Development of urban bird indicators using data from monitoring schemes in two large European cities

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Abstract

Development of urban bird indicators using data from monitoring schemes in two large European cities.— Bird monitoring projects have provided valuable data for developing biological indicators to evaluate the state of natural and agricultural habitats. However, fewer advances have been made in urban environments. In this study we used bird monitoring data from 2002 to 2012 in two cities with different climates (Brussels and Barcelona), to generate two multi–species urban indicators to evaluate temporal trends on abundance of urban avifauna. To do this we used two different conceptual approaches, one based on a list of widespread species in European cities (WSEC) and another based exclusively on species widespread at city level (WCS) regardless of the birds occurring in other cities. The two indicators gave a similar general pattern, although we found a 3% difference in the mean annual change in both cities, thus suggesting that the values provided by urban indicators may differ depending on the conceptual approach and, hence, by the species list used to generate them. However, both indicators may have their own value and could be treated as complementary indices.

Key words: Urban indicator, Biodiversity, Bird monitoring, Species selection, Barcelona, Brussels.

Resumen

Desarrollo de indicadores de aves urbanas a partir de datos de sistemas de monitoreo en dos grandes ciudades europeas.— Los proyectos de monitoreo de aves han proporcionado datos valiosos para el desarrollo de indicadores biológicos que evalúan el estado de los hábitats naturales y agrícolas; sin embargo, los avances han sido menores en los ambientes urbanos. En este estudio se utilizaron los datos del monitoreo de aves de dos ciudades climáticamente diferentes (Bruselas y Barcelona; período 2002–2010) para generar dos indicadores urbanos multiespecíficos que valorasen las tendencias temporales en la abundancia del conjunto de las aves urbanas. Para hacer esto, utilizamos dos enfoques conceptuales distintos, uno basado en una lista de especies de amplia distribución en las ciudades europeas (WSEC) y otro basado exclusivamente en especies de amplia distribución a nivel de ciudad (WSC), independientemente de las aves de otras ciudades. Los dos indicadores dieron un patrón general similar, aunque un 3% de diferencia entre ellos en cuanto a los valores de cambio promedio anual se encontró en ambas ciudades. Esto sugiere que los valores producidos por los indicadores urbanos pueden diferir dependiendo de la aproximación conceptual y, por tanto, por la lista de especies utilizada para generarlos. Ambos indicadores pueden tener su propio interés y pueden ser tratados como complementarios.

Palabras clave: Indicador urbano, Biodiversidad, Monitoreo de aves, Selección de especies, Barcelona, Bruselas.

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Introduction

Thanks to the many large–scale monitoring schemes, birds currently constitute one of the backbones of biodiversity monitoring in Europe (Schmeller, 2008). Many institutions run volunteer–based bird monitoring projects at national or regional level. Trends of European common birds are updated annually within the framework of the Pan–European Common Bird Monitoring Scheme, which combines the results of these projects to provide trends at a continental scale for 145 common bird species (Voříšek et al., 2008; PECBMS, 2011). Data on trends in bird populations have been increasingly used in recent times to develop indicators of environmental health (Gregory et al., 2005), since experience shows that habitats in which bird numbers are declining tend also to be losing species belonging to other faunal groups (e.g. Robinson & Sutherland, 2002). This has led to the launch of a policy to devise relevant synthetic indicators, and the Farmland Bird Index has even been included in EUROSTAT as one of the continent's sustainability indicators (http://epp.eurostat.ec.europa.eu).

To date, indicators of environmental health for particular habitats have been developed basically for farmland and woodland ecosystems (PECBMS, 2011). Nevertheless, as most human population in Europe live in urban centres, the development of indicators of the biodiversity in cities and towns would also seem to be relevant. These indicators may be an important tool to measure the process of adaptation of biodiversity in this new environment, and also to determine the readiness of design and planning in urban areas to harbour biological diversity (Adams et al., 2006). This is particularly important if we consider that urban habitats grow year after year. Furthermore, given the extent of city environments in Europe and their influence on the quality of life and education of urban dwellers, the development of such indicators may also facilitate the preservation of biodiversity in more natural ecosystems (Savard et al., 2000; Fuller et al., 2009).

