caused by traffic load in 1997 and by pedestrian rate in 1998 (Table 4).

I modeled the occupation patterns of eight species, of which five yielded representative models in both years, explaining 65–93% of the variability (Table 5). Street location raised the probability of occupation of five species (Great Tit, Coal Tit, Magpie, Starling, Woodpigeon; Table 5). Another relevant factor was traffic load, which negatively affected three species (Great Tit, Serin, Greenfinch; Table 5). Grass and shrub cover, number of shrub and tree species (PC1), and tree structure (PC2, tree height and number of stems >30 cm dbh) brought about positive influences in the presence of three and two species respectively; all were ground/tree species (Table 5). Shrub height and coniferous cover (PC3) and number of stems 10–30 cm dbh (PC4) positively influenced one ground/tree-hole (starling) and one ground/tree species (Magpie), respectively (Table 5). Pedestrian rate lowered the probabilities of occupation in two cases, both ground/tree species (Table 5).

Discussion

Wooded streets potentially could function as corridors and enhance bird movement, because they are intermediate landscape elements used by several bird species that inhabit forest fragments (urban parks) embedded in a harsh urban matrix. With a structural complexity akin to that in urban parks, wooded streets might enhance the overall connectivity of the landscape, increasing the available proportion of suitable habitat above the threshold used by different species (Keitt et al. 1997; Metzger & Décamps 1997). Yet I detected only 56% of urban-park species richness in wooded streets, corresponding

Table 4. Multiple stepwise regression models of number of species in wooded streets (species richness), persistence, density variability (Den Var), and guild density of species with different food and nesting requirements.

						Wooded street features[a]						
Dependent variable	F	*df*	p	r^2	*Intercept*	*STPL*	*PC1*	*PC2*	*PC3*	*PC4*	*PEOPLE*	*CAR*
Species richness 1997	4.72	3,26	0.009	0.35	2.77	2.08				0.41	−0.08	
Species richness 1998	7.44	4,25	0.001	0.54	4.08	2.25			0.91	0.76	−1.01	
Persistence	7.36	2,27	0.003	0.35	0.53			0.08			−0.03	
Density[b]												
variability[c]	5.03	1,28	0.033	0.17	320				407			
tree/tree 97	7.9	3,26	0.001	0.39	9.32	7.53		5.9				−0.24
tree/tree 98	5.8	1,28	0.022	0.14	0.81	8.36						
ground/tree-hole 97	17.1	3,26	0.001	0.65	24.3			14.5	33.8			−0.35
ground/tree-hole 98	30.1	3,26	0.001	0.69	6.01			4.9	12.1			−0.64
ground/tree 97	10.4	2,27	0.001	0.39	80.2		57.6					−0.57
ground/tree 98	6.6	2,27	0.005	0.27	155		30.5				−5.51	

[a] *For abbreviations see Table 2.*
[b] *The first word indicates food and the second nesting requirements (see Table 1).*
[c] *Variability in overall density was calculated as (1997 total corridor density − 1998 total corridor density)^2.*

to only four out of eight guild categories. This lack of species probably has to do with habitat requirements or the inherent properties of corridors (largely edge habitats with high ratios of edge to interior; Saunders & Hobbs 1991; Rich et al. 1994). Species not recorded on wooded streets were those that require breeding substrates not provided by these linear strips, which would include ground and bush nesters (Robin, Wren, Sardinian Warbler, Bonelli's Warbler), or that need large areas for foraging or breeding (Treecreeper, Blackcap, Long-tailed Tit) (McCollin 1998).

The suitability of wooded streets as habitat for urban species may be inferred by the temporal patterns of variability in occupation and density (Wiens 1989). Species feeding in trees and nesting in tree holes showed the most variable occupation pattern, possibly because trees with holes may be less available in wooded streets, coupled with a possible dearth of abundant insect resources in such linear edge habitats (Burke & Nol 1998). Higher species persistence and a lower variability in density among years were a function of the quality of a particular wooded street, which rested on shrub and tree complexity and low human disturbance levels. Improving corridor quality may be a useful management tool, as has been proposed through modeling approaches (Henein & Merriam 1990; Henein et al. 1998). This could increase corridor occupation (this study) and survival probabilities (Harrison 1992; Machtans et al. 1996) and provide suitable habitat not only for individual movements but also for survival within corridors, ensuring long-term dispersal to other isolated fragments (Fahrig & Paloheimo 1988; Tischendorf & Wissel 1997).

