Ornis Fennica 84:66–77. 2007

Factors influencing the bird community of urban wooded streets along an annual cycle

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Received 28 July 2006, revised 22 February 2007, accepted 16 March 2007

Although the bird communities of some urban habitats have received considerable research attention, the bird fauna of wooded streets have been little studied despite the fact that wooded streets constitute a distinct feature of the urban landscape. In order to examine the effects of vegetation structure and floristic attributes on bird species richness and bird abundance, 216 wooded streets in the city of Valencia (Spain) were surveyed during three consecutive seasons in the year 2000. During the survey 1,378 individuals of 14 bird species were recorded. With the exception of the House Sparrow (*Passer domesticus*) and the Collared Dove (*Streptopelia decaocto*), most of these species had very low abundances. Depending on the season, the species recorded in wooded streets represented between 19–25% of the species recorded in the nearby urban habitats. Across seasons, tree species richness, tree abundance and tree height were the main factors influencing bird species richness and bird abundance. 34 tree species out of 41 were used by birds. Some large tree species like the Box Elder (*Acer negundo*), the Siberian Elm (*Ulmus pumilla*) and the White Poplar (*Populus alba*) were preferred. A substantial change in the design and management of wooded streets in order to improve their suitability for bird fauna is suggested.

1. Introduction

The last two decades have seen an increase in research of urban bird communities (Marzluff *et al*. 2001), largely because of a growing concern about the deleterious influence of urbanization on biodiversity and environmental processes (Miller & Hobbs 2001, McKinney 2002). While urban parks (Fernández-Juricic & Jokimäki 2001, Marzluff *et al*. 2001) and remnants of native habitats encapsulated in the urban matrix (e.g. Soulé *et al*. 1988, Parsons et al. 2003) have received considerable attention, other urban habitats, like wooded streets, have been far less studied (but see Fernández-Juricic 2000a, White *et al*. 2005).

Wooded streets are an intermediary habitat between urban parks and streets without vegetation cover (Fernández-Juricic 2000a), and usually adopt the form of narrow strips composed of trees and, less frequently, of bushes and grass verges (Gilbert 1989). Depending on their structural complexity (Fernández-Juricic 2000a) and floristic composition (White *et al*. 2005), wooded streets may constitute a functional habitat for some bird species. Potentially, wooded streets could facilitate the movement of birds through the urban landscape by acting as ecological corridors (Fernández-Juricic 2000a, White *et al*. 2005).

Due to the scant attention devoted to bird faunas of wooded streets our knowledge of their role in conserving urban bird diversity is still limited. Previous studies have been carried out during the breeding season (Fernández-Juricic 2000a) or during the non-breeding season (White *et al*. 2005), and there is thus a lack of information concerning the whole annual cycle. This is important, because seasonality (i.e. predictable variation in conditions and resources on an annual basis) affects the population parameters and the behavior of species, which could vary their patterns of habitat use (e.g. Bilcke 1984, Murgui 2007). Thus, results obtained during a particular season may not apply to others. From an applied point of view, a greater insight into seasonal issues is desirable because, when facing the conservation of migratory birds, both breeding and wintering processes are important (Baillie & Peach 1992). There are many studies of urban bird communities (or populations) of whole urban areas through different methodological approaches (for recent examples see Turner 2003, Kelcey & Rheinwald 2004, Witt *et al*. 2005). Nevertheless, surveys of particular habitats at the same spatial scales have been mostly limited to urban parks (Jokimäki 1999, Gough 2005, Murgui 2007). Therefore, despite the fact that wooded streets constitute a distinct feature of the urban landscape, their influence on urban bird faunas remains unexplored (but see Murgui & Martínez 2000, Murgui 2006).

This paper seeks to assess the suitability of wooded streets for bird fauna across seasons. This is achieved by sampling the bird fauna of a relatively large number of wooded streets in order to minimize the influence of nearby urban parks. I also analyze the influence of the characteristics of wooded streets on the richness and abundance of bird species, paying special attention to the floristic attributes which constitute a factor important in shaping woodland bird communities (Fuller 1995), and a major feature to take into account in the design and subsequent management of wooded streets (Gilbert 1989).

2. Methods

2.1. Study area

This study was conducted in the city of Valencia (around 35 km^2) which is inhabited by about 800,000 people. The city of Valencia is a dense and heterogeneous urban fabric, comprising primarily of block buildings, most of them having five or more stories. Buildings are interrupted by four other habitat types: wooded streets, urban parks (public sites used mainly for recreation purposes) residential gardens and derelict land (non developed spaces dominated by spontaneous ruderal vegetation).

