Urbanization of the Iberian Mediterranean coast: effects on the species richness of forest birds

Sergi Herrando & Lluís Brotons

The effects of the urbanization of the Mediterranean coast on forest-bird richness were studied in the north-east of the Iberian Peninsula. We measured the effects using two different perspectives: first, we assessed the effects of increasing urbanization on local bird richness; and, second, we used a European conservation value (the SPEC index of the species recorded) to assess the effects of urbanization on bird richness from a wider geographical perspective. Our results showed that local bird richness and the conservation value of the bird community inhabiting forest patches responded differently to the landscape gradients related to urbanization. Local bird richness was negatively affected by the urbanization of surrounding grasslands but was not influenced by the urbanization of surrounding forests. Contrastingly, the mean conservation value of the bird community was strongly and negatively affected by the urbanization of both habitat types. Therefore, these results highlight that the use of estimates exclusively based on local richness may not show the real effects of such disturbances, since the maintenance of species richness can be associated with a parallel loss of the species of greater conservation value.

Key words: bird conservation, landscape patterns, habitat fragmentation, SPEC, north-east Spain.

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Urbanization is the process by which urban areas spread around centres of economic activity while reducing the area available for other land uses. Urbanization provokes profound modifications of both habitat and landscape, as natural systems are substituted or heavily modified by human activities which make the spontaneous recovery of natural communities impossible, at least in the medium term. In many areas, this phenomenon has acquired spectacular proportions. This is the case of some areas along the western Mediterranean coast, where the tourist boom has led to the urbanization of more than 50% of the total area of coast (Blondel & Aronson 1999).

Several studies have found that urbanization has a negative influence on bird richness (Batten 1972, Huhtalo & Järvinen 1977, Hohtola 1978, Beissinger & Osborne 1982, Jokimäki & Suhonen 1993, Clergeau *et al.* 1998, Cam *et al.* 2000). Nevertheless, these studies have focused on the effects of urbanization on bird richness on a local scale, assessing how the total number of species present in an area changes with increasing urbanization. This approach may not be sufficient to evaluate the influence of such activity from a wider, European conservation perspective. Other parameters that reflect the conservation status of the species involved, such as the SPEC (Species

of European Conservation Concern) value (Tucker & Heath 1994) are required to determine the consequences of urbanization on overall richness in European birds.

The aim of this paper is to determine the effects of increasing levels of urbanization on the bird communities inhabiting forest patches on the Iberian Mediterranean coast, an area that has received little attention from the researchers on this topic. Using a study of an urbanized coastal zone near Barcelona, we address the following specific questions: how the current levels of urbanization are affecting local bird richness; and what the association is between the level of urbanization at a site and the conservation value of its bird community estimated from an European perspective. We also study to what degree these two approaches are analogous in assessing the effects of urbanization on the bird community in a coastal area. Since many bird species with special conservation status tend to be very sensitive to habitat alterations (Tucker & Heath 1994), we expect that urbanization may exert a stronger effect on the conservation value of bird communities than in local bird richness.

Methods

Study area

Fieldwork was carried out in a coastal area located 20 km south of Barcelona, in the northeast of the Iberian Peninsula (41° 2'N, 2° 0'E). The study area correspond to the coastal fringe of the Llobregat Delta, which is mainly covered by farmland, transport facilities (airport, roads, railways, etc.) and urban areas. Natural vegetation is scarce and is concentrated along the coast. It consists basically of a mosaic of coastal marshes, grassland and stone pine *Pinus pinea* forest (Fig. 1). These trees were planted in belts