Table 5. Logistic regression models for species with at least five wooded streets occupied in Madrid.[a]

						Wooded street features[b]						
Species/year	χ^2	*df*	p	*%CC*	*Constant*	*STPL*	*PC1*	*PC2*	*PC3*	*PC4*	*PEOPLE*	*CAR*
Great Tit 1997	19.04	2	0.001	93	−9.98	14.12						−0.10
Coal Tit 1998	4.21	1	0.04	76	−2.08	1.74						
Serin 1997	4.91	1	0.027	74	0.19							−0.31
Serin 1998	12.69	1	0.001	77	3.19							−0.37
Greenfinch 1997	7.68	1	0.006	76	1.47							−0.20
Blackbird 1997	10.23	1	0.001	59	−2.44		1.85					
Blackbird 1998	15.26	3	0.002	65	0.53		0.97	0.94			−0.31	
Magpie 1997	16.16	2	0.001	84	−1.19	2.79	1.14					
Magpie 1998	13.29	2	0.001	83	−0.26	4.57				2.66		
Starling 1997	5.04	1	0.025	76	−1.31				1.12			
Starling 1998	8.52	2	0.014	80	−2.13	2.07			1.21			
Woodpigeon 1997	8.69	2	0.013	73	−1.06	1.52		0.79				
Woodpigeon 1998	12.5	2	0.002	66	1.14			1.28			−0.33	

[a] *The table depicts the factors and their b-coefficients, the χ^2 statistic and its probability, and the percentage of wooded streets correctly classified as occupied or unoccupied (%CC).*
[b] *For abbreviations see Table 2.*

My results support corridor occupation patterns throughout the three scales I considered: community, species groupings, and individual species. Street placement within the landscape could be considered a regional trait, a first or coarse-grain step in the habitat selection process which affects mainly tree/tree-hole species and some ground/tree species. But corridor quality may differ according to the particular habitat requirements of individual species (Henein & Merriam 1990). Landscapes with high connectivity between isolated patches are essential for specialists (such as *Parus* sp., McCollin 1998; see also Keitt et al. 1997; Henein et al. 1998) because corridors provide safe passage through a hostile matrix, thereby increasing the probability of survival (Tischendorf & Wissel 1997) and reducing fragmentation effects (Noss 1987).

At a more local scale involving fine-grained processes of habitat selection, the suitability of wooded streets appears to be influenced by vegetation structure and human disturbance. The complexity of the vegetative cover greatly increases the probabilities of occupation of ground/tree-hole and ground/tree species in particular, possibly because of a greater availability of feeding and nesting substrates. On the contrary, human disturbance (pedestrian or traffic load) restrains the available area and time that wooded streets could be exploited. High rates of pedestrian traffic may decrease the availability of cover (a consequence of the rectangular geometry of these linear strips), which lowers the amount of time spent searching and consuming food in favor of more time being vigilant (Fernández-Juricic & Tellería 2000). The negative effects of traffic load may be due to high noise levels (Foppen & Reijnen 1994). Noise could interfere with acoustic communication (songs, contact calls) in birds and may induce higher levels of stress (Reijnen et al. 1995). Several studies highlight how traffic load decreases the abundance of breeding species near roads and highways (reviewed in Reijnen et al. 1997). The implication is that this factor ought to be carefully controlled, not only in urban landscapes but also in frequently visited reserves or natural parks.

As this urban landscape exists, occupation of wooded streets is more likely among species that utilize a broad range of food resources (ground/tree and ground/tree-hole species) than among those that rely on special habitat requirements (tree/tree-hole species). It is possible that tree/tree-hole species may not fare well in wooded streets because their minimum habitat requirements are seldom reached, or because the presence of urban predators, such as Magpies (Groom 1993), leads to high mortality levels. From a management perspective, it is worthwhile to consider whether increasing the quality of wooded streets would be useful to specialist species or a way to enhance the prevalence of generalist species. The relevance of both processes requires proper evaluation concurrent with the precise objective of any management program.

From the perspective of wildlife corridor theory (McEuen 1993), the empirical results of this paper support (1) the potential use of corridors as alternative habitats that provide feeding and nesting substrates, thereby enlarging the potential area effects of suitable fragments (Wiens 1989), (2) the differential use of corridors by species with different habitat requirements (particularly ground/tree and ground/tree-hole species), (3) the positive influences on corridor occupation of corridor placement in the landscape and of vegetation structure, variables that have been used mainly in modeling approaches (Henein & Merriam 1990; Keitt et al. 1997; Henein et al. 1998), (4) the negative effects of human disturbance on corridor use, and (5) the role of corridors as elements that could potentially reduce the effects of forest fragmentation. Local improvements in corridor suitability might positively affect regional patterns of corridor use by increasing the connectivity threshold of the whole system (Metzger & Décamps 1997). Corridor implementation, however, should take into account not only a general improvement of corridor quality but also its suitability for the species subject to management (Saunders & Hobbs 1991).

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