There are around 800 wooded streets in Valencia (Samo *et al*. 2001) in which trees are arranged linearly on sidewalks, usually without associated bushes or grass verges. 37,768 trees of 91 different species (many of them non-indigenous) are planted in the wooded streets of Valencia (Ayuntamiento de Valencia 1997). The ten most abundant species constitute 66% of the total number of trees, and the Box Elder (*Acer negundo*), Orange Tree (*Citrus aurantium*) and Chinaberry (*Melia azedarach*) are the more abundant tree species (Ayuntamiento de Valencia 1997).

2.2. Selection of sampling units

Prior to the present survey, 191 700 × 700 m squares encompassing the city of Valencia and its surrounding landscape were surveyed in 1997–1998 in order to obtain an atlas of the wintering and breeding birds (for details see Murgui 2004, Murgui 2006). From the 51 squares corresponding to the city I selected the 38 showing the highest densities of wooded streets (Murgui 2006). During the year 2000 all the wooded streets in each square were surveyed except for wooded streets connected with urban parks (or residential gardens or patches of derelict land) in order to minimize the influence of nearby habitats. The only exception to this rule were some long streets (length >500 m) connected with parks where I sampled the sector placed 100 m from the park. Further, I did not survey wooded streets connected directly with other wooded streets. Surveyed streets were separated by a minimum distance of 50 m, most of them 100 m or more.

The sample included 216 streets (27% of wooded streets of the study area) summing a total length of 39.2 km. Mean length of streets (± S.D.) was 221 ± 4.2 m, ranging between 55 and 1309 m. The sample included 7,292 trees of 41 species i.e.

19% of trees and 68% of species planted in Valencia.

2.3. Bird surveys of wooded streets

Each street was surveyed in one occasion per season during the winter (December–January) of 1999–2000, and the spring (April to May) and summer (June–July) of 2000. All bird censuses were conducted between 08:00 and 11:00 hours on days of good weather (i.e. avoiding windy or rainy days). Surveys were conducted during workdays (Monday to Friday) in all streets except for 15 long and wide streets where the detectability of birds was reduced by the noise of high traffic load. In these streets, the bird census was made on Sunday mornings.

Streets were surveyed walking across sidewalks at a steady pace and recording birds seen or heard while using trees. According to Fernández-Juricic (2000a), birds recorded at ground level were included in the survey only if they landed, after fleeing, in nearby trees of the street. Depending on the length of the streets, and the characteristics and abundance of trees, I walked the streets for 5 to 70 minutes with an average of 10 minutes/200 m, a census effort similar to the 45–60 min/km recommended for a linear transect census (Järvinen *et al*. 1991). Most of the streets were about 20 m wide so 10 minutes were spent in 0.4 ha. Lesser census rates have been considered enough to obtain a representative sample of bird species using urban habitats (e.g. 30–60 min/c.15 ha in the city of Rennes, Clergeau *et al*. 1998; 20 min/10 ha in Finnish cities, Jokimäki & Kaisanlathi-Jokimäki 2003; 60 min/49 ha in Valencia, Murgui 2004). Because in many streets the abundance of trees was low and trees were small (see Fig. 1 for a representative example) it is almost certain that I recorded most of the birds occurring in the streets at the time of the visits.

In order to compare the ability of wooded streets to attract the bird fauna of nearby urban habitats two additional sources of data were used. First, from the 1997–1998 urban bird atlas (Murgui 2004, Murgui 2006) mentioned above, I obtained the number of bird species inhabiting the 38 squares where the wooded streets were located. Secondly, the bird fauna of 22 urban parks (which include the largest parks of the city and the smaller parks between them, range 0.07–18.6 ha) has been surveyed monthly since 1999 (see Murgui 2007), and I used data corresponding to the year 2000. Species belonging to genus Ardeidae, Anatidae, Falconidae, Laridae, Apodidae and Hirundinidae, the Rock Dove *Columba livia* and the Blue Rock Trush *Monticola solitarius* were removed from all data sets because they do not use wooded streets or their distribution is driven by other factors like the availability of breeding sites in buildings. The remaining species were divided into three categories according to their phenology: (a) exclusively migratory – species present only during the migratory seasons (March to May and September to November); (b) wintering species – present from December to February; and (c) breeding species. All the species breeding in wooded streets are sedentary in the study area except for the Spotted Flycatcher *Muscicapa striata*.