Generation of an urban indicator based on bird monitoring data has traditionally been hindered by the definition of the urban ecology of species. European cities and towns provide suitable habitats for many bird species (Kelcey & Rheinwald, 2005; Caula et al., 2010). Most of these species are generalists that can be found in other environments (Clergeau et al., 2006; Devictor et al., 2007) and have only relatively recently colonized and adapted to urban areas (Blair, 1996; Evans et al., 2009; Møller, 2009; Sattler et al., 2010). Thus, they could be described as 'urban adapters'. Also, in a few cases, this process of colonization has led to a shift in a species' populations in urban areas to a degree that their numbers have become higher than in nearby natural areas (Blair, 1996); these species could be referred to as 'urban exploiters'. Using this latter quantitative concept, several attempts have been made to classify species as elements of a multi–species urban indicator (*e.g.* DEFRA, 2002; Zbinden et al., 2005; SEO/BirdLife, 2010). However, including only 'urban exploiters' means that the list of urban species is very short and mostly contains those species that use buildings for nesting (*e.g.* House Martin *Delichon urbicum*, House Sparrow *Passer domesticus*, Common Swift *Apus apus* and Feral Pigeon *Columba livia*). Yet, the largest proportion of urban bird richness comes from greener urban habitats such as parks, avenues with trees, and gardens (Kelcey & Rheinwald, 2005). Indicators of urban biodiversity should therefore probably include not only the 'exploiters' but also, in some way, the 'adapters'. The inclusion or otherwise of the 'urban adapters' in the indicator list is a crucial question, since many of the species inhabiting both urban and other habitats have different behavioural traits that could imply different population dynamics (Adams et al., 2006). Consequently, the development of bird indicators for urban areas is complicated by the choice of an appropriate species set whose numbers show what is happening specifically in urban areas and at the same time, also represent urban bird biodiversity as a whole.

An urban bird indicator may have more than one objective and serve to highlight the health of urban bird populations, changes in populations of special conservation interest, the degree of 'urbanization' of the local avifauna, or the impact of certain environmental pressures. As shown by Gregory et al. (2005) for farmland indicators, common birds could be good candidates for developing bird indicators aimed at evaluating the general state of urban bird populations. In addition, bird species may provide information as a proxy for the state of other taxa in urban gradients (*e.g.* Blair, 1999; but see Gagné & Fahrig, 2011). This framework could be particularly useful for the study of European urban areas and, in particular, the large cities where breeding bird monitoring projects are currently carried out.

As for the Pan–European Common Bird indicators (Voříšek et al., 2008), in practice, urban indictors could be calculated as aggregated population trends using the geometric mean of annual population indices of a group of species. At this point, it is essential to establish which species set is to be included in the indicator, taking into account that a low number of species in an indicator would make it susceptible to single species fluctuations, and thus it would be less relevant as an indicator of the general state of the environment (Butler et al., 2012). For urban areas, we can use two different conceptual approaches that differ in focus, thereby maximizing the possibilities to compare results between cities at both taxonomic (species that are present in many cities) and ecological (species considered functionally relevant because of their great abundance) levels. In the first approach, the urban indicator could include species that are widespread across many European cities, while in the second, the urban indicator of each city could include only the species that are widespread in a particular city, independently of whether they are present in other cities or not. Nevertheless, both indicators are likely to indicate different things. The first is more about the overall state of common European urban