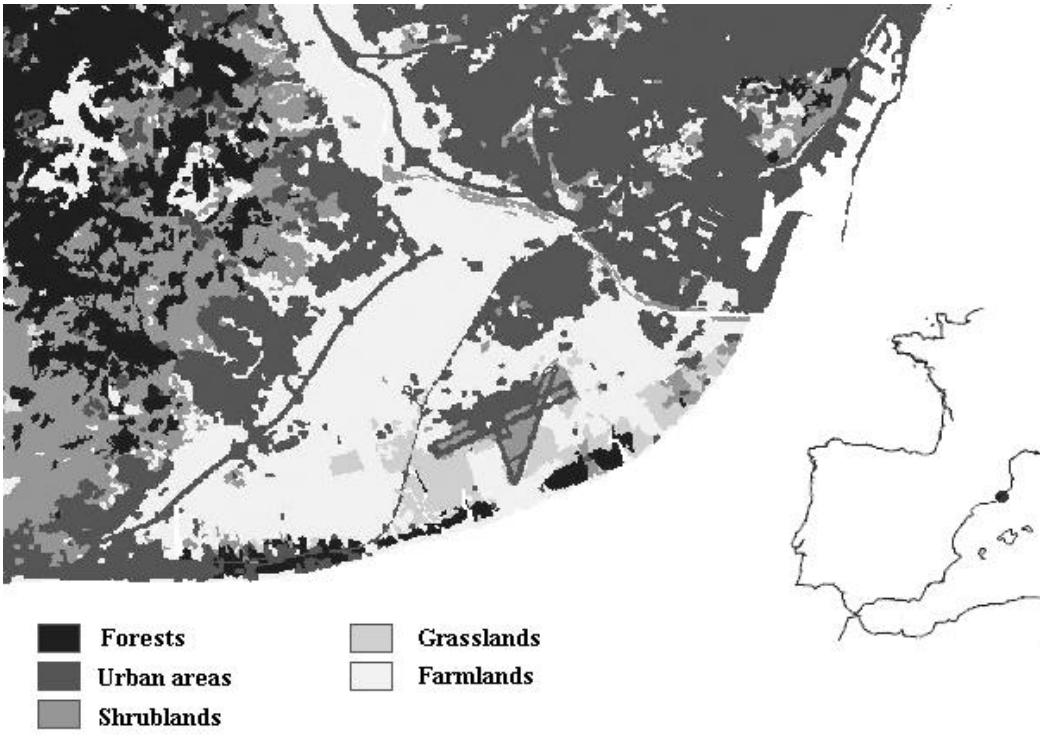

Figure 1. Location of the coastal-fringe study area within the Llobregat Delta, and main landscape units. Notice the coastal narrow stripe still covered by forests and grassland but also occupied by urban areas, especially in the west.
Localització de la franja costanera objecte d'estudi al delta del Llobregat i de les seves principals unitats de paisatge. Especial atenció mereix l'estreta franja costanera encara recoberta de boscos i formacions herbàcies, que estan sent ocupades per zones urbanes, especialment a l'oest.

500-1,000 m wide along the coast at the beginning of the 20th century in order to fix dunes, although historical records mention planting of Stone Pines in the area as far back as the 16th century (Valverde 1997). In recent decades, grassland and forest have progressively been substituted by residential areas and associated works, and this process remains active.

Bird survey

We selected 21 bird survey stations in pine forest patches surrounded by anthropogenic structures or natural vegetation to variable degrees. This selection was made assuring that the minimum distance between stations was 300 m to minimise pseudoreplication, although the average distance between closest stations were slightly over 400 m. Point-counts were employed to record the presence/absence of bird species within a 50-m band (Bibby *et al.* 1992). We conducted a 20-minute survey at each station. This long time frame is suitable for detecting most of the breeding bird species, but it is not appropriate for estimating bird abundance (Drapeau *et al.* 1999). All surveys were conducted during the breeding season of the year 2000 (June), during the hours of maximum bird activity, i.e. for 3 hours starting at dawn; they were not conducted in adverse weather conditions such as rain or strong wind. Bird richness was calculated as the number of species detected at each point-count.