Table 1. Mean ± SD describing habitat structure of 110 wooded streets. D.B.H. stands for diameter at breast height. *: Data of measured trees were averaged for each street, and then streets were averaged to yield street-level habitat information.

Variable	Mean ± SD	Min–Max
Number of trees	41.9 ± 314.6	4–306
Number of tree species	1.6 ± 1.3	1–11
Height (m)*	8.3 ± 3.8	2–31.2
D.B.H (cm)*	21.1 ± 12.7	3.9–95.5
Width of the top (m)*	3.1 ± 1.4	0.6–10.5
Development of canopy (%)	18.5 ± 24.3	0–100

2.4. Habitat structure

The number of trees of each species was recorded in each of the 216 streets. Additionally, the height of the tree strips was estimated visually, a procedure facilitated by previous training in urban parks (Murgui 2007), and by comparisons with the nearby buildings.

A more detailed measurement of the structure of trees (Table 1) was carried out in May 2000 by means of a sampling scheme developed in three steps. First, 25 squares out of the 38 surveyed were selected at random. Second, in each square, some streets were randomly selected (on average 75% (range 50–100%) of streets in a square, depending of the number of streets per square). Lastly, in the thus selected streets measurements were made of trees. The number of measured trees per street varied from 3 to 49 trees (depending on the total number of trees in the street), with a mean percentage of measured trees per street of 10%. Measured trees were regularly located on each side of the streets. In total, the characteristics of 1,055 trees in 110 streets were measured. Measurements included the diameter at breast height (d.b.h.), tree height, width of the top (distance in meters between the two outermost branches of the tree), and whether the top contacted or not with the tops of the nearby trees in order to obtain an estimate of the development of the canopy. This value was standardized by dividing it by the total number of trees measured in the street (Table 1). Because the tree strips were very homogeneous (Fig.1), and no cover of bushes or grass existed, I consider this description of habitat structure of wooded streets accurate.

A proper measurement of the pedestrian activity and traffic load in 216 wooded streets largely exceeded the possibilities of this study. I have thus assumed that the effect of such factors was similar in most streets and comparable with that occurring in wooded streets of other cities (e.g. Fernández-Juricic 2000a).

2.5. Statistical analyses

Dependent variables were the number of bird species and the total abundance of birds per street or tree species, and independent variables were the habitat features of wooded streets and the structural characteristics of the individual tree species. Prior to analyses, the normality of variables was checked by means of a one sample Kolmogorov-Smirnov test. If necessary, normality of data was improved using the proper transformations (Zar 1996). Differences in bird species richness and bird abundance across seasons were explored using Repeated Measures ANOVA analyses. The influence of wooded street characteristics on bird community parameters was tested by means of linear multiple regression, and the differences in the habitat structure of used vs unused streets was explored by means of two samples Student t test (James & McCulloch 1990, Hair *et a*l. 2000). Spearman and Pearson tests and partial correlations were used to examine the relationships between bird community parameters and characteristics of individual tree species.

Patterns in the selection of the tree species by birds were assessed according Manly *et al.* (1993). A selection index was obtained comparing data on the availability of resource units (number of trees of a particular tree species divided by the total number of trees in the sample) and their use (number of birds using a particular tree species divided by the total number of birds recorded), and its statistical significance was tested by means of a Chi-square test (Manly *et al.* 1993). The majority of bird species recorded exhibited very low abundances and the abundant ones used a large number of tree species. Therefore the analyses were limited to the three most abundant bird species (Collared Dove *Streptopelia decaocto*, Chiffchaff *Phylloscopus collybita* and House Sparrow *Passer domesticus*). Different tree species of the same tree genus (e.g. *Populus*) were pooled, and the selection indexes were calculated only for the tree species (or genus) where ten or more birds were recorded. The remaining tree species were pooled under the category “others”.

3. Results

3.1. Characteristics of wooded streets and tree species

Most of the surveyed streets (86%) were composed of 1 to 2 tree species. The number of tree species was positively related with the number of trees per street (whole sample Pearson’s r_{216} = 0.62, P = 0.001; sample selected for the measurement of structure of the vegetation Pearson’s r_{110} = 0.57, P = 0.001). Some of the tree species were very abundant, in particular Box Elder, Orange Tree, Glossy Privet (*Ligustrum japonicum*), London Plane (*Platanus* × *hispanica*) and Chinaberry with abundances ranging between 1,166 and 550 trees.

