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Chapter · January 2017

DOI: 10.1007/978-3-319-43314-1_22

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Chapter 22
Indicators of the Effects of the Urban Greening on Birds: The Case of Barcelona

Sergi Herrando, Lluís Brotons, Marc Anton, Martí Franch, Javier Quesada, and Xavier Ferrer

Abstract Building and maintaining an urban green infrastructure, which can be understood as a network of urban parks, private gardens or forest areas, can potentially contribute to reverse the trend of biodiversity loss. In this context, developing indicators of the changes produced by green infrastructures on urban biodiversity represents a task of particular interest for planning and governance approaches. The results of long-term bird monitoring schemes in many cities, mainly based on volunteer programmes, may provide a good opportunity to obtain robust data on the spatial patterns and temporal trends of species populations. In addition, recent development of multispecies indicators can now be implemented to make use of common bird monitoring datasets with the aim to generate robust

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E. Murgui, M. Hedblom (eds.), *Ecology and Conservation of Birds in Urban Environments*, DOI 10.1007/978-3-319-43314-1_22

policy relevant evaluation tools. In this chapter we show a procedure to track the effects of urban greening on birds using common bird monitoring data from the city of Barcelona (north-east Iberian Peninsula). Essentially, the proposed approach requires to quantify the species' response to the green infrastructure at a population level and to integrate all this information in combined indicators of the effect of urban greening. Using this approach we developed a first indicator to track temporal changes on bird populations linked to the greening and a second indicator to determine the areas of the city in which the level of development of the green infrastructure is already having a positive effect on biodiversity.

Keywords Indicators • Bird monitoring • Breeding bird atlas • Urban planning • Green infrastructure

22.1 Introduction

22.1.1 The Challenge of the Urban Green Infrastructure

Urban areas are composed of a combination of built-up surfaces and patches of vegetation, often named grey and green infrastructures, respectively. After a long period of developing intensively grey infrastructures, in 2013, the European Commission adopted a Green Infrastructure Strategy to promote its development both in urban and rural areas (EC 2013). This strategy defines the green infrastructure as a strategically planned network of natural and seminatural areas designed and managed to deliver a wide range of ecosystem services (TEEB 2011). The urban green infrastructure plays a major role in densely populated areas since it is not only a natural capital itself but also an essential component to help reducing the fragmentation of the ecosystems (Benedict and McMahon 2006; see also Goddard et al. 2016; Heyman et al. 2016; Meffert 2016).

Developing a green infrastructure in urban regions implies accounting for a matrix of different components of vegetation in and on the edge of cities and towns, either cultivated or spontaneously developed (e.g. remnants of natural vegetation such as forests or shrublands, riparian or coastal vegetation, urban parks, wastelands, tree plantations, farmland, house gardens, green roofs, green walls and scattered shrubs and trees). Greening cities and towns usually represents a challenge since mentalities favouring grey infrastructures for immediate and single purposes should be at least partially shifted towards principles aimed at protecting and enhancing natural processes from which human societies get different ecosystem services. One of the contrasted differences between the grey and the green approach is that the outcomes of the latter deeply depend on the interaction between human management and natural processes.

Undoubtedly biodiversity is one of the elements more intrinsically linked to the natural processes occurring in the green infrastructure, and urban greening represents an immense opportunity for restoring biodiversity and its associated functional traits, as expressed by the Goal D of the Strategic Plan for Biodiversity

2011–2020 (SCBD 2014). Within this context, there is an evident interest in implementing indicators to track if the development of the urban green infrastructure is actually unfolding positive responses in biodiversity, and this unequivocally requires an appropriate monitoring for at least some of their biological components.

22.1.2 Monitoring Urban Birds for Developing Indicators

Monitoring biodiversity is not a trivial task either in natural or human-modified environments. The complexity of biodiversity is so high that there is a clear need of developing essential biodiversity variables (EBV) to track the effects of environmental change in organisms (Pereira et al. 2013). Developing EBVs is crucial for a robust assessing of progress towards the 2020 targets of the convention on biological diversity. They should be sensitive to change over time, of relevance to the broader community (including scientists/researchers, governments, decision/policymakers, assessment bodies, conservation professionals and conventions), and feasible in terms of monitoring. One of the examples of EBV is provided by data from population abundance for species sets representative of some taxa (Pereira et al. 2013).

