FACTORS SHAPING A BREEDING BIRD COMMUNITY ALONG AN URBANIZATION GRADIENT: 26-YEAR STUDY IN MEDIUM SIZE CITY (LUBLIN, SE POLAND)

ABSTRACT: We investigated the spatiotemporal dynamics of a breeding bird community in the urbanized landscape of Lublin city (150 km², 0.5 million inhabitants, SE Poland). We conducted 211 separate territory mapping surveys during 26 years (1982–2007) in 24 green areas (0.2–30.1 ha in size), distributed along an urbanization gradient. We recorded a total of 16,151 territories of 65 species. According to the estimated species richness, we detected all the species present in the studied plots. The three species community indices (species richness, Shannon-Wiener index and abundance – number of breeding pairs in census plot) increased with increasing tree stand age and area of the site, while it decreased as the proportion of biologically inactive areas increased. The three indices showed significant negative trends as the study period progressed. The mean decreasing rate was 0.2 species and 2.3 territories per year. Distance to the city centre and understorey cover negatively affected bird abundance, while they positively affected species richness and the Shannon index. Tree stand age seems to be the most important of the three indices among the analyzed explanatory variables. Our results show that the diversity of breeding avifauna in an urbanized landscape can be significantly shaped by the proper management of vegetation and size of green areas in the city. The long term decline of the three diversity indices seems to be the most important outcome of our study and requires further research and monitoring.

KEY WORDS: avifauna of cities, bird communities, species composition, urban green areas

1. INTRODUCTION

The population of animals within an urbanized landscape has attracted considerable attention of researchers in recent decades (Beissinger and Osborne 1982, Luniak 1983, Tilghman 1987, Konstantinov 1996, Clergeau et al. 1998, Jokimäki 1999, Fernández-Juricic 2000, Savard et al. 2000, Fernández-Juricic 2001, Cushman and McGarigal 2002, Chace and Walsh 2006, Palomino and Carrascal 2006, Kim et al. 2007, MacGregor-Fors 2008). The problem of the ecology of wild animals inhabiting cities can be addressed in a broad context, as it is connected to several important ecological issues, both purely theoretical as well as at the level of applied ecology and management implications. Data on the spatiotemporal distribution of biodiversity within a highly transformed landscape provide a great opportunity to describe and test several hypotheses of great importance to ecology and evolution (e.g. Evans et al. 2010). Research addressing the issues of wildlife within cities formerly concentrated on the
basic parameters of population ecology, such as frequency, distribution and abundance of populations (Luniak 1981). However, during recent decades, other issues have also been addressed by research and several aspects of animals’ biology and ecology within cities have been described in detail. For instance, data on breeding biology (Wang et al. 2009), foraging (Zmihorski and Rejt 2007, Kubacka et al. 2010), colonization patterns (Evans et al. 2010), morphology (Liker et al. 2008, Evans et al. 2010) and the genetic structure of populations (e.g. Rutkowski et al. 2010) have been the targets of many projects.

However, despite this impressive effort, several issues of wildlife ecology within an urbanized landscape are still insufficiently explored. The especially important context of time seems to be underestimated in the data on animal biology collected in cities. The urbanized landscape as a habitat for wildlife is relatively young and extremely dynamic, resulting in great changes over time in the evolution of species and the temporal aspects of their populations and communities. This can be easily observed, as colonization of cities by many species is still in progress (e.g. the kestrel Falco tinnunculus L. in central and eastern Europe - Rutkowski et al. 2010 and references therein). Therefore, referring to the temporal variability of animals’ biology within cities is crucial for interpreting the obtained data in an evolutionary context. In the present study, we made an attempt to address the issue of variability of bird community characteristics in a long-term research project. We aimed to describe the indices of diversity of the community and their changes over the last 26 years. We proposed a hypothesis on the temporal variation of bird community characteristics. Specifically, we expected that species richness, bird abundance and diversity have been decreasing over last 26 years since habitat quality in urbanized landscape decreased as a result of increase of traffic, air pollution and building density.