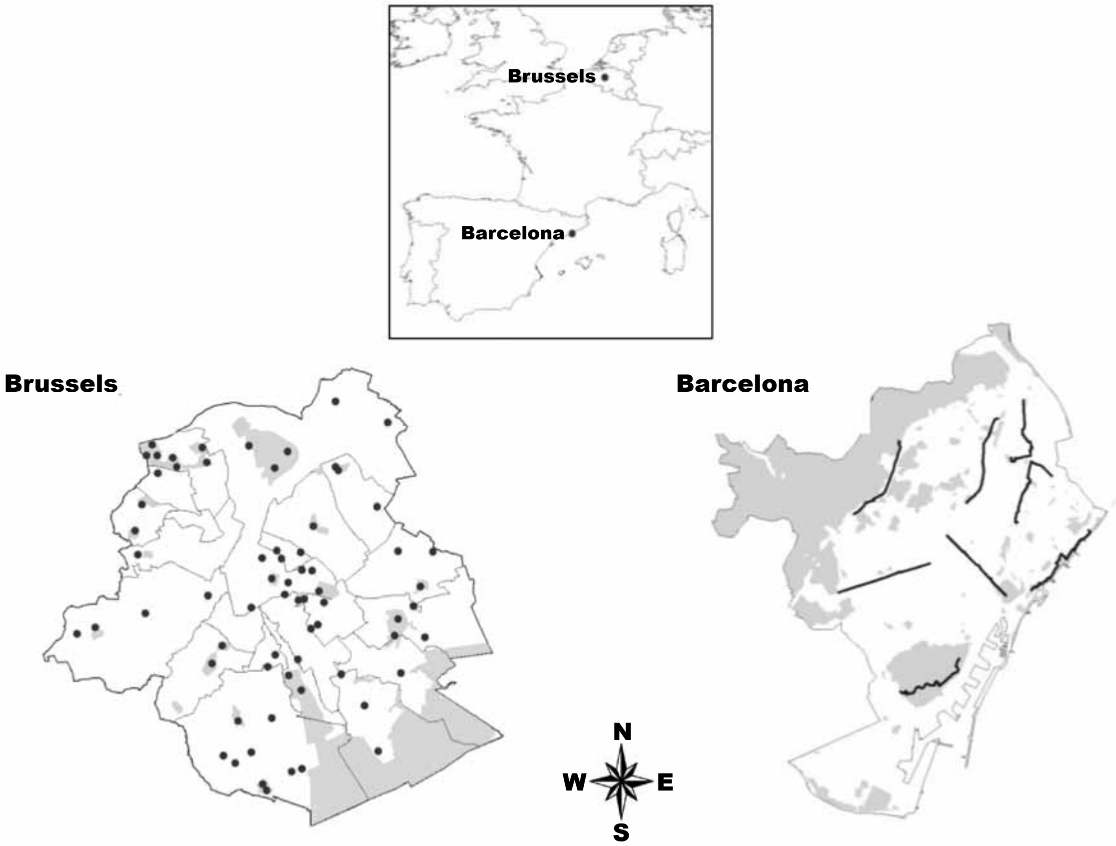

Fig. 1. Location of the sampling plots: point-counts in Brussels, and line-transects in Barcelona. Grey areas correspond to green spaces; in the case of Brussels, the grey area to the south is the Forest de Soignes, while in Barcelona, Collserola Natural Park lies to the north–west. Sampling plots located in these two natural areas were excluded from the analyses and only plots situated in the built-up areas and urban parks are shown.

Fig. 1. Localización de las áreas de muestreo: estaciones de escucha en Bruselas y transectos lineales en Barcelona. Las áreas grises corresponden a espacios verdes, en el caso de Bruselas, el área gris situada al sur corresponde al bosque de Soignes, mientras que en Barcelona, Parque Natural de Collserola se encuentra al noroeste. Las áreas de muestreo situadas en estas dos áreas naturales fueron excluidas de los análisis y sólo se muestran aquellas que se encuentran en las áreas urbanizadas y los parques urbanos.

birds (in a set of cities), while the latter is more about the state of urban birds in a specific city and refers to environmental conditions in specific cities.

In this study we developed two multi–species indicators as a means of advancing towards the generation of an urban indicator aimed at revealing the response of urban birds to the overall environmental changes occurring in urban habitats. Specifically, we calculated and compared these two indicators (widespread species in European cities and widespread species in each particular city) using bird monitoring data from Brussels (Belgium) and Barcelona (Catalonia, Spain). We also discuss their outcomes in the light of the methodological limitations and applications.

Material and methods

Study areas

Taking into account that the driving forces affecting species dynamics can be very distinct inside and outside cities (Adams et al., 2006), we generated urban bird indicators using data collected exclusively inside cities and rejected data from agricultural and natural areas from outside cities (peri–urban areas). We believe that the cities of Brussels and Barcelona represent an interesting study framework given their distinct biogeographical locations within Europe, the former in the Eurosiberian region and the latter in the Mediterranean.

Brussels

Brussels is located close to the Atlantic coast of Europe (in the centre of Belgium; fig. 1). The city covers 162 km^2 and contains a mosaic of districts whose green spaces cover 53% of the territory (numerous parks, gardens, small woodlands and a large beech forest 'the Forest of Soignes', which represents a tenth of the Brussels' surface area). Parks and gardens are often highly managed, with large lawns, even though the management of an ever–increasing part of public green spaces is beginning to take biodiversity into account. Most of the urban parks and woodland were planted with beech *Fagus sylvatica*, ash *Fraxinus excelsior* or a variety of exotic species at the end of the nineteenth century and so most trees are today very old; active regeneration is under way. The neighbouring areas mainly consist of residential areas, farmland and small towns.

Changes in common bird populations in the Brussels region have been monitored using point–counts (Bibby et al., 2000) since 1992. In practice, 98 point–counts located mostly in green areas throughout the city are sampled twice a year during the breeding season (Weiserbs & Jacob, 2007). Given our aim of focusing on species living in urban habitats, the present analysis did not take into account the 31 points located in the Forest of Soignes. Thus, a total of 67 point–counts was used in this study, each of which was used as a sample unit in subsequent analyses (fig. 1).