Birds represent the most popular taxonomic group for delivering indicators of population change in the framework of EBVs. In Europe, birds account for almost 40 % of all species monitoring schemes (EuMon 2015). To understand the prominence of birds in this context, it should be taken into account the ease with which they can be monitored, the involvement of amateur ornithologists in citizen science projects, the existence of scientifically robust methods for monitoring their populations and a general acceptance of their use as indicators of environmental change (Furness and Greenwood 1993; Gregory et al. 2008).

Bird monitoring projects have been particularly successful in providing relevant indicators to track the loss of biodiversity in farmlands (e.g. Gregory et al. 2005), and the European Union has adopted the farmland bird indicator as a structural indicator, a sustainable development indicator and a baseline indicator for monitoring the implementation of the rural development regulation under the common agricultural policy (EEA 2015). However, indicators based on urban bird data have been poorly developed, and their acceptance as policy relevant tools in Europe is still an ongoing process. This could be at least partially explained by the lack of unambiguous messages regarding what urban bird indicators actually indicate in the framework of planning and conservation strategies. Many urban bird indicators actually show trends composed of species that usually live in cities, towns and villages, with more or less strict approaches on the species urban-related ecology depending on each case (e.g. Zbinden et al. 2005; Sudfeldt et al. 2013; SEO/BirdLife 2014). In general urban bird indicators have been developed at a country level, and only in few cases, the focus has been a particular metropolitan area (e.g. Herrando et al. 2012; see van Heezik and Seddon 2016). All these methodological approaches represent interesting experiences to inform on the population changes for a number of species associated to urban habitats, but cannot provide unambiguous information on the degree of achievement of the goals of strategies aimed at improving biodiversity by means of urban greening. The evaluation of the process of urban greening should be definitely conducted by means of a species set closely related to urban green habitats and not to man settlements.

22.1.3 Indicators to Track the Effect of Urban Greening on Birds

The development of indicators capable to specifically track the response of birds to urban greening should be situated within the general context of indicators of "pressure" upon biodiversity (Butchart et al. 2010). Ideally, these indicators should not track the magnitude of the pressure itself (urban greening) but its direct effect on biodiversity (population response to urban greening), thus being more informative than indirect data based on implicit assumptions linking the environmental change and the response of biodiversity (Collen and Nicholson 2014).

Within this framework, Gregory et al. (2009) generated a methodology to evaluate the impact of climate change on bird populations by means of the indicator of climatic impact on bird populations. More recently, Herrando et al. (2014) adapted this methodology to develop indicators of the impact of land abandonment in a Mediterranean region, thus broaden the former methodological approach to land use changes. In this study we develop multispecies indicators to evaluate the effects of the green infrastructure on bird populations both on a temporal and spatially explicit basis. The experience is implemented in the city of Barcelona, where the existence of an active policy to improve the urban green infrastructure and the wealth of bird monitoring data represent an ideal framework to develop these indicators.

The election of birds for this particular purpose is obviously associated to the availability of monitoring data and the development of technical approaches to generate indicators. Nevertheless, birds have also their intrinsic value within the study context of urban greening since this taxonomic group may contribute some of the ecosystem services recognised by the UN Millennium Ecosystem Assessment (Whelan et al. 2008). As in any other terrestrial ecosystem, regulation services such as control of insect populations and plant seed dispersal can be important elements in green urban environments. Finally, the cultural role of birds (spiritual enrichment, cognitive development, reflection, recreation and aesthetics) is particularly important in these green urban areas, where citizens have regular contact to this conspicuous biodiversity component.