2. STUDY AREA

Lublin city occupies an area between 51°08’ and 51°18’ NL and between 22°27’ and 22°41’ EL. The city extends 17.7 km north to south and 15.5 km west to east. Since 1989, the city has occupied an area of 147.55 km², with almost 460,000 inhabitants. Lublin is situated in the north of “The Lublin Upland” of SE Poland. It lies on several hills separated by river valleys, which mark district boundaries. Numerous ravines with an abundance of herbaceous vegetation and groups of trees or shrubs are characteristic of the north and northwest parts. In recent years, this biotope has decreased greatly as the land has been used for the development of, for example, hypermarkets and new residential districts. The eastern parts of the city are comprised of slightly undulating land of shallow limestone. The valley of the Bystrzyca River, which is 300–1500 m wide and divides the city into two parts (east and west) has an important influence on local nature and the climate. The elevation of Lublin city is 162.5–233.7 m above sea level.

The area of Lublin city belongs to the meso-climatic zone which is generally cooler than central Poland. The mean annual temperature is 7.9°C; January is the coldest month (~3.6°C) and July the warmest (18.6°C). Winter is longer and colder than in central Poland. Spring begins rather late and is cool, especially at the beginning. The mean relative humidity is 79%; the minimum occurs in May (70%) and maximum between October and January (87–88%). Fog generally occurs on 40 days per year and rainfall on 185, with storms on 25–30 days. The average annual rainfall is 566 mm; the lowest amount (97.5 mm) occurs in winter; the highest (218.7 mm) in summer. The prevailing wind (40% of the recorded wind directions) is from the southwest/west.

The study was conducted in Lublin city at 24 sites with high vegetation, totaling an area of 140.9 ha. We collected several environmental variables for every site, which were used as potential predictors to explain the variability of the breeding bird community. For each site we assessed (1) age of the tree stand (4 classes: up to 30 years old, 30–50 years, 50–70 years, over 70 years old), (2) understorey coverage (3 classes: up to 5%, 5–10%, over 10%), (3) coverage of ‘dead area’, i.e. biologically inactive surfaces such as paths, squares, grave sites and others (4 categories: up to 5%, 5–25%, 25–50%, over 50%), (4) distance to the city.
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3. METHODS OF SAMPLING AND STATISTICAL ANALYSIS

Counts of birds were conducted in the 24 sites for at least 9 breeding seasons. Counts were made by the mapping method (IBCC 1969, Tomiałojć 1980, Bibby et al. 1992) supplemented by personal modifications. Birds were counted 10–13 times at each site during the breeding season. The counts were always conducted before noon, generally between 5:00–10:00 at a pace recommended by the cartographic method (2–3 h 10 ha⁻¹).

We used rarefaction curves implemented in EstimateS 800 software (Colwell 2005) to analyze bird species diversity and to assess the efficiency of the sampling (Gotelli and Colwell 2001). We used the Mao Tau estimator as a function of the number of samples (sample-based rarefaction curve). For this purpose, the bird species composition in each park and each year was treated as an independent sample. The estimator presents the mean expected cumulative number of species for a given number of samples in random order (Colwell 2005). As a consequence, we were able to assess the expected cumulative number of species for a given number of samples. Next, we attempted to estimate the total species richness of bird communities in the studied locations. For this purpose we estimated the number of unseen species (i.e. missed during sampling) with the help of the abundance-based coverage estimator (ACE). The ACE approach uses the abundances of rare species to estimate the number of all species in a given habitat (Chao et al. 2006). By comparing the observed species richness (i.e. number of species) with estimated species richness, we were able to infer the efficiency of the bird sampling conducted.

We investigated whether habitat characteristics included in the analyses affect the bird community. For this purpose, we used the generalized linear model with a normal probability distribution and identity link function implemented in SPSS. We used three partially dependent indices of bird community as response variables in the modeling.