Barcelona

Barcelona is located in the western Mediterranean Basin (north–east Spain; fig. 1). It covers 101 km^2 and is dominated by built–up areas, although the Collserola Natural Park in the west of the city is a large natural area. Apart from this site, the network of green areas includes urban parks (mainly small, < 3 ha) scattered among buildings, and private gardens. In total (including Collserola), green spaces cover 36% of the city and its municipal area. Urban parks have a mixture of autochthonous and exotic plants, and many of the city's streets are tree–lined. Trees in public parks and gardens were mainly planted from 1980 onwards. The city of Barcelona itself is at the centre of a highly urbanized metropolitan area covering 636 km^2.

The monitoring of common birds in Barcelona started in 2002. As in Brussels, censuses are conducted twice during the breeding season. The system adopted is the line–transect method (Bibby et al., 2000) and 11 3–km transects are currently conducted, all as part of the Catalan Common Bird Survey (SOCC) that covers the whole of Catalonia (NE Spain). In this study, we did not take into account the two transects located in Collserola Natural Park, nor a transect located in the large urban park of Montjuic for which some degree of spatial overlap occurs. Thus, a total of eight 3–km transects were taken into consideration, each one taken as a sample unit (fig. 1).

Data analysis

We calculated the trends of common species separately for each of the cities using the time–effects model of the TRIM program (Pannekoek & van Strien, 2005). In these analyses at species level, the period taken into account was 2002–2010, the years for which data was available for both monitoring projects. Every species for which the sample size was sufficient was analysed by TRIM (with a minimum presence of 10 point counts in Brussels and four line–transects in Barcelona). However, introduced species (*e.g.* Red–necked Parakeet *Psittacula krameri* and Monk Parakeet *Myiopsitta monachus*) and feral pigeons (*Columba livia*), whose population dynamics are strongly influenced either by exponential growth at the initial stages of invasion (Crooks, 2005) or by specific management (Sol & Senar, 1995), were not included in the analyses. We also excluded swifts (*Apus apus, A. pallidus* and *A. melba*) because sampling bias probably existed (serious mobility and aggregation effects) in the censuses. Given their abundance, swifts could probably be a highly relevant species in an urban context, but a species–specific monitoring scheme would have to be set up if data from these species were to be included in the analyses.

We selected different multi–species urban indicators for each conceptual approach. The first one considered that to advance towards the generation of an urban indicator that would be comparable across European cities, this should minimise the taxonomic variance by containing species that are widespread in European cities (widespread species in European cities, hereafter WSEC). Thus, we used information collected by Kelcey & Rheinwald (2005) in 16 European cities (St. Petersburg, Moscow, Warsaw, Lublin, Sofia, Bratislava, Vienna, Prague, Berlin, Bonn, Hamburg, Brussels, Florence, Rome, Valencia and Lisbon) and assumed that this sample represented the main environmental gradients in European cities. Specifically, we included in this approach all species breeding in at least 14 of these16 cities, that is, a total of 37 species (table 1). The threshold of 14 instead of the total 16 was chosen to avoid the exclusion of some fairly common species that were not present in the extremes of the ecological gradient represented by this set of cities, mainly in the two cities of the northeast (St. Petersburg and Moscow) or southwest (Valencia and Lisbon). Thus, in this first conceptual approach all species present in a given city on the list could be used to build the multi–species urban indicator, although to be definitively included as part of the indicator in a given city they should be abundant enough to provide reliable information through the monitoring project. The second approach indicates that all widespread urban species in each city should contribute to the index, regardless of how they are distributed in other European cities, thereby maximising urban habitat or ecological coverage in comparisons between cities. In this context, we considered that species present in at least 75% of monitoring plots in a given city during the study period (2002–2010 in our case) could be included as species that are widespread in the

Table 1. Species considered in the widespread species in European cities (WSEC) urban index. This list of bird species was elaborated using the information compiled by Kelcey & Rheinwald (2005) for 16 European cities (St. Petersburg, Moscow, Warsaw, Lublin, Sofia, Bratislava, Vienna, Prague, Berlin, Bonn, Hamburg, Brussels, Florence, Rome, Valencia and Lisbon). Specifically, the list includes 37 species breeding in at least 14 of the 16 cities (see Material and methods). In the cases of House Sparrow *Passer domesticus* and Italian Sparrow *P. italiae*, and Common Starling *Sturnus vulgaris* and Spotless Starling *S. unicolor,* these pairs of species were treated as one because of their very similar ecology and almost non–overlapping distributions.