22.2 A Study Case in Barcelona

22.2.1 Introduction to the Green Infrastructure in Barcelona

Barcelona is located on the shore of the Mediterranean Sea in the north-east of the Iberian Peninsula (latitude, 41°23′3″N, longitude, 2°10′34″E). With a total of 1,602,386 inhabitants and a size of 10,216 ha, this is a very dense metropolis (157 inhabitants per ha in 2014), and consequently, it is mainly a grey city (Fig. 22.1). The extent of water masses (blue infrastructure) within the city is

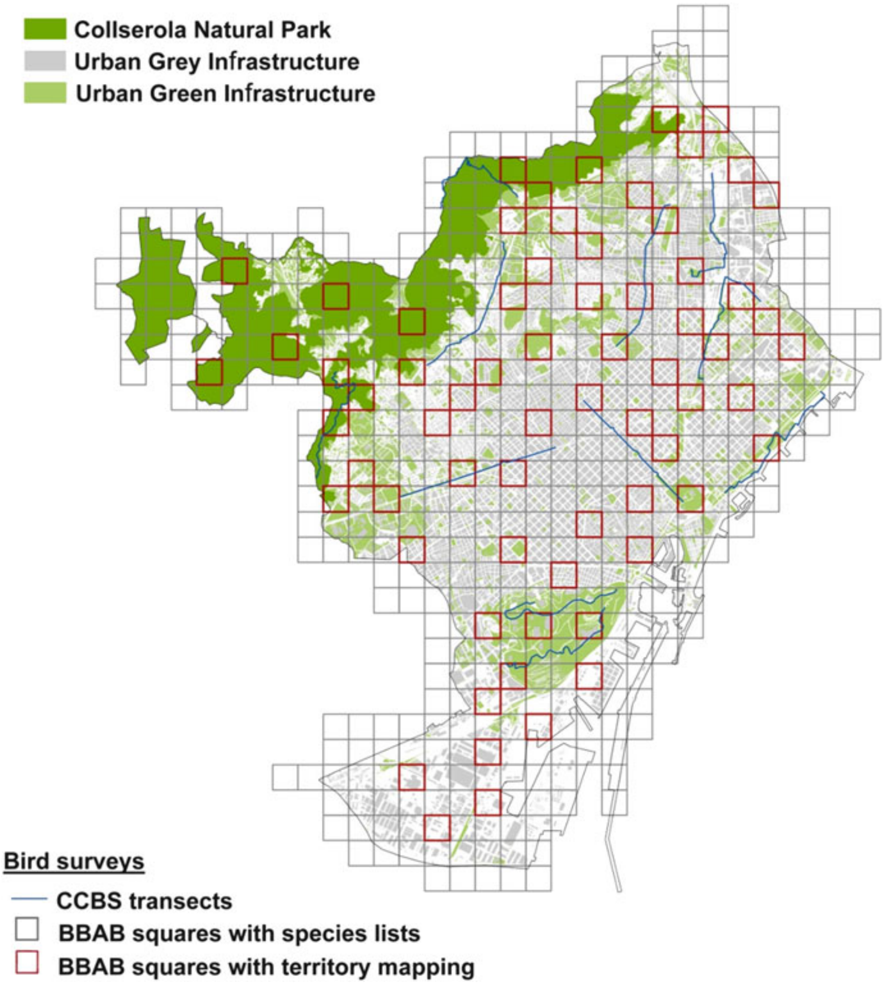

Fig. 22.1 Location of the green and grey infrastructure and of the bird surveys carried out in Barcelona: Catalan common bird survey (CCBS) and breeding bird atlas of Barcelona (BBAB)