In order to determine the effects of increasing rates of urbanization on birds from a strict conservation perspective, we used a European conservation criterion and constructed an index based on averaging the conservation value of the species that occurred at each counting station. Thus, we first classified species according to their European Conservation Concern (SPEC), following the index proposed by Tucker & Heath (1994) (Table 1). The SPEC index gives the highest value (SPEC 4) to those with

Table 1. Bird species occurrence in the study stations, which were all situated in forest patches mainly surrounded by urbanized areas and grassland. The bird SPEC category (Tucker & Heath 1994) and its reclassification to obtain a progressive index for all the species are also shown.
Presència d'espècies d'ocells a les estacions estudiades, totes elles situades en fragments forestals envoltats bàsicament per zones urbanitzades o herbàcies. També es mostra la categoria SPEC dels ocells (Tucker & Heath 1994) i la seva reclassificació, feta amb l'objectiu d'obtenir un índex de conservació progressiu per a totes les espècies.

Bird species	*% Stations occupied*	SPEC Category	Reclassified SPEC Category
Falco tinnunculus Kestrel	4.7	3	2
Streptopelia decaocto Collared Dove	61.9	-	0
Columba livia Rock Dove	4.8	-	0
Columba oenas Stock Dove	4.7	4	1
Columba palumbus Woodpigeon	19.0	4	1
Myiopsitta monachus Monk Parakeet	9.5	-	0
Athene noctua Little Owl	4.7	3	2
Upupa epops Hoopoe	14.3	-	0
Picus viridis Green Woodpecker	33.3	2	3
Motacilla alba White Wagtail	19.4	-	0
Turdus merula Blackbird	14.3	4	1
Cettia cetti Cetti's Warbler	4.7	-	0
Cisticola juncidis Fan-tailed Warbler	14.3	-	0
Sylvia melanocephala Sardinian Warbler	90.5	4	1
Muscicapa striata Spotted Flycatcher	4.7	3	2
Aegithalos caudatus Long-tailed Tit	4.7	-	0
Parus ater Coal Tit	9.5	-	0
Parus cristatus Crested Tit	33.3	4	1
Parus major Great Tit	33.3	-	0
Certhia brachydactyla Short-toed Treecreeper	66.6	4	1
Sturnus sp. Starling	38.1	-	0
Passer domesticus House Sparrow	90.5	-	0
Pica pica Magpie	71.4	-	0
Serinus serinus Serin	57.1	4	1
Carduelis chloris Greenfinch	52.4	4	1
Carduelis carduelis Goldfinch	23.8	-	0

lower conservation concern and the lowest (SPEC 1) to those with high priority. Indeed, there are also species without any SPEC category as a result of a combination of favourable status and distribution not concentrated in Europe. Therefore, to obtain a progressive index that allowed a consistent scaling for all species, we reclassified SPEC indexes, scoring as 0 those species without SPEC value, as 1 those with SPEC 4, as 2 those with SPEC 3 and so on (Table 1). Second, we obtained the mean reclassified SPEC value of each census station by averaging the reclassified SPECs of the species present.

Local habitat structure and landscape variables

Using a circular plot of 50 m radius located at each bird count station, we estimated structural characteristics of the studied forest patches by measuring mean tree height, mean tree diameter and understorey cover. Understorey cover was defined as the projection of the shrub layer on a horizontal plane, and was estimated by comparison with a reference chart, following the procedure described by Prodon & Lebreton (1981).

Landscape structure was measured in square plots of 16 ha (400 x 400 m), the centre of each corresponding to a bird census station. To analyse the effects of landscape characteristics on bird assemblages, we used digitalised aerial photographs (1:5,000, Institut Cartogràfic de Catalunya, 1996) to construct IDRISI image files using the program MiraMon GIS (Marcer & Pons 1998). These images were analysed with FRAGSTATS Software (McGarigal & Marks, 1995) to obtain the following landscape metrics: percentage of the three main habitat types (forests, urbanized areas and grassland); forest patch density; and grassland patch density. These latter variables represented respectively the number of forest and grassland patches in the study plot (McGarigal & Marks 1995).

Data analyses

The original number of local habitat and landscape variables were grouped into a few independent factors using a principal component analysis (PCA) with a varimax normalised rotation. The number of factors selected were those with eigenvalues greater than 1. This procedure was established to reduce multicolinearity in the multivariate analysis of bird responses to habitat and landscape characteristics (Hinsley et al. 1995, Jokimäki & Huhta 1996, Diaz *et al.* 1998).