We used (1) species number in each park and year, (2) Shannon species diversity index and (3) abundance (number of all pairs of all species pooled). As explanatory variables we used park area (used as a covariate), tree stand age (fixed factor), proportion of understorey (fixed factor), size of dead area (fixed factor) and distance to the city centre (covariate). We also used year (covariate) in order to control possible trends in the bird community. Based on the available explanatory variables, we constructed seven competing models (seven for each dependent variable) and used the Akaike information criterion (AIC) to select the most informative model among the set of seven competing models (Johnson and Omland 2004).

Finally, a redundancy analysis (RDA) implemented in CANOCO 4.5 was used to visualize general patterns of variability of the three studied indices in relation to the studied explanatory variables (Lepš and Šmilauer 2003). The general additive model (GAM) was used to fit the variability of bird community indices to the studied explanatory variables, and the variability was shown using isolines (Lepš and Šmilauer 2003). For this analysis, we used the indices of the bird community as samples (three RDA were conducted for each bird community index independently) and habitat characteristics as environmental variables in the RDA procedures. However, year and park area were used as co-variables (not as explanatory variables) in this analysis and were not shown to improve the clarity of the charts.

4. RESULTS

4.1. General characteristics of avifauna

A total of 65 breeding species were confirmed, 51 of them were observed both at the beginning and the end of the study period. The core breeding groups of the studied sites – exhibiting varying numbers in various periods – were the Collared dove Streptopelia decaocto (Frisv.), Wood pigeon Columba palumbus L., Blackbird Turdus merula L., Fieldfare Turdus pilaris L., Spotted flycatcher Muscicapa striata (Pall.), Chiffchaff Phylloscopus collybita (Vieill.), Icterine warbler Hippolais icterina (Vieill.), Rook Corvus frugilegus L.,
Magpie *Pica pica* (L.), Jackdaw *Corvus monedula* (L.), Starling *Sturnus vulgaris* L. Blackcap *Sylvia atricapilla* (L.), Great tit *Parus major* L., Blue tit *Cyanistes caeruleus* L., Tree sparrow *Passer montanus* (L.), Serin *Serinus serinus* (L.), Chaffinch *Fringilla coelebs* L., Greenfinch *Carduelis chloris* (L.) and Goldfinch *Carduelis carduelis* (L.).

In recent years, mostly birds from the agricultural landscape have stopped nesting in the study area: Grey partridge *Perdix perdix* (L.), Yellow wagtail *Motacilla flava* L., Wheatear *Oenanthe oenanthe* (L.), Whitethroat *Sylvia communis* Lath., Garden warbler *Sylvia borin* (Bodd.), Marsh warbler *Acrocephalus palustris* (Bechst.), Willow tit *Parus montanus* Conrad, Tree sparrow, Yellowhammer *Emberiza citrinella* L. and Linnet *Carduelis cannabina* (L.). The Short-toed tree creeper *Certhia brachydactyla* C. L. Brehm, and Redstart *Phoenicurus phoenicurus* (L.), which had disappeared for many years as breeders, began nesting again at the end of the 1990s. New species appeared as regular breeders: Sparrowhawk *Accipiter nisus* (L.), Syrian woodpecker *Dendrocopos syriacus* (Hempr. et Ehrenb.), Song thrush *Turdus philomelos* C. L. Brehm, Jay *Garrulus glandarius* (L.) and Hawfinch *Coccothraustes coccothraustes* (L.).

A distinct rise in the number of breeding pairs was confirmed for the Wood pigeon, with a smaller increase for Rook, Chaffinch, Blue tit and Blackcap. A clear decrease in population occurred among those species associated with urban green areas: Collared dove, Lesser whitethroat *Sylvia curruca* (L.), Golden oriole *Oriolus oriolus* (L.), Wood warbler *Phylloscopus sibilatrix* (Bechst.), Willow warbler *Phylloscopus trochilus* (L.), Thrush nightingale *Luscinia luscinia* (L.), Robin *Erithacus rubecula* (L.) and Greenfinch. A drastic decrease was noted for the Collared dove and House sparrow *Passer domesticus* (L.), which stopped nesting in most of the study sites.