Tabla 1. Especies consideradas en el indicador urbano de especies de amplia distribución en las ciudades europeas (WSEC). Esta lista de especies de aves fue elaborado utilizando la información recopilada por Kelcey & Rheinwald (2005) para 16 ciudades europeas (San Petersburgo, Moscú, Varsovia, Lublin, Sofía, Bratislava, Viena, Praga, Berlín, Bonn, Hamburgo, Bruselas, Florencia, Roma, Valencia y Lisboa). En concreto, la lista incluye 37 especies que se reproducen en al menos 14 de las 16 ciudades (ver Material y métodos). En el caso de gorrión común Passer domesticus *y el gorrión italiano* P. Italiae *y de los estorninos pintos* Sturnus vulgaris *y negro* S. unicolor*, estos pares de especies fueron tratados como una sola a causa de su ecología muy similar y de que casi no se superponen las distribuciones.*

English name	Scientific name
Mallard	*Anas platyrhynchos*
Blackcap	*Sylvia atricapilla*
Kestrel	*Falco tinnunculus*
Wren	*Troglodytes troglodytes*
Moorhen	*Gallinula chloropus*
Spotted Flycatcher	*Muscicapa striata*
Coot	*Fulica atra*
Great Tit	*Parus major*
Little Ringed Plover	*Charadrius dubius*
Coal Tit	*Periparus ater*
Wood Pigeon	*Columba palumbus*
Blue Tit	*Cyanistes caeruleus*
Collared Dove	*Streptopelia decaocto*
Long tailed Tit	*Aegithalos caudatus*
Turtle Dove	*Streptopelia turtur*
Nuthatch	*Sitta europaea*
Cuckoo	*Cuculus canorus*
Red–backed Shrike	*Lanius collurio*
Tawny Owl	*Strix aluco*
Magpie	*Pica pica*

English name	Scientific name
Swift	*Apus apus*
Jay	*Garrulus glandarius*
Wryneck	*Jynx torquilla*
Common Starling	*Sturnus vulgaris*
Spotless Starling	*Sturnus unicolor*
Green Woodpecker	*Picus viridis*
House Sparrow	*Passer domesticus*
Italian Sparrow	Passer italiae
Great Spotted Woodpecker	*Dendrocopos major*
Tree Sparrow	*Passer montanus*
Swallow	*Hirundo rustica*
Chaffinch	*Fringilla coelebs*
House Martin	*Delichon urbica*
Goldfinch	*Carduelis carduelis*
Pied Wagtail	*Motacilla alba*
Greenfinch	*Carduelis chloris*
Robin	*Erithacus rubecula*
Serin	*Serinus serinus*
Blackbird	*Turdus merula*

habitats of the city (widespread species in each city, hereafter WSC). This quantitative criterion selected the commoner species; scarcer species, while being potentially interesting urban indicators, are more difficult to monitor properly. For each of these two candidates (WSEC and WSC), we assessed two multi–species urban indicators for Brussels and Barcelona using the procedure developed by Gregory et al. (2005). In this approach, for a particular set of species a multi–species index for a given year can be obtained as the geometrical mean of the species population index obtained by TRIM, while standard errors can be obtained by a Taylor linearization of the nonlinear geometric mean (Gregory et al., 2005). The statistical significance of the changes shown by the indicators was evaluated using 95% confidence intervals (95% CI); if the 95% CI of a given annual value did not include the reference initial value of the temporal

Table 2. Species with large enough sample size to be considered in the analyses of population trends in each city. The species that fitted the criteria to be considered as widespread in European cities (WSEC) or widespread in each city (WSC) and that have been use to build these indicators are marked (see Materials and methods). According to the TRIM results (see Materials and methods), mean annual change (%) and significant decreases and increases over the period 2002–2010 are also marked: moderate decline (↓), moderate increase (↑), stable (–) and uncertain (?). These four trend categories follow the classification reported in Pannekoek & Van Strien (2005), in which 'moderate decrease' and 'moderate increase' correspond to significant trends and 'stable' and 'uncertain' correspond to non–significant trends; species considered 'stable' were those for which their mean annual changes are clearly less than 5% per year, whereas 'uncertain' includes species whose mean annual changes are clearly not less than 5%.