We used a backward step-wise multiple regression (Crawley 1993) to detect relationships between dependent variables (bird richness and the mean SPEC value of each station) and the factors resulting from the PCA conducted with habitat and landscape variables. These regression models were conducted with p to enter = 0.05 and p to remove = 0.10 (see StatSoft, Inc. 1995). All statistical analyses were run with Statistica Statsoft.

Results

Altogether 26 bird species were recorded during the fieldwork. The average number of bird species per point count was 7.85 (s.d. 2.74), while the minimum and maximum values were 4 and 14 species, respectively. Only one of the detected species had a SPEC value of 2; 3 had a SPEC value of 3; 8 had a SPEC value of 4 and 14 had no SPEC value. (Table 1). Amongst the most widely distributed species there were some man-associated birds such as the House Sparrow *Passer domesticus*, the Magpie *Pica pica* and the Collared Dove *Streptopelia decaocto*; some generalist species such as the Sardinian Warbler *Sylvia melanocephala*, the Serin *Serinus serinus* and the Greenfinch *Carduelis chloris*; and a typical forest species, the Short-toed Treecreper *Certhia brachydactyla* (Table 1).

The main habitat types surrounding our studied forest patches were other Stone Pine forests and urban habitat, whereas grassland was scarcer. The urbanized area within the 400 x 400 m plot surrounding our study stations was highly variable and ranged from 0.1 to 90% ($\bar{x}$=43.4; s.d.=23.6). Similarly, the cover of forests in these 16 ha varied from 7 to 97% ($\bar{x}$=47.8; s.d.=23.6), whereas the grassland cover ranged from 0 to 22% ($\bar{x}$=5.2; s.d.=14.0).

The principal component analysis conducted with landscape and local habitat variables produced two factors with eigenvalues greater than 1, which altogether accounted for 80% of

the variance contained in the original data set. The first factor obtained in this PCA (URBFOREST) was negatively associated with forest cover and positively with urban cover. This factor also showed that, in parallel with urbanization on a landscape scale (16 ha), on the local scale (approximately 1 ha) the forest patches contained tall trees with sizeable trunk perimeter, whereas natural understorey became scarce (Table 2). The second factor (URBGRASS) represented a gradient of increasing urbanization and decreasing amount of grassland areas (Table 2).

The regression model showed that bird richness was positively related to URBANGRASS, i.e. it was negatively affected by the reduction of grasslands and the simultaneous increase of urbanized areas (Table 3). In contrast, bird richness was not significantly associated with URBANFOREST, i.e. we did not find that the bird richness of the studied forest patches was affected by the amount of forest in the surrounding landscape (a 16-ha plot). On the other hand, the mean reclassified SPEC value of a station was positively related to URBANFOREST and URBANGRASS, which means that urbanization in both forest and grassland areas around forest patches was clearly negative for the group of birds with special conservation status (Table 3).

Table 2. Variables describing habitat and landscape structure and factor loadings of each variable in relation to the two factors (those with eigenvalues greater than 1) obtained in the principal-component analysis (factor rotation: varimax normalised).
Variables descriptores de l'estructura de l'hàbitat i el paisatge i valor de cada variable en relació amb els dos factors (amb vectors propis més grans que 1) obtinguts en l'anàlisi de components principals (rotació dels factors: amb normalització varimax).