Mean tree height ranged from 3.90 m (Orange Tree) to 9.62 m (Box Elder), but usually the tree strips did not form a continuous cover (Table 1; see

Fig. 1. Representative examples of wooded streets in the city of Valencia where this study was carried out. (above) A street lined with Chinaberry trees (*Melia azedarach*), a popular tree species. (below) A street lined with Orange trees (*Citrus aurantium*). Trees are typically not very high, and form a sparse, monotonous and highly linear habitat for birds.

Fig. 1 for an example). Variables describing the tree structure were correlated. For example, diameter at breast height (d.b.h.) was highly correlated to tree height (r_{1055} = 0.77) and development of the canopy (r_{1055} = 0.50). A list of all tree species, along with its abundance and structural features, is available upon request directly from the author.

3.2. Seasonal patterns of bird fauna

During the survey 1,378 observations of 14 bird species were recorded (Table 2). Across seasons, the bird community was dominated by resident species (Table 2). House Sparrow was the most abundant and widely distributed species in all seasons (42–68% of total) followed by Collared Dove (28–34% of total). The rest of the species showed lower abundances and more restricted ranges (Table 2).

The total number of species recorded in spring was 11 (mean bird species richness ± S.D. per street 0.90 ± 1.03, range 0–8), 5 in summer (0.72 ± 0.79, range 0–3), and 8 in winter (0.86 ± 0.96, range 0–4). There were no differences across seasons in the mean number of bird species recorded

Table 2. Abundance (and number of streets where the species was recorded) of bird species detected in wooded streets across season. Status: phenological status (S: sedentary; O: occasional records; W: wintering; M: exclusively migratory; MB: migratory breeding species). Food: feeding substrate (G: ground; T: tree); Nesting: nesting substrate (T: tree; TH: tree hole).

Species	Status	Food	Nesting	Spring	Summer	Winter
Collared Dove (*Streptopelia decaocto*)	S	G	T	148 (65)	107 (60)	173 (69)
Monk Parakeet (*Myiopsitta monachus*)	S	G	T	2 (2)	0	0
Budgerigar (*Melopsittacus undulatus*)	O	G	–	1 (1)	0	0
Black Redstart (*Phoenicuros ochruros*)	W	G	–	0	0	5 (4)
Blackbird (*Turdus merula*)	S	G	T	2 (2)	0	0
Blackcap (*Sylvia atricapilla*)	W	T	–	2 (2)	0	12 (8)
Chiffchaff (*Phylloscopus collybita*)	W	T	–	0	0	87 (27)
Willow Warbler (*Phylloscopus trochilus*)	M	T	–	1 (1)	0	0
Spotted Flycatcher (*Muscicapa striata*)	MB	T	T	0	2 (1)	0
Great Tit (*Parus major*)	S	T	TH	12 (10)	2 (2)	2 (2)
Spotless Starling (*Sturnus unicolor*)	S	G	TH	3 (1)	0	0
House Sparrow (*Passer domesticus*)	S	G	T	322 (98)	251 (88)	216 (70)
European Greenfinch (*Carduelis chloris*)	S	G	T	5 (2)	0	2 (2)
European Goldfinch (*Carduelis carduelis*)	S	G	T	17 (7)	2 (2)	2 (2)

in the streets (Repeated Measures ANOVA $F_{2,214B} = 2.37$ P = 0.095). The total number of birds recorded in spring was 515 (mean bird abundance ± S.D. per street 2.39 ± 4.22, range 0–30), 364 birds in summer (1.69 ± 2.58, range 0–14), and 499 birds in winter (2.33 ± 4.19, range 0–29). There were no differences across seasons in the mean numbers of birds recorded in the streets (Repeated Measures ANOVA $F_{2,214B} = 2.80$ P = 0.062).

3.3. Ability of wooded streets in attracting bird fauna of the city

According to data of the 1997–1998 urban bird atlas (see Methods), 31 and 27 species were recorded during winter and the breeding season respectively in the 38 700×700m squares where the surveyed wooded streets were located. Therefore, the number of wintering bird species recorded in the wooded streets during 2000 constituted 25% of the wintering bird fauna and 19% of the breeding bird fauna.

Compared to the bird fauna recorded in a sample of 22 urban parks during 2000, bird species using wooded streets constituted 26% of birds recorded in urban parks in winter, 24% in spring, and 22% in summer.