very low. Barcelona as a compact city provides only 18 m^2 green space per inhabitant (Barcelona City Council Statistical Yearbook 2014). This low value, otherwise usual in Mediterranean cities, represents a poor green space allocation per capita (Fuller and Gaston 2009). The total green space of Barcelona amounts for 2,911 ha, mostly located in the Collserola Natural Park (1,795 ha), a peri-urban natural green space placed in the Catalan Coastal Mountain Chain. The city green extends over 1,116 ha (7 m^2 of green space per inhabitant) mainly located in two-step hill systems surrounded of built-up areas, i.e. Montjuïc (251 ha) and Els Tres Turons (123 ha). As Baró et al. (2014) showed, this low level of green space is partly counterbalanced by the high number of trees on streets, accounting for 161,423 specimens in 2013 from 150 species, mainly *Platanus hispanica* and *Celtis australis* (Barcelona City Council Statistical Yearbook 2014). This represents a ratio of 100 street trees per 1,000 inhabitants, a high value compared to other European cities which mostly range between 50 and 80 street trees per 1,000 inhabitants (Pauleit et al. 2002). The largest part of the green infrastructure is relatively recent (c. 1980), with some noticeable exceptions such as the first urban park in the city, Parc de la Ciutadella (built in 1872), and a few more from the early twentieth century as El Laberint d'Horta. As a result, most of trees found in city parks are relatively young.

22.2.2 The Strategy of Green Infrastructure and Its Link to Bird Biodiversity

The Barcelona Green Infrastructure and Biodiversity Plan falls in line with the 2020 EU Biodiversity Strategy and the strategies laid out along these lines by the UN by means of the Aichi targets for 2011–2020. This plan envisages the city in 2050 as a place where nature and urbanity interact and enhance one another by ensuring the connectivity of greenery (Barcelona City Council 2015). It is essentially defined by two goals: increasing the connectivity of green infrastructure and renaturalising the city. Green corridors are the tool aimed at achieving connectivity, defined as belts with abundant vegetation where pedestrians and cyclists must be given priority. The renaturalisation of the city is expressed by action points in "opportunity areas" which vary in terms of size and type: unoccupied plots, roofs, balconies and generally speaking all areas that can potentially keep flora and fauna (Barcelona City Council 2015). The plan is organised in ten strategic lines and the urban bird projects fit into mainly number 1 *preserving the city's natural heritage* and 7 *improving knowledge for the management and conservation of green infrastructure and biodiversity* and more indirectly to others.

22.2.3 Bird Monitoring Strategy in Barcelona

Bird monitoring is included in the action plan of the Agenda 21, the local road map for working in accordance with sustainable development principles (Barcelona City Council 2013). Two monitoring programmes are implemented in close collaboration among the Barcelona Local Council, the University of Barcelona and the Catalan Ornithological Institute, organisations that promote the monitoring of urban birds in the city. In particular, these main programmes are the Barcelona's nodule of the Catalan Common Bird Survey (CCBS; known also by its Catalan acronym SOCC) and the Breeding Bird Atlas of Barcelona (BBAB; for a review on urban bird atlases see Luniak 2016). While the main objective of the first is to determine temporal patterns of change, the second aims to determine spatial patterns. These two projects are based on citizen science; people actively participate in fieldwork following basic rules designed to facilitate their collaboration and ensuring minimum standards of robustness for subsequent data analyses. In total, nine ornithologists participate in the CCBS every year, while a total of 318 people have collaborated in the BBAB fieldwork during the years 2012–2014. Recruitment of volunteers is done by the Catalan Ornithological Institute thanks to the support for coordination provided by the regional and local governments. In general urban areas such as Barcelona are not very attractive to ornithologists, but the number of inhabitants interested in the discipline is enough to cover CCBS requirements. For the BBAB, massive dissemination of the project allowed to achieve a high number of participants in the extensive surveys, but territory mapping could not be covered exclusively on a volunteer basis, and five professionals were hired to cover some other additional squares (see below for details on these two methodological protocols). As a whole, these cooperative social projects do not only provide crucial EBVs but also improve the citizen awareness and enjoyment of urban nature.

The CCBS is an ongoing monitoring project that is based on a network of 3 km line transects sampled two times in spring (Herrando et al. 2012). Its coverage remains constant in Barcelona since 2005, with 11 transects (Fig. 22.1). The CCBS is the chosen programme to derive metrics to track the temporal change of urban birds, both native and alien (Barcelona City Council 2013). The CCBS feeds key information for the evaluation of the Barcelona Green Infrastructure and Biodiversity Plan deriving indicators to assess how birds are changing along time as the plan progressively unfolds.