	URBFOREST	URBGRASS
Pine height	-0.90	-0.02
Pine perimeter	-0.94	0.03
Cover of natural understorey	0.83	0.48
% urbanized area	-0.69	-0.68
% pine forests	0.84	0.35
% grassland	-0.13	0.82
Forest-patch density	-0.61	-0.59
Grassland-patch density	0.29	0.76
Eigenvalue	5.00	1.40
% variation explained	62.70	17.40

Discussion

We did not find that the urbanization of forest areas induced a reduction in the number of bird species. This is not consistent with the common view of urbanization as a process intimately linked to reduction in bird richness (Batten 1972, Huhtalo & Järvinen 1977, Hohtola 1978, Beissinger & Osborne 1982, Clergeau *et al.* 1998, Cam *et al.* 2000) but, although the low sample size resulting from the small study area implies that some caution is required in discussion of this non-significant relationship, there are some biological processes that could be associated with this pattern. One of the probable causes of this lack of association between the urbanization of forest areas and the loss of bird richness is that forest-bird communities in Mediterranean areas are an impoverished pool of northern Palearctic forest areas (Blondel & Aronson 1999), which may imply that the remnant Mediterranean forest bird assemblages may be more resilient to forest fragmentation that other, more complex forest-bird communities. Another possible explanation of this pattern could be related to the high habitat quality of remaining forest patches within the urban matrix. As shown by the ordination of variables in the first factor of the PCA, largely forested 16-ha plots are associated with a local forest structure characterised by short, thin pines, whereas

Table 3. Results of the backward stepwise multiple regression models (p-to-enter=0.05, p-to-remove=0.10, n=21 point counts), given for richness and the mean reclassified SPEC value.
Resultats del model de regressió múltiple pas a pas enrere (p-per-entrar-= 0,05; p-per-sortir= 0,10; n=21 estacions d'escolta), donats per riquesa i pel valor mitjà dels SPECs reclassificats.

	Coefficient	F	p	R^2
Bird richness				
URBANGRASS	1.3	5.9	<0.05	0.28
Model				0.28
Mean reclassified SPEC value				
URBANFOREST	0.2	22.5	<0.001	0.46
URBANGRASS	0.9	8.2	<0.05	0.17
Model				0.63

the forest patches embedded in the urban matrix were characterised by the presence of tall pines with large trunk perimeters, which in turn have been found to have a positive effect on forest-bird richness (López & Moro 1997, Brotons & Herrando 2001). Similarly, Cleargeau *et al.* (1998) also explained a low response in bird richness to an urbanization gradient in Rennes (France) as a consequence of the well-structured nature of the vegetation prevailing in the city. Fernandez-Juricic (2000) found in other Mediterranean areas that, in spite of the habitat loss, many forest species found suitable habitats in these urban landscapes. Furthermore, in addition to the presence of this pool of forest species, urbanized areas are also occupied by man-associated species that make up numbers in the total species pool.

Contrasting with Clergeau *et al.* (1998), who found that the type of surrounding landscape (farmland or woodland) did not influence the patterns of bird richness in urban-rural gradients in temperate areas, we found that bird richness in the studied forest patches was associated with the amount of grassland in the surrounding landscape. This suggests that the landscape context is determinant for predicting the effects of urbanization on Mediterranean bird communities, which could be related to the fact that Mediterranean birds often inhabit in highly heterogeneous landscapes (Blondel & Aronson 1999), leading to the appearance of habitat complementation and supplementation processes (Dunning *et al.* 1992). For instance, some bird species detected in the studied patches (e.g. Woodpigeon *Columba palumbus*, Green Woodpecker *Picus viridis*, Serin, etc.) use different resources from both forest and grassland and, therefore, the urbanization of this open habitat may be clearly negative for such species.

We found interesting differences between the consequences of urbanization for bird richness and for the conservation interest of the remaining bird assemblages. First, the model performed with the mean reclassified SPEC value of the stations accounted for 63% of the variance of the data matrix, whereas the model obtained for bird richness accounted only for 28%. Therefore, this conservation index was more influenced by the predictor variables than local bird richness, which supports the interest of SPECs in analysing the effects of habitat and landscape modifications on bird communities. Second, and contrasting with bird richness, the reclassified SPEC value was highly and negatively associated with the urbanization of surrounding forests, which implies that forest species with higher conservation values were negatively affected by the reduction of forest cover in the area. This pattern could be related to the more specific requirements of these species, which probably require larger and less disturbed wooded areas than other forest species of less conservation concern. Therefore, when considering changes in bird community structure, it is remarkable that, although urbanization did not affect the total number of species, the bird community composition changed and there is a loss of the species more sensitive from a conservation point of view. Finally, the mean reclassified SPEC value of a station was also negatively associated with the urbanization of grasslands, thus indicating that its urbanization can be seen as negative for bird richness from both local and European perspectives.