Tabla 2. Especies con tamaño de muestra suficientemente grande como para ser consideradas en el análisis de las tendencias demográficas en cada ciudad. Las especies que se ajustaron a los criterios para ser consideradas como especies de amplia distribución en las ciudades europeas (WSEC) o de amplia distribución en cada ciudad (WSC) están marcadas (ver Material y métodos). De acuerdo con los resultados TRIM (ver Material y métodos), la variación promedio anual (%) y las disminuciones y los incrementos significativos durante el período 2002–2010 también están marcados: disminución moderada (↓), incremento moderado (↑), estable (–) e incierto (?). Estas cuatro categorías de tendencia siguen la clasificación mostrada en Pannekoek & Van Strien (2005), en las cuales 'disminución moderada' e 'Incremento moderado' corresponden a tendencias significativas y 'estable' e 'Incierto' corresponden a no significativas, siendo consideradas 'estable' aquellas especies para las cuales su tasa promedio de cambio es con certeza menos del 5% anual, mientras que las que tienen la categoría de 'incierto' hacen referencia a aquellas en las que su tasa promedio de cambio anual no es seguro que sea menor del 5%.

		Brussels		Barcelona	
English name	Scientific name	Trend	Indicator	Trend	Indicator
Stock Dove	*Columba oenas*	–10%,↓	WSC		
Wood Pigeon	*Columba palumbus*	0%,–	WSC,WSEC		
Collared Dove	*Streptopelia decaocto*	–8%,↓	WSC,WSEC	+9%,?	WSC,WSEC
Green Woodpecker	*Picus viridis*	–5%,?	WSC,WSEC		
Great Spotted Woodpecker	*Dendrocopos major*	–2%,?	WSC,WSEC		
Swallow	*Hirundo rustica*			–4%,?	WSC,WSEC
Pied Wagtail	*Motacilla alba*	+7%,?	WSEC	–4%,?	WSC,WSEC
Dunnock	*Prunella modularis*	+4%,?	WSC		
Robin	*Erithacus rubecula*	–2%,?	WSC,WSEC	+7%,?	WSC,WSEC
Song Thrush	*Turdus philomelos*	–2%,?	WSC		
Blackbird	*Turdus merula*	–2%,↓	WSC,WSEC	+1%,?	WSC,WSEC
Garden Warbler	*Sylvia borin*	–11%,?			
Blackcap	*Sylvia atricapilla*	–3%,↓	WSC,WSEC		
Sardinian Warbler	*Sylvia melanocephala*			+5%,?	WSC
Willow Warbler	*Phylloscopus trochilus*	–5%,?			
Chiffchaff	*Phylloscopus collybita*	–6%,↓	WSC		
Wren	*Troglodytes troglodytes*	–2%,↓	WSC,WSEC		
Spotted Flycatcher	*Muscicapa striata*			+6%,?	WSEC
Great Tit	*Parus major*	+2%,–	WSC,WSEC	+19%,?	WSC,WSEC
Blue Tit	*Cyanistes caeruleus*	–2%,–	WSC,WSEC	+30%,↑	WSC,WSEC
Marsh Tit	*Poecile palustris*	–4%,?			
Long–tailed Tit	*Aegithalos caudatus*	+3%,?	WSEC	–15%,?	WSEC
Nuthatch	*Sitta europaea*	–1%,?	WSEC		

Table 2. (Cont.)

English name	Scientific name	Brussels Trend	Brussels Indicator	Barcelona Trend	Barcelona Indicator
Short–toed Treecreeper	*Certhia brachydactyla*	–5%,↓	WSC		
Magpie	*Pica pica*	–3%,↓	WSC,WSEC	+10%,?	WSC,WSEC
Jay	*Garrulus glandarius*	+2%,?	WSC,WSEC		
Jackdaw	*Corvus monedula*	+11%,↑		+2%,?	
Carrion Crow	*Corvus corone*	+4%,↑	WSC		
Starling	*Sturnus vulgaris*	–8%,↓	WSC,WSEC	+8%,↑	WSC,WSEC
House Sparrow	*Passer domesticus*	+8%,↑	WSEC	–5%,↓	WSC,WSEC
Chaffinch	*Fringilla coelebs*	+8%,↑	WSEC		
Goldcrest	*Regulus regulus*	–8%,?			
Goldfinch	*Carduelis carduelis*			–7%,?	WSC,WSEC
Greenfinch	*Carduelis chloris*	+15%,↑	WSEC	–3%,?	WSC,WSEC
Serin	*Serinus serinus*			+5%,?	WSC,WSEC

series, then these two values were considered to be significantly different (see Pannekoek & Van Strien, 2005 for the same approach at species level). Finally, we assessed a magnitude of yearly average change in the indicators (WSC and WSEC) by calculating the parameter (slope) in the simple regression model between the yearly value of the indicator (dependent variable) and time (predictor).