The BBAB attempts to determine the distribution of breeding birds in Barcelona (under publication). For BBAB the municipality is subdivided in 528 500×500 m squares, and each of these squares is visited twice during the breeding season (30 min each visit) to generate species lists (Fig. 22.1). These extensive surveys across all the squares of Barcelona are complemented by a more intensive survey in a sample of 69 randomly selected squares to derive detailed information on birds' location. This second type of survey is based on the territory mapping method (Bibby et al. 2000), and its main aim is having a robust dataset to generate fine-grained maps (100×100 m resolution) based on niche-based models (Guisan and

Zimmermann 2000). The main project objectives are also closely related to the development of green infrastructure because it allows determining the areas of the city in which bird biodiversity is responding to the targets of the Barcelona Green Infrastructure and Biodiversity Plan.

22.2.4 Assessment of Species' Response to Urban Greening

To develop the indicators of the effect of urban greening on birds, we quantified the responses of bird species to this process as the change in their occurrence in an ecological gradient ranging from urban areas with high coverage of green surface to urban areas with high coverage of grey surface. This statistical analysis was the basis for the selection of the set of species to be included in the indicators and of the relative contribution of each selected species to the final index.

To quantify the species' responses to urban greening, we used the data gathered for the intensive surveys carried out in the territory mapping in a sample of 500×500 m squares. Within each of these squares, we randomly selected five noncontiguous 100×100 m squares and determined the bird species occurrence from the map location of individual birds in field observations. A total of 140 100×100 m squares were selected for this purpose. Information on the area of green and grey infrastructures in each square was obtained from high-resolution land use maps (Barcelona City Council 2012).

We carried out generalised linear models (GLM) to determine the species response to urban greening. GLM were run with a binomial error distribution and a logit link function; the occurrence of the species (0-1) was used as the response variable and the percentage of a green surface as the independent factor. We selected species with significant models at $p < 0.1$ and then used the obtained model parameter as an estimation of their affinity to the focal gradient. These statistical analyses were carried out using the R package (R Development Core Team 2008).

Gregory et al. (2009) provided a new approach to determine the impact of climate change on birds by assessing the overall population response to the set of species positively (+) affected by climate change and that of the populations negatively (−) affected by this driving force. A few years later, Herrando et al. (2014) developed a similar methodological approach to assess the impact of land use changes on birds and applied it to the process of land abandonment and its impact on Mediterranean bird populations. In both cases the number of species in the two sets (+ and −) sufficed to implement multispecies indices. In contrast, in this study, only the set of 18 species positively affected by urban greening were included in the analytical approach (Table 22.1). Only two species (the feral pigeon and the house sparrow) showed a negative response to this environmental change, i.e. their occurrences were negatively related to the amount of green infrastructure (−). Irrespective of its position on the gradient, the particular case of the feral pigeon is useful to illustrate the typical example of nonvalid species in this indicator

Table 22.1 Bird species whose occurrence within the urban area was significantly associated with the amount of green infrastructure

Latin name	English name	Estimate	No. of squares	Trend
Streptopelia decaocto	Collared dove	0.008^{+}	284	(+2 %)
Cyanistes caeruleus	Blue tit	0.012^{+}	148	(+5 %)
Serinus serinus	Serin	0.013*	272	−5 %
Carduelis carduelis	Goldfinch	0.013^{+}	182	(−3 %)
Pica pica	Magpie	0.015**	292	0 %
Turdus merula	Blackbird	0.016**	266	−5 %
Carduelis chloris	Greenfinch	0.019**	166	(−11 %)
Erithacus rubecula	Robin	0.022**	112	(−1 %)
Parus major	Great tit	0.025**	188	(−1 %)
Aegithalos caudatus	Long-tailed tit	0.029**	40	–
Sylvia melanocephala	Sardinian warbler	0.029**	215	(+4)
Periparus ater	Coal tit	0.032**	74	–
Columba palumbus	Wood pigeon	0.032**	260	16 %
Lophophanes cristatus	Crested tit	0.045**	107	(16 %)
Certhia brachydactyla	Short-toed tree creeper	0.049**	63	(−2 %)
Regulus ignicapilla	Firecrest	0.051**	43	(+2 %)
Sylvia atricapilla	Blackcap	0.053**	73	(−2 %)
Phylloscopus bonelli	Western Bonelli's warbler	0.073*	16	–