The number of streets occupied was independent of abundance of bird species in urban parks during spring (Spearman $r_{11} = 0.44$, P = 0.15) and summer (Spearman $r_5 = 0.59$, P = 0.66) but positively correlated during winter (Spearman $r_8 = 0.81$, P = 0.01).

3.4. Factors affecting avifauna on wooded streets

Data for all three seasons were pooled, because there were no seasonal differences in bird community parameters. I used the mean number of bird species and mean number of individuals per street as dependent variables. Mean bird species richness was positively related to tree height, abundance of trees, and number of tree species per street ($F_{3,\,106} = 30.71$, $p = 0.0001$, $R^2 = 0.45$). Mean bird abundance was positively related to tree height and abundance of trees per street ($F_{2,\,107} = 34.74$, $p = 0.0001$, $R^2 = 0.39$).

In each season, no bird was recorded in around half (range 97–103 for the 216 streets, and 46–50 for the 101 streets) of the streets surveyed. Further, 74 out of 216 non-used streets were the same in spring and summer, and 65 were the same in spring and winter.

In the wooded streets used by birds there were a larger number of tree species, and the trees were

Table 3. Differences in habitat characteristics between used and unused wooded streets. Results corresponding to spring; the other two seasons showed similar results

	Mean ± S.E.		*t* Test
	Used (n = 64)	Unused (n = 46)	
Tree species richness	1.90 ± 1.61	1.30 ± 0.62	tB_{108B}= 2.41, p = 0,017
Number of trees per street	47.14 ± 49.16	24.43 ± 24.81	tB_{108B}= 2.89, p = 0,004
Mean tree height (m)	9.73 ± 2.68	6.42 ± 2.84	tB_{108B}= 4.95, p < 0,001
Mean d.b.h. (cm)	26.26 ± 11.34	16.65 ± 10.16	tB_{108B}= 4.59, p < 0,001
Size of top (m)	3.42 ± 1.17	2.68 ± 1.87	tB_{108B}= 2.64, p = 0,009
Development of canopy (%)	41.35 ± 39.21	21.17 ± 38.15	tB_{108B}= 2.66, p = 0,008

Table 4. Number of bird species and bird abundance associated to the ten more used tree species.

	Tree features		Bird community features	
	Mean height (m)	Abundance	Species Richness	Abundance*
Box Elder (*Acer negundo*)	7.6	1,166	9	0.21
Siberian Elm (*Ulmus pumilla*)	8.0	190	8	0.54
White Poplar (*Populus alba*)	11.0	323	7	0.50
Black Locust (*Robinia pseudoacacia*)	7.8	454	7	0.34
Glossy Privet (*Ligustrum japonicum*)	4.1	736	6	0.08
London Plane (*Platanus x hispanica*)	9.4	576	6	0.32
Bottle Tree (*Brachichyton populneum*)	6.5	390	5	0.11
White Mulberry (*Morus alba*)	6.6	189	4	0.12
Holly Oak (*Quercus ilex*)	3.0	66	4	0.09
Honey Locust (*Gleditsia triacanthos*)	9.8	84	3	0.54

* number of birds divided by abundance of tree species

taller and they had wider tops than in the non-used streets (Table 3).

3.5. Selection of tree species

Twenty-three tree species during spring and 25 during summer and winter respectively were used by birds. Since the results were very similar across seasons the analyses were performed over the total of birds recorded in each tree species.

Some of the larger and more abundant tree species were used by a greater number of bird species and individuals (Table 4). However, in spite of their medium size, two tree species that provide seeds and fruits – the Bottle Tree (*Brachichyton populneum*) and the Glossy Privet – were used by a relatively high number of bird species (Table 4). Controlling for tree abundance, partial correlation of tree height with bird species number (r_{38} = 0.45, p = 0.003) and bird abundance (r_{38} = 0.39, p = 0.023) were both significant indicating that larger tree species were used by more bird species and individuals, irrespective of their abundance.

Analyses performed at the species level showed that House Sparrow used 26 tree species out of 41 (63%), Collared Dove used 18 tree species (44%) and Chiffchaff used 7 tree species (17%). Selection ratios of the tree species used by birds were mostly non-significant (Table 5). House Sparrow and Collared Dove used the Box Elder, genus *Populus*, London Plane, Black Locust and Siberian Elm significantly more than in proportion to its availability, and the Chiffchaff selected positively the genus *Populus* and the Orange Tree (Table 5).