Results

During the study–period a total of 84 native breeding species were recorded in Brussels and 76 in Barcelona. Only for some of these species (30 in Brussels and 17 in Barcelona), was sample size considered sufficient (see Material and methods) to run TRIM over the period 2002–2010 (table 2). Species trends in Brussels showed that in the period 2002–2010, seven species (28%) decreased significantly, two (8%) were stable, and five (20%) increased significantly, whereas in Barcelona, where most species' trends were non–significant, only one species (6%) decreased and two (12%) increased significantly (table 2).

We compared the two approaches to develop urban indicators (WCS and WSEC), which varied according to the species included in each case (table 2). The two indicators gave similar temporal patterns for each of the cities (fig. 2). Overall, the change was non–significant over the study period in both cities, although there was a slight increase in Barcelona (5% annual increase for WSC and 2% for WSEC), while the indicators for Brussels showed a slight decrease or remained stable (3% annual decrease for WSC and 0% for WSEC) over the study period (fig. 2).

Discussion

The development of a reliable, urban multi–species indicator based on bird monitoring data is not a simple task. Starting with data gathering, urban habitats are often under–represented in large–scale monitoring schemes since they are less interesting for ornithologists than more natural areas (*e.g.* Saris et al., 2004; McCaffrey, 2005; but see also Ferrer et al., 2006). This is partially compensated for by the efforts of some local councils, as in Barcelona and Brussels. Nevertheless, monitoring schemes specifically designed for cities have to cope with relatively low sample sizes compared to whole regions or countries, and this often limits the number of species in the data set to just a few dozen (see table 2 for the studied cities). This small set of species could grow if the survey efforts (either in common bird censuses or in species specific schemes) and/or the number of species adapted to such artificial environment increases over time. Hence, in a few years' time the number of available species to generate an urban indicator may also increase, and so it would be useful to establish procedures that describe when and how such species should be included in the indicators, and what the consequences will be in relation to the results of former indices.

Within this context, the selection of a group of bird species to provide better information on changes in urban biodiversity is also hampered by the definition of the urban ecology of the species, above all if we consider that an important component of urban variability depends on the avifauna in surrounding habitats (Sattler et al., 2010). Even within Europe, the number of urban adapters varies from one city