Estimates correspond to the slope parameters of the GLM; the higher the value, the stronger the response of species occurrence to the amount of green infrastructure. Species sorted from low to high estimates (levels of significance, p: $^{+} < 0.1$, $* < 0.05$, $** < 0.01$). For each species, information about the number of occupied squares over a total of 351 500 × 500 m squares within urban area (excluding those located in Collserola Natural Park, BBAB data), and their trend (mean yearly change over the period 2005–2014, CCBS dataset) is also shown. Non-significant trends are shown between brackets

framework since the species is so intensively managed in Barcelona that their population patterns cannot be associated to the greening process. As a consequence, the spatial and temporal indicators of the effects of urban greening were generated using exclusively the 18 bird species whose occurrence were considered to be positively influenced by this driving force (+).

22.2.5 Indicator of the Effect of Urban Greening Over Time

Bird monitoring data from CCBS provided a valuable framework for studying the changes revealed by the studied indicators over time. In order to analyse trends in the indicators of the effect of urban greening, we selected monitoring plots located in the city and rejected those located in the Collserola Natural Park (two transects; Fig. 22.1).

Using data from the nine urban transects, we estimated annual population indices and trends (period 2005–2014) for these common bird species that showed a significant positive response to urban greening (+). These population values were assessed using the time-effects model of TRIM, a software package based on the analyses of time series of counts using a Poisson regression (Pannekoek and van Strien 2005). Population trends greatly differed depending on the species, but most of the calculated trends were not statistically significant (Table 22.1). This general lack of statistical significance at species level is at least partially related to the low sample size (number of transects) and hampers interpretation of these trends. In these cases finding procedures for aggregating species data at a multispecies level may help finding ecological patterns of more robust interpretation.

The temporal multispecies indicator developed in this study was based on the geometric mean of abundance indices across species and was computed by taking the average of the log of the annual indices of n species followed by a back transformation. This type of index satisfies the majority of the desirable mathematical properties for indicators of biodiversity change (van Strien et al. 2012). These multispecies indicators were calculated using geometric means, but with a weight (Wi) for each species obtained from its response to urban greening (species estimate/sum of all estimates). This enabled the concept of the unequal relative contribution of each species to the indicator to be introduced into the procedure (van Strien et al. 2012).

For each species we used the annual index obtained by TRIM as the population index for year a (Ia). Then, we obtained a value of change (Xab) between years a and b, where $b = a + 1$, using the formula $Xab = \log (Ib/Ia)$. Subsequently, we calculated the sum of $Wi \times Xab$ for i species, where Wi is the weight of each species in the indicator (considered constant over the study period). The value obtained for this sum represents the logarithm of the proportional change in the index between two consecutive years for a given set of species. We then applied the antilogarithm to obtain the annual index value. By establishing an initial value of the indicator at 100 for the first year (2005), we used the previously calculated values of annual change to calculate the annual values of the indicator. The 90 % confidence limits for each annual value of the indicator were defined by the central 9,000 values of the ranked 10,000 bootstrap estimates (Gregory et al. 2009).

We found that the indicator of the effects of urban greening did not show a clear pattern within a 10-year study period and values for the latest years did not significantly differ from those of the beginning of the studied time series (90 % confidence intervals overlap between the first and last studied years) (Fig. 22.2). This result contrasts with the progressive increase of urban green space in the municipality of Barcelona in the period 2005–2013 (Fig. 22.2), and in fact, the values of the indicator were not significantly correlated with those of the green area (Pearson $r = 0.24$; $p = 0.51$).