Table 5. Estimation of selection indexes for tree species. Pi: proportion of available resource units that are in category i; Ui: individuals observed in category i; Esp: number of expected individuals in category i; W: selection ratio. Positive selection is symbolized by +. To test the significance of the selection ratio the chi-squared statistic with one degree of freedom is used. The category "others" include the tree species (number in brackets) used by less of ten birds.

		House Sparrow			Collared Dove			Chiffchaff		
	Pi	Obs.	Exp.	W	Obs.	Exp.	W	Obs.	Exp.	W
Box Elder	0.16	127	20.3	+ 1.00 n.s.	105	16.7	+ 1.53 *	0		
Bottle Tree	0.05	30	1.6	+ 0.71 n.s.	10	0.4	+ 0.17 n.s.	0		
Orange Tree	0.16	52	8.3	+ 0.40 n.s.	0			34	6.2	+ 2.46***
Honey Locust	0.01	35	0.4	+ 3.84 n.s.	10	0.1	+ 2.02 n.s.	0		
Glossy Privet	0.11	49	5.5	+ 0.55 n.s.	10	1.1	+ 0.29 n.s.	0		
White Mulberry	0.03	13	0.3	+ 0.63 n.s.	11	0.2	+ 0.99 n.s.	0		
Chinaberry	0.07	53	4.0	+ 0.88 n.s.	22	1.6	+ 0.68 n.s.	0		
White Poplar	0.05	92	5.0	+ 2.14**	63	3.1	+ 2.71***	42	2.3	+ 8.84***
Cherry Tree	0.02	16	0.4	+ 0.78 n.s.	0			0		
London Plane	0.08	104	8.2	+ 1.66*	70	5.5	+ 2.07**	0		
Black Locust	0.06	83	5.2	+ 1.68 n.s.	59	3.6	+ 2.21 *	0		
Pagoda Tree	0.01	37	0.6	+ 2.77 n.s.	21	0.3	+ 2.90 n.s.	0		
Siberian Elm	0.02	52	1.4	+ 2.52 n.s.	37	0.9	+ 3.31*	0		
Others (12) Sparrow	0.09	46	4.5	+ 0.55 n.s.						
Others (6) Dove	0.03				10	0.4	+ 0.58 n.s.			
Others (5) Chiffchaff	0.01							12	3.7	+ 1.94 n.s.

* P < 0.05, ** P < 0.01, *** P < 0.001

4. Discussion

4.1 Birds in the streets

Bird species number and the composition of the species pool recorded in the wooded streets of Valencia in the present study (8 species during winter and 11 during the breeding season) were very similar to the results corresponding to wooded streets of a previous survey of birds of the city during 1997–1998 (13 in winter and 12 in the breeding season; Murgui 2004, 2006). Such similarity, along with the homogeneity of results across seasons, suggests that the bird-habitat relationships derived of a single-visit per street and a single-year survey are justified.

The wooded streets of Valencia can be described as a poor functional habitat for birds: the number of bird species recorded in the wooded streets accounted for about 25% of species recorded in the adjacent habitats, the mean number of bird species per street was very small (around 1), and the majority of bird species exhibited a low abundance and occurred in a small number of streets. These results are in sharp contrast with others corresponding to the wooded streets of Madrid (56% of the breeding avifauna of urban parks, an average of 3 species per street; Fernández-Juricic 2000a) or Melbourne (57% of non-breeding avifauna in wooded streets, 4.4–11.6 species per street; White *et al*. 2005). Such differences could be attributed to a number of factors. First, there are a larger number of *Parus* spp. and other woodland species in Madrid than in Valencia (10 vs 5 species). Particularly, the low populations of parids and related species in Valencia (Murgui 2007) would prevent the tendency to form mobile multispecies flocks in winter (Fernández-Juricicic 2000b) and the consequential increase in the number of occupied streets. Second, Fernández-Juricic (2000a) included in the sample also wooded streets connected with urban parks, and the streets were included in the sample by White et al. (2005) irrespectively of its vicinity to urban parks or gardens. Conversely, in the present study, streets connected with urban parks were not included. Therefore, the smaller number of species recorded, compared with the other studies, give additional support to the idea that wooded streets could act to enlarge the area of urban parks (Fernández-Juricic 2000a) in a similar way as hedgerows can enlarge the area of woods (Bellamy *et al*. 1996). Third, the low suitability of wooded streets in Valencia compared to other studies could be a consequence of the differences in habitat structure.