![Fig. 1. Expected cumulative number of bird species as a function of the number of samples.](image1)

![Fig. 2. Biplot of the redundancy analysis (RDA) implemented in CANOCO software showing the variability of the three characteristics of the breeding bird community presented using isolines fitted with the General Additive Model (GAM). Vectors show the habitat characteristics used as explanatory variables. Note that year and park area were used as co-variables.](image2)
4.2. Efficiency of the sampling and estimated species richness

Increasing the sampling effort to ca 40 samples (controls in each park in each year are treated as independent samples here – see Methods) resulted in a sharp increase in the number of species detected to 63.81 species on average (98% of all species recorded during the study). However, the additional 171 samples were much less efficient in term of detecting new species. Increasing the sampling effort to 211 samples resulted in the detection of just 1.19 additional bird species on average (Fig. 1). After including 119 randomly selected samples, the probability that some species remain unseen is less than 5%. The estimated species richness, corrected for unseen species in the samples, did not differ from the observed species richness. The abundance based coverage estimator (ACE) indicated 65 species, which led to the suggestion that no species remained undetected (Fig. 1). The mean number of species with
only one individual (singletons) decreased from over 25 to zero as the sampling effort increased (Fig. 1).

4.3. Factors explaining bird species diversity in an urbanized landscape

Analyses revealed that the habitat characteristics taken into account determined the variability of the three bird species’ community characteristics. Among the set of competing models explaining the variability of the three bird species’ community characteristics, full models were the most parsimonious when assessed with the AIC (Table 1).

The variability of bird species numbers increased with increasing stand age, understorey cover and distance to the city centre, while it decreased with increasing dead area (Table 2). Almost the same effects were confirmed for the model explaining the variability of the Shannon diversity index. However, the importance of dead area was not significant. The number of individuals increased with increasing stand age. However, the effect of understorey cover was different compared to the two preceding models, because abundance decreased as understorey cover exceeded 10%. Moreover, contrary to the two preceding models, density decreased with increasing distance to the city centre. The variability of all three characteristics of the breeding bird community was positively affected by park area (Table 2, Fig. 2).

The three indices of the bird community in Lublin city showed a significant decline during the last 27 years. The significance of the decline was confirmed in the GLM (Table 2) as well as in the simple regression analysis. What is important, the decline was significant both for the full data set (i.e. years 1982–2007) as well as for the reduced data (i.e. 1992–2007; Fig. 3).

5. DISCUSSION

In general, our sampling, conducted over 27 years, seems to be sufficient for a reliable inference on the variability of the bird community within urban parks. As shown by the total species richness estimation, we detected all of the species inhabiting the studied habitat, which led us to believe that the further
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analysis provided in this paper refers to a complete bird community and can be generalized.

We recorded that the bird community was significantly affected by the factors studied. Both the landscape context of the studied plots (area, distance to the city centre) and habitat features (stand age, understorey cover and dead area) significantly affected the indices. However, the composition of breeding avifauna in cities is also shaped by the geographic location of the study area and progression of the synurbization process among specific species. To a great extent, it may also depend on population trends occurring at a larger scale and over a longer period of time (Głowaciński 1992, Konstantinov et al. 1996, Tomiałojć 2007). According to Luniak et al. (2001), the state of avifauna depends in large part on factors occurring on a regional, continental or even broader level. In the present study, we did not address the effects of these external factors (e.g. large scale trends). Therefore, the modeling presented in our study explains only part of the variability of bird community diversity and this should be kept in mind when interpreting our results.