There are a number of reasons that could help to explain why we did not find a nice correlation between the results of the indicator and the increase in green spaces in Barcelona along time. The first one is purely methodological since available bird

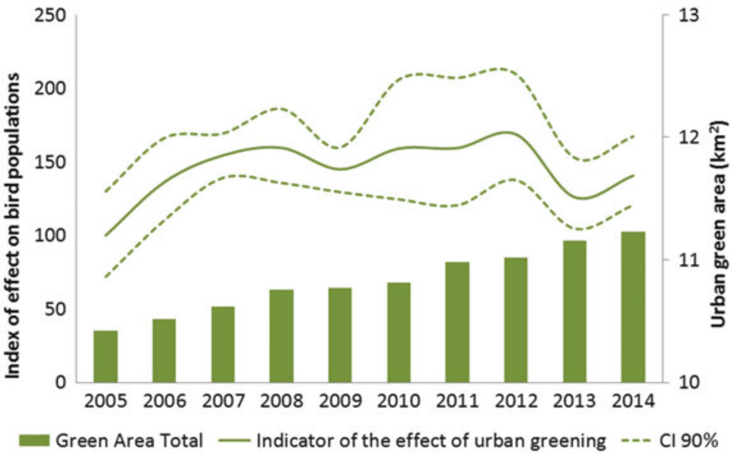

Fig. 22.2 Temporal change in the indicator of the effect of urban greening on bird populations in the city of Barcelona. This composite index was calculated using species yearly abundance indices from CCBS transects ($n = 9$ 3-km transects) and population responses according to BBAB datasets (see Table 22.1). The indicator of the effect of urban greening was set to a reference value of 100 in 2005. Change in the area of urban green in Barcelona is also shown (*Source*: Barcelona City Council 2014)

monitoring sample size is small (only 9 3-km transects), and this may influence the accuracy of this bird indicator. A second potential cause is related to the magnitude of change in the green area, which, although noticeable over the period 2005–2013 (7 %), might constitute an insufficient increase for bird populations. Obviously it is hard to determine which may be the ecological threshold in the amount of green habitat gained to produce a noticeable effect on bird biodiversity (Hedblom and Söderström 2010). A third hypothetical cause of the lack of correlation could be related to the type of green habitats that have been created within the urban matrix. Urban green areas do not always refer to the same wooded habitats, and even within these habitats, the bird species response could be associated to the species of tree or shrub and to its size and age. Finally, creating or improving the green infrastructure does not necessarily imply a simultaneous improvement of their associated biodiversity and time lags could be expected.

The need of long-term monitoring is thus crucial to robustly analyse the effects of urban greening on biodiversity. Altogether, these considerations make us remind on the original aim of this type of indicator that is not informing on the magnitude of the pressure in itself (urban greening) but its direct effect on biodiversity (population response to urban greening). At this point, it might be argued that this indicator is not a valid tool and does not inform on patterns related to urban greening. Fortunately we have a complementary source of information that enables to further explore if we are in the right direction: the spatial patterns of the indicator and its relation with the green surface.

22.2.6 Indicator of the Effect of Urban Greening Across Space

The spatially explicit approach of the indicator of the effects of greening in Barcelona attempts to provide synthetic data on the distribution of the indicator across space at a given time. In our case, this cartographic information corresponded to the period of the extensive atlas survey (2012–2014). It represents a complementary approach to the temporal scale since it allows determining the areas of the city in which the level of development of the green infrastructure is already having a positive effect on biodiversity and where this is intended to be improved in the future.

The procedure implemented in this study to depict the indicator across the municipality of Barcelona is based on the extensive surveys of the BBAB. The selected set of species was well distributed in Barcelona, being the majority present in more than 20 % of 500 × 500 m square of its urban area, but with some species rather scarce within the urban matrix (Table 22.1). The resolution of the indicator map is 500 × 500 m, the same of the original species set. Essentially, in order to calculate the indicator value for each square, we followed the same conceptual approach of species-depending contribution, incorporated as the affinity of each species for the green surface (Wi) for all species present in the square. Likewise in the temporal approach, the weight (Wi) for each species is calculated as species estimate/sum of the estimates for all species included in the indicator.