Wooded streets in Madrid give the appearance of a continuous green cover on both sides of the streets (Fernández-Juricic 2000a), which is a description that corresponds to a small proportion of the wooded streets of Valencia. Likewise, from the categories defined by White *et al*. (2005), "Recently developed streetscapes" would be the category more similar to many wooded streets of Valencia.

Wooded streets constitute extremely narrow linear habitat patches, thus stressing the harmful edge effects which in cities include increasing predation (Sorace 2002), traffic noise and disturbance from pedestrians (Fernández Juricic 2000a), and probably an increasing exposure to toxins (Solonen *et al*. 1999). In Valencia, the influence of avian predators and of feral animals seems negligible (although the effect of *Rattus* spp. could be important). Other factors – along with floristic attributes and management of trees – could thus force birds to avoid wooded streets as breeding or feeding habitat. Such avoidance may also occur during winter or during the migratory passage, when habitat requirements of species are less demanding (e.g. Petit *et al*.2000), and when the number of species that could potentially use wooded streets and the density of some of them both increase noticeably in other habitats of the city (Murgui 2004). Additionally, the relatively small populations and the low breeding success of many non-synanthropic species in urban areas (Jokimäki & Huhta 2000, for review see Marzluff 2001) probably cause individuals to select the most suitable habitats (i.e. urban parks) rather than wooded streets. Natal dispersal, a phenomenon characterized by high mobility of juveniles (Baker 1993), towards wooded streets is probably limited, resulting in a low usage of wooded streets by most of the bird species and individuals across seasons.

The factors outlined above, along with the isolation of the sampled streets from urban parks, probably determine that the occupancy of streets was not related to the abundance of birds in urban parks during the breeding season suggesting that the population dynamics of wooded streets are not connected with parks, and are largely independent of factors regulating the more suitable habitat patches (Pulliam & Danielson 1991). Interestingly enough, when the opposite situation is analyzed (i.e. a set of wooded streets connected with parks) there is a strong positive relationship between street occupancy and abundance of breeding birds in parks (Fernández-Juricic 2001).

Coinciding with previous studies (Fernández-Juricic 2000a, White *et al*. 2005), bird species richness and, up to a point, bird abundance were positively influenced by tree species richness and the degree of development of the vegetation. This positive effect probably stems from an increase in the diversity and quantity of feeding and nesting resources. In Valencia, tree species that provide resources such as the Siberian Elm, Glossy Privet, Pagoda Tree *Sophora japonica* and Bottle Tree are, in spite of the small to medium size of some of them, frequently used by frugivorous bird species (Murgui 2002). These species played a decisive role in increasing bird species richness in many streets (for the association of birds with plant species in urban areas see Debussche & Isenman 1990, Reichard *et al*. 2001, Merino & Nogueras 2003). Other tree species like the Orange Tree or trees of the genus *Populus* were positively selected by insectivorous species such as the Chiffchaff during winter. Possibly, this attraction was due to the abundance of invertebrates, but further investigation is needed for a full understanding of this aspect.

An increase in the tree cover in wooded streets could benefit bird populations also through other mechanisms. First, larger trees may provide safer nest places and holes for cavity nesters. Tree species most used by birds were Box Elder, Siberian Elm and London Plane (i.e. species representing a greater proportion of large trees). Second, tall trees exhibiting dense canopies could mitigate some of the negative effects of traffic load (see Reijnen *et al*. 1997; Forman & Alexander 1998) and pedestrian activity reported for wooded streets (Fernández-Juricic 2000a). Species foraging in the tree canopy may avoid the influence of pedestrian activity (van der Zande & Vos 1984, van der Zande *et al*. 1984) but disturbance would be more accentuated for species that forage or nest in the ground (like the Blackbird, Fernández-Juricic & Telleria 2000). Disturbance can partially explain why such a small number of these species have been recorded in wooded streets (Fernández-Juricic 2000a). Last, an increase in tree cover could enhance its potential role in providing connectivity between urban habitats, a circumstance independent of its value as functional habitat (Simberloff *et al*. 1992, Rosenberg *et al*. 1997). It may be logistically impossible to demonstrate that biological corridors actually increase the rate of successful movement of animals between patches (Rosenberg *et al*. 1997, but see Castellón & Sieving 2006 for recent approaches), but at worst wooded streets could help to make the landscape matrix more usable and less hostile for biota. A greater insight into the dispersal dynamics and patterns of movement of birds across landscape would be critical for understanding many ecological patterns and processes (Wiens 1996, Harrison & Bruna 1999), and the scattered literature about these topics in the urban landscape suggests a promising research frontier.