In conclusion, the urbanization of these coastal Mediterranean ecosystems seems negative for bird conservation. Grassland loss negatively affected bird richness from both local and European perspectives, whereas forest urbanization did not affect bird richness negatively from a local perspective but it did so from a broader, continental perspective. In addition, since the restructuring of bird assemblages in disturbed sites did not result in a loss of local bird richness but could contribute to the selective loss of species with a greater conservation concern, our study stresses the interest in studying the effects of disturbances on bird richness by taking alternative approaches to the use of measures exclusively based on local richness.

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Resum

La urbanització de la costa ibèrica mediterrània: efectes sobre la riquesa d'ocells forestals

Es van estudiar els efectes de la urbanització de la costa mediterrània sobre la riquesa d'ocells forestals al nord-est de la península Ibèrica. Vam mesurar aquests efectes mitjançant dues perspectives diferents. D'una banda, vam calcular els efectes de la creixent urbanització sobre la riquesa local d'ocells. D'altra banda, en la segona perspectiva, vam utilitzar un índex de conservació a nivell europeu (l'índex SPEC de les espècies detectades) per calcular l'efecte de la urbanització sobre la riquesa des d'un punt de vista geogràfic més ampli. Els nostres resultats van mostrar que la riquesa local d'ocells i el valor de conservació de la comunitat ornítica que habitava els fragments forestals responien de forma diferent als gradients paisatgístics relacionats amb la urbanització. La riquesa local d'ocells va estar negativament afectada per la urbanització de les zones herbàcies del voltant del fragment, mentre que aquest paràmetre no va estar influenciat per la urbanització dels boscos que envoltaven el fragment. Per contra, el valor mitjà de conservació de la comunitat d'ocells estava fortament i negativament afectat per la urbanització del voltant del fragment, tant si es tractava de zones obertes com de zones forestals. Per tant, aquests resultats subratllen el fet que l'ús d'estimes exclusivament basades en la riquesa local pot amagar els efectes reals d'aquestes pertorbacions, ja que el manteniment de la riquesa local d'espècies pot estar associat amb una pèrdua en paral·lel de les espècies de major interès des del punt de vista de la conservació.

Resumen

La urbanización de la costa ibérica mediterránea: efectos sobre la riqueza de aves forestales

Se estudiaron los efectos de la urbanización de la costa mediterránea sobre la riqueza de aves forestales en el nordeste de la península Ibérica. Estos efectos se midieron desde dos perspectivas diferentes. Por una parte, se calcularon los efectos de la creciente urbanización sobre la riqueza local de aves. Por otra parte, desde la segunda perspectiva, se utilizó el índice de conservación a nivel europeo (índice SPEC de las especies detectadas) para calcular el efecto de la urbanización sobre la riqueza desde un ámbito geográfico más amplio. Nuestros resultados mostraron que la riqueza local de aves y el valor de conservación de la comunidad ornítica que habitaba los fragmentos forestales respondían de modo diferente a los gradientes paisajísticos relacionados con la urbanización. La riqueza local de aves estaba negativamente afectada por la urbanización de las zonas herbáceas alrededor del fragmento, mientras que este parámetro no estuvo influenciado por la urbanización de los bosques que rodeaban el fragmento. Contrariamente, el valor medio de conservación de la comunidad de aves estaba fuerte y negativamente afectado por la urbanización alrededor del fragmento, tanto si se trataba de zonas abiertas como de zonas forestales. Por tanto, estos resultados subrayan el hecho de que el uso de estimas basadas exclusivamente en la riqueza local puede ocultar efectos reales de estas perturbaciones, ya que el mantenimiento de la riqueza local de especies puede estar asociado a una pérdida en paralelo de las especies de mayor interés desde el punto de vista de la conservación.

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