Luniak (1981, 1983) states that the number and population size? density? of species depend on the age of the tree stand and extent of a site’s tree cover. In our study, the age of tree cover increased the diversity of the breeding bird community: the mean number of species in green areas characterized by old stand age was on average 9 species more compared to areas where the stand age was not older than 30 years. In his Guadalajara (Mexico) studies, MacGregor-Fors (2008) also showed that the number of species rises as the tree stand ages and crown cover increases. According to Fernández-Juricic (2000), one of the most important factors responsible for avifaunal diversity is the age of a park. Other authors also have stated the opinion that stand age plays an important role in shaping avian species’ diversity (Lancaster and Rees 1979, James and Wamer 1982, Tilghman 1987, Kujawa 1997, Jokimäki 1999, Chace and Walsh 2006, Palomino and Carrascal 2006). This effect is most probably connected with the higher availability of breeding and foraging sites for many bird species in old stands relative to younger ones (e.g. Camprdodon et al. 2008).

The effect of understorey cover on the three analyzed diversity indices was not clear. On one side, number of species and species diversity increased following an increase in the understorey cover. The abundance of shrubs was favorable only for the numbers of Chiffchaff, Willow warbler, Thrush nightingale, Garden warbler and Blackcap. Luniak’s conclusions confirm that the abundance of undergrowth mainly increases avian diversity (Luniak 1981, 1983). This is also consistent with the many years’ observations of Askins and Philbrick (1987) in forests. Aging trees accompanied by a diminishing understorey resulted in a regression of the number of forest species and an increase of species undergoing synurbization. Also, Cyr and Cyr (1979) believe that the quality of the understorey has the greatest influence on the number of species. This may be connected to the role of understorey and undergrowth as nesting and foraging places for birds (see: Orłowski et al. 2008). On the other hand, bird abundance showed an opposite relationship with understorey cover. Most possibly, a more detailed characterization of the understorey (e.g. in respect to its height, plant species composition, spatial pattern, etc.) needs to be conducted to explain its effect on birds. A significant factor, but one difficult to capture, may be the general richness of vegetation in a city. This is how Witt et al. (2005) explained the differences in the numbers of many species in Warsaw, Hamburg and Berlin.

An increase in the ‘dead zone’ accompanied a decrease in the number of species and their abundance. This result agrees with our expectations and shows that man-made habitat transformations in urban green areas negatively affect the bird community. According to this result, further increases in biologically inactive surfaces, e.g. increase in path density, will lead to a decrease of avifauna diversity.

It is interesting that placement of a habitat patch within the city affected bird species’ diversity: sites located in the city centre were on average less diverse compared to patches in the outskirts. This issue needs further research. However, such results may lead to a suggestion that the landscape context of a habitat patch significantly contributes to the
biodiversity of this patch, which follows the classical theory of island biogeography. This seems to be especially important in designing protected areas in the urbanized landscape.

Long term negative trends of the three studied diversity indices were recorded and this is potentially the most important result of our study in the context of biodiversity conservation. This result was not expected, since many bird species were reported to have expanded to urban habitats during recent decades (Konstantinov et al. 1996, Lunia k et al. 2001, Biaduń 2004, Evans et al. 2010, Rutkowski et al. 2010). Our results suggest that despite the urbanization process of many species in central Europe, the overall diversity of urban fauna can definitely decrease. An important question arises: what are the causes for the overall and long term decrease of bird diversity in Lublin city? The detailed characteristics of urban habitats with special reference to green areas may help to answer this question, but such data are lacking. Nevertheless, since our results are partially in accordance with other reports long term changes of urban birds (Mazgajski et al. 2008, Żmihorski et al. 2010), a monitoring program seems to be necessary to account for the trends of wildlife in urbanized habitats.

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5. REFERENCES
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Kubacka J., Żmihorski M., Mirski P., Rejt Ł. 2010 – Central-place foraging in an urban landscape: body mass of Common voles (Microtus arvalis Pall.) caught by breeding Kestrels (Falco tinnunculus L.) is positively correlated with availability of hunting sites – Pol. J. Ecol. 58: 387–392.


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