4.2. Wooded streets management and urban birds

Wooded streets seem to be a habitat intrinsically unsuitable for bird species that forage or nest on the ground or in bushes. Additionally, they seem unsuitable for many arboreal species, even for those that use a broad range of resources and are relatively tolerant to human disturbance. Leaving aside the harmful edge effects associated with linear habitats, the situation is probably worsened by the choice of tree species. Management mainly deals with maintenance costs and problems associated with tree planting (see Kendle & Forbes 1997), and usually does not take into account the conservation or enhancement of bird populations (or other biological taxa) in the urban landscape. As a rule, the planting of large tree species or fruit bearing trees is discouraged in favor of smaller ornamental trees or fruitless cultivars which are less damaging to paving surfaces and have less safety issues associated with them (Gilbert 1989). In addition, attending mostly to aesthetic criteria, the planting of single tree species strips is the standard despite the risk of promoting plant diseases. In summary, design and management of wooded streets are often against the factors promoting a diverse and abundant bird community.

In order to increase both the suitability of wooded streets as a functional habitat for birds and its potential ability in connecting the habitat patches of the urban landscape a different approach would be necessary. This would greatly benefit from a deeper understanding of the bird-habitat relationships in wooded streets. For instance, Chinaberry trees are large trees that are available in high abundance, but were used by a low number of mainly House Sparrows and Collared Doves. Collared Doves do not nest in Chinaberry trees (although they frequently nest in Box Elders in wooded streets nearby to those with Chinaberry trees), and no insectivorous/frugivorous bird species was recorded in this tree species (although Debusche & Isenmann 1990 have reported the occurrence of fruits of Chinaberry in the diet of Blackcap). Whether these results can be attributed to a shortage of the foraging or nesting resources remains an open question. It has been argued that native tree species support more associated invertebrate species than exotic species (Kennedy & Southwood 1984) but this need not hold true for all circumstances (Kendle & Rose 2000). The suitability of the different tree species as nesting sites or in providing invertebrate resources to bird species is a little explored and potentially insightful topic for research.

Finally, the design and management of wooded streets tailored to the conservation of birds and other biological groups would not only have a positive impact on urban biodiversity, but could also contribute to the well-being of city dwellers through a direct experience of nature (see Savard *et al*. 2000). Such exposure to urban nature could have additional benefits for the conservation of biodiversity in the forthcoming decades. Because of the increasing size and political influence of human population inhabiting cities, an enhancement of daily contacts of citizens with nature (Turner *et al*. 2004) may improve the social support for conservation of biodiversity not only in cities but at a global scale (McKinney 2000, Dunn *et al.* 2006).

Acknowledgements. I thank José Antonio González Oreja, Jukka Jokimäki and John White for their valuable comments on the manuscript. I thank also Andrea Martínez for her assistance in measuring the characteristics of trees.

Kaupunkien tienvarsipuiden vaikutuksia lintuyhteisöihin

Tienvarsien puiden vaikutuksia lintuyhteisöihin on tutkittu erittäin vähän siitä huolimatta, että puut teiden varsilla ovat huomattava ja näkyvä osa kaupunkiluontoa. Valenciassa seurattiin vuonna 2000 kolmena vuodenaikana 216 tietä, joiden varsilla oli puustoa. Seurannan aikana havaittiin 1 378 yksilöä 14 lintulajista. Varpunen ja turkinkyyhky olivat ainoat runsaina havaitut lajit. Vuodenajasta riippuen puustoisilta teiltä havaittu lajisto vastasi 19–25 % ympäröiviltä kaupunkialueilta havaitusta lajistosta. Puulajiston rikkaus, puiden määrä ja niiden korkeus olivat tärkeimmät tekijät tienvarsien lajirikkauden ja yksilömäärän takana. 41 puulajista 34:ssä havaittiin lintuja. Eräät suuret puulajit kuten saarnivaahtera, siperianjalava ja hopeapoppeli olivat erityisen suosittuja. Parantaaksemme tienvarsien suotuisuutta linnustolle suosittelemme merkittävää muutosta puistoteiden hoitoon ja suunnitteluun.

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