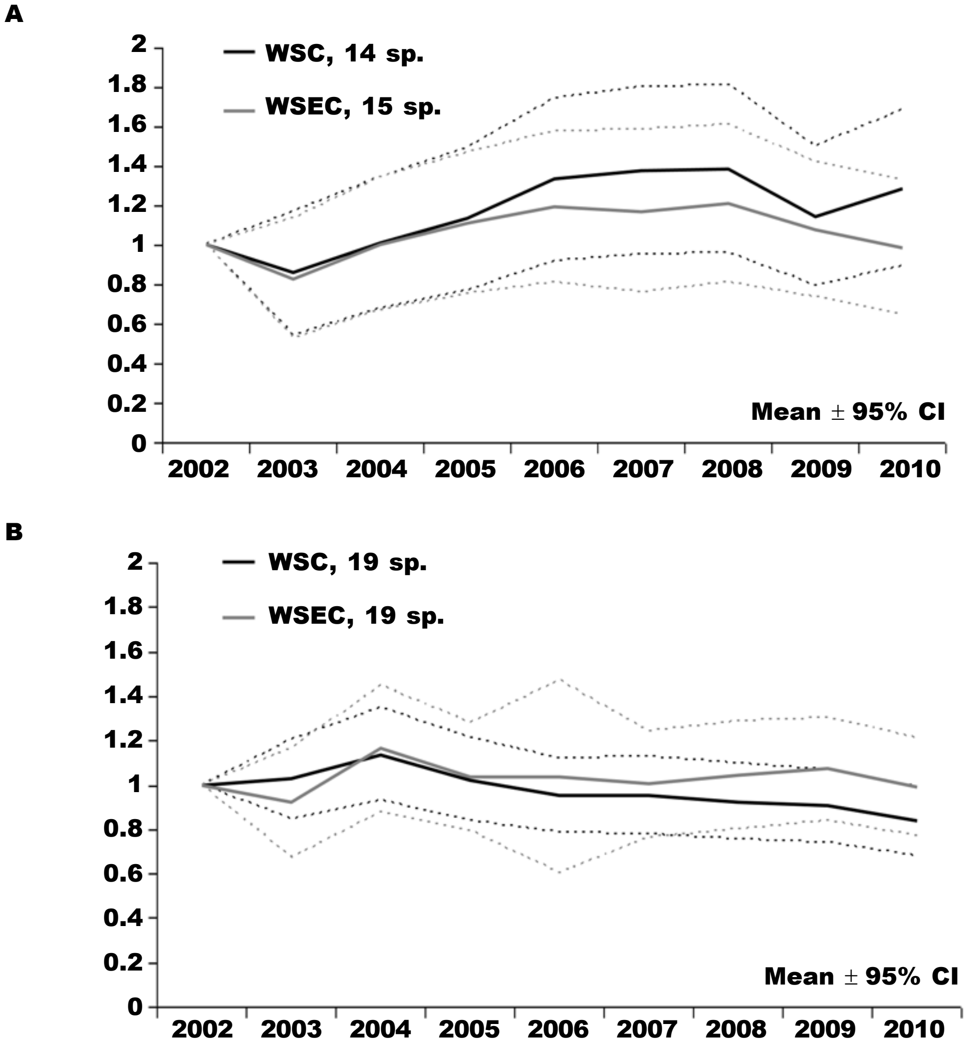

Fig. 2. Changes revealed by the two different candidates for an urban indicator (WSC and WSEC) during the study period in Barcelona (A) and Brussels (B). (For abbreviations see material and methods.)

Fig. 2. Cambios mostrados por los dos distintos candidatos a indicador urbano (WSC y WSEC) durante el periodo de estudio en Barcelona (A) y Bruselas (B). (Para las abreviaturas ver Material y métodos.)

to another (Kelcey & Rheinwald, 2005) and gradually increases as additional species invade and adapt to urban areas (Rutz, 2008; Evans et al., 2009). Therefore, in this study we focused fundamentally on the urban character of the study sites rather than that of the bird species, thereby rejecting non–urban sites and focusing on urban sites, mainly consisting of built–up areas and city parks. This approach is different from that of other Pan–European indicators such as the Farmland Bird Index (Voříšek et al., 2008) that uses species lists whatever the habitat that the monitoring data is collected in.

In this study we used data from monitoring projects carried out in Barcelona and Brussels to derive two urban multi–species indicators that could potentially be applied in other European cities. We took into account the fact that inter–city comparisons could be maximized either at species level (using lists of bird species that are as similar as possible to minimize taxonomic variation) or at ecological level (regardless of the number of species shared among cities and trying to maximize the information provided by birds on the state of their habitats in each city). In the first approach, we used a set of species that are widespread in the 16 European cities cited in Kelcey & Rheinwald (2005). However, it could be argued that these cities are not totally representative of the overall European urban avifauna since 50% of them are located in central Europe, and there are, for example, few western, southern and northern European cities. Thus, although we considered that this was probably among the best sources of information, this potential weakness should be taken into account in future studies. The second approach did not present such limitations because it was city–specific, but both approaches had a subjective threshold for a given species to be included in the indicator (present in at least 75% of monitoring plots in a particular city, or species breeding in at least 14 of the 16 cities), and hence these criteria would also deserve further investigation.

Although several important issues on conservation rely on the trends of a particular species (*e.g.* threatened species), multi–species indicators better capture ecosystem complexity than indicators based on one or a few species (Buckland et al., 2005; Gregory et al., 2005; Butler et al., 2012). In our case, the analysis by species gave relatively little information and statistically significant trends were only obtained for a small number of species, especially in Barcelona. This could be caused, in part, by the short time framework, as illustrated by the fact that in Brussels an analysis including the 10 previous years of sampling provided more significant results at species level (Weiserbs, 2010). Nevertheless, trends in the multi–species indicators generated in this study seem to be more robust than the individual species trends. Overall, the values shown by the indicators did not change significantly over the period 2002–2010 in either of the two cities, although there was a slight non–significant increase in Barcelona and the indicators for Brussels showed a slight non–significant decrease or remained stable (fig. 2). Regardless of the city, the pattern revealed by the two indicators (WSC and WSEC) was relatively similar. Nevertheless, the detected 3% difference in the overall trend could be considered relevant and reveals the importance of the species–selection procedure and the criteria used. The WSEC indicator shows performance of European species that are widespread in urban environments at a continental scale, whereas the WSC focuses on the species of a particular city. Thus, the two types of indicators presented in this study give different messages. We consider that both indicators have their value and should be treated as complementary indicators rather than competing indicators. Nevertheless, these indicators do not shed light on their respective accuracies with respect to what they are expected to indicate, and more studies are needed to analyse the relation between these patterns and other independent sources of information about the state of the environment (*i.e.* revealing relationships between indicators and environmental predictors relevant for population dynamics).

Further studies are also obviously needed if we are to define a set of the most suitable species for creating a multi–species urban indicator, and collaboration between European cities will be crucial if this is to be to achieved. Indeed, this may eventually result in the generation of biodiversity indicators not only for specific cities, but also for all urban areas in a country or, even, in a whole continent.

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