The indicator of the effects of urban greening in Barcelona shows a clear spatial pattern, with high values close to the Collserola Natural Park and the coast line and low values in densely built-up areas of the city centre (Fig. 22.3). Statistically, the pattern is intimately related to the percentage of green space in each square (Pearson $r = 0.46$; $p < 0.0001$). It is important to highlight that results shown in this map were obtained from an independent dataset than that used for calibrating the species response (intensive surveys) and shows that the approach carried out to develop this indicator responds to the amount of available green space. In addition to this technical approach, the spatial representation of the indicator can be considered a valuable tool for managers since it allows to determine the areas where bird biodiversity associated to the green infrastructure is better developed and thus considers this information in the process of ecosystem restoration established in the Barcelona Green Infrastructure and Biodiversity Plan.

The ultimate objective of this study is contributing to develop scientific tools to evaluate urban greening for biodiversity in a way understandable for managers, policymakers and citizens. Although this indicator has not been included so far within the set of indicators of the Agenda 21 of the Barcelona Local Council, the authors of this manuscript and policymakers in the city are currently discussing on its potential future role. We hope that our experience in Barcelona stimulates further research in this field and that robust indicators will be progressively developed and incorporated into such planning strategies.

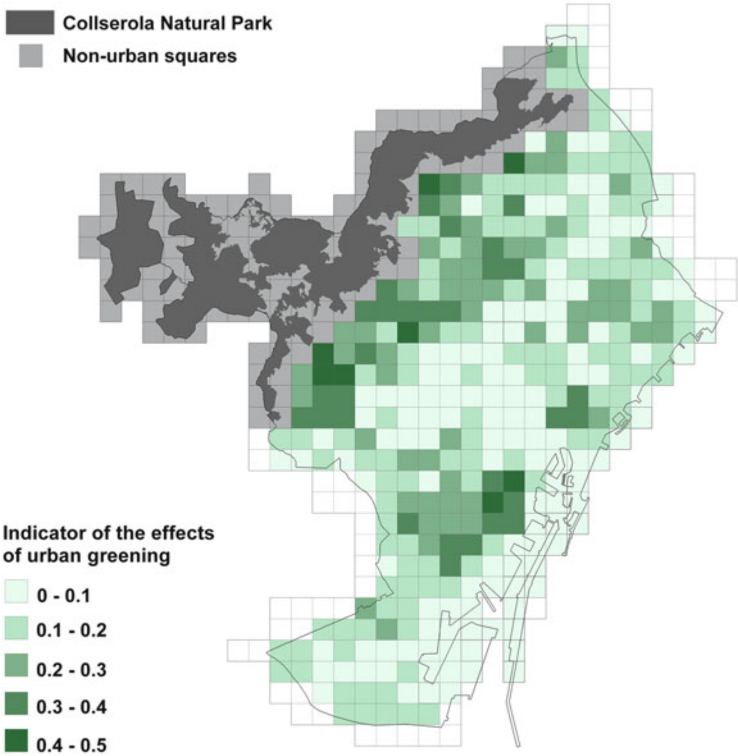

Fig. 22.3 Spatial pattern of the indicator of the effect of urban greening on bird populations in the city of Barcelona using data from BBAB (2012–2014). Since the target of the Barcelona Green Infrastructure and Biodiversity Plan lies in the urban matrix, the evaluation of the birds' response by means of this indicator is projected into the urban squares and not in those located in the Collserola Natural Park. Square size: 500 × 500 m

Acknowledgements The data analysed in this study was obtained by volunteers, without whom bird monitoring in Barcelona would not be possible. Bird monitoring projects in Barcelona receive financial support from the Catalan Government, the Barcelona Local Council and the Barcelona Zoo Foundation and are run by the Catalan Ornithological Institute and the University of Barcelona. Partial funding was received from the EU BON project (308454; FP7-ENV-2012, European Commission).

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