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Green space area and type affect bird communities in a South-eastern European city

Abstract

Urbanization decreases the species richness and results in the homogenization of bird communities. Bird species are important indicator species for biodiversity and reflect the habitat quality of urban forests and other green spaces. In this study we investigated the key drivers that influence bird communities in urban forests and green spaces in the Southeastern European city of Ljubljana, Slovenia. We were interested in how the number of species, species dissimilarity and indicator species are affected by the type of green space (urban forest vs park), area of green space and type of urbanization (urban vs peri-urban areas). We sampled birds twice in 2012 in 39 standardized point counts across Ljubljana. We found that the abundance was influenced by the area of the green space. Species dissimilarity and species turnover are affected by the area and type of green space. Interestingly, the analysis showed that the species composition of peri-urban areas was similar to that of urban areas. Indicator species were found for all environmental variables. On the basis of the results, we suggest the strategy that would increase the diversity of birds and increase the stability of their populations in urban areas. Urban planners should encourage 1) both forests and parks since they harbour different species of birds, 2) larger green spaces since larger areas have species that are more typical of larger areas and 3) a mosaic of a larger number of smaller forest remnants combined with larger forest complex serving as source areas.

Keywords: Urban forest, bird species composition, forest remnant, urbanization, peri-urban forest, bird monitoring, species richness

Introduction

Urbanization is one of the greatest threats to biodiversity (McDonald et al. 2013). Worldwide many habitats are also increasingly disappearing due to the spread of settlements (Habel et al. 2013; Wilby and Perry 2006). Biodiversity has been shown to decrease in species richness and to become more homogeneous along a gradient from the countryside to urban areas (Sol et al. 2014; Wilby and Perry 2006). Cities contain a relatively high proportion of generalists, and specialists have experienced a dramatic decline (Clergeau et al. 2006; Devictor et al. 2007). Various strategies have been implemented to halt the loss of biodiversity in cities (Bonthoux et al. 2014; Davies et al. 2009; Hedblom and Söderström 2010). Important is to increase the area of urban forests and green spaces and establishing corridors (Beninde et al., 2015). However, guidelines are needed to optimize the effectiveness of this approach.

Urban forests and other green spaces such as parks provide multiple ecosystem services (Pearlmutter et al. 2017). Although biodiversity is decreasing due to urbanization, urban forests and other green spaces can be a stronghold for biodiversity in the city (Beninde et al. 2015; Croci et al. 2008; Zapata and Robledano 2014). However, due to the multifunctional character of the green spaces, different uses can also often conflict each other, e.g. recreation pressure vs. biodiversity, and therefore a strategy should be developed to optimize the different uses in urban forests and other green spaces. Since the evidence on the requirements of urban residents towards green space is piling up, lately accelerated by the COVID – 19 epidemic (Ugolini et al. 2020), the first step would therefore be to understand the requirements needed of biodiversity in the different types of green spaces.

In this study we used passerine birds as a model for biodiversity and propose requirements for the management of green spaces. The advantage of focusing on birds is that they are well known charismatic species that are important indicator species and play many roles in the ecosystems (Whelan et al. 2008). Furthermore, they are often umbrella species that provide a good indication of the richness of the biodiversity in certain area (Branton and Richardson 2011), and they serve as flagship species for communicating the importance of nature conservation to the general public. Several studies have already examined birds along an urbanization gradient (e.g. Lepczyk and Warren 2012; Marín-Gómez and MacGregor-Fors 2021; Marzluff 2001; Mbiba et al. 2021; McKinney 2008; Murgui and Hedblom 2017; Zuñiga-Palacios et al. 2021). These studies found that species richness, species homogenisation and specialist richness decrease towards the centre of cities and that parks and other green spaces are an important driver of higher species richness (White et al. 2009). However, few studies have investigated the influence of urban forests in South-eastern Europe and the factors that positively affect bird composition and species richness in urban green spaces.

The main aim of this study was to use an integrated approach to describe bird community in relation to landscape-wide differences in urban forests and other green spaces, such as parks, by the use of multiple community metrics in south-eastern European city. We investigated the factors influencing species richness, species dissimilarity and indicator species in urban green spaces. We therefore tested the following hypotheses: 1) larger urban forest fragments contain a larger number of forest birds since more niches are available, 2) suburban areas have a larger number of species relative to urban areas because there is more habitat for additional species and 3) small fragmented forest patches homogenize bird communities compared to larger forest patches because smaller patches are disproportionately affected by the urban area, and specialized forest birds are more prevalent in larger forest areas. On the basis of our results, we developed a strategy that would increase the diversity of birds and increase the stability of their populations in urban areas.

Materials and Methods

Area description

The study area is the City of Ljubljana, the capital of Slovenia (46°04′ N, 14°31′ E), with a population of almost 300,000 (Jazbinšek Seršen et al. 2014). The city is situated in the Ljubljana Basin, which is characterized by a continental climate (CfB according to the Köppen climate classification system) with well-defined seasons. Mean annual precipitation is 1363 mm, and mean annual air temperature is 10.9 °C (Slovenian Environmental Agency). The intrannual variability of precipitation is rather significant, with maximum precipitation in summer and fall (Zupančič 1995). In the south, the city borders the Ljubljana moor, while in the north it borders the Sava River. In the east and west, there are forested hills. Two large green patches of urban forests, Rožnik (372 ha) and Golovec (666 ha), penetrate the city, almost reaching the city centre from the east and west. Parks and small forest patches can be found all over the city. Almost half of the municipality is covered by forests. The urbanized part of the municipality has almost 8 % forest cover (Simončič et al. 2020), not taking into account numerous trees, tree lines and other groups of trees in the urban fabric. In the south of the city, there are eight forest remnants of floodplain forests containing typical tree species such as oak, ash and willow, while in peri-urban areas there are some large areas of floodplain forests (up to 173 ha). The hills have a large variety of tree species, with the main tree species being beech, oak, sweet chestnut, spruce and pine. The Sava River is flanked by lowland floodplain forest and large pine forests with occasional oak remnants surrounded by agricultural land (Vilhar et al. 2013). The main function of the forests in Ljubljana is recreation, water provision, air pollution reduction, noise reduction, carbon sequestration etc. but they are also used for wood production and nature conservation, particularly the larger forest areas. Parks, which make up the remainder of the green spaces, are scattered throughout the city. Most of the parks contain a mosaic of grasslands and trees. The largest park in Ljubljana is Tivoli (39 ha).

Sampling methodology

Birds were counted with the point count method proposed by Bibby et al. 2000 and according to the monitoring system for assessing the status of artificial and natural urban and peri-urban forests (Barbante et al. 2014) developed in the frame of the EMoNFUr LIFE+ project (LIFE+10 ENV/IT/000399). The main objective of the EMoNFUr project was to develop a monitoring system for assessing the status of artificial and natural urban and peri-urban forests, and to measure the adaptability of new lowland forests to climate change. The project aimed to provide parameters of ecological and environmental relevance, such as plant and animal biodiversity in lowland forests, carbon dioxide sequestration capacity and the ability to buffer air temperatures.

Bird sampling was conducted through 10-minute point counts in predetermined locations (Figure 1). The individuals of species were counted within a radius of 25 m. The 25-m radius was used because many forest fragments had a width of 50 m and we were sure that all species were detected in this area. The method used during the study had a smaller radius (25 m) than that normally used in point counts (50 m) (Bibby et al 2000). A radius of 25 m was chosen because the smallest green spaces had a diameter of 50 m. The problem with such a small diameter is that certain species are not included or are found in lower numbers. Birds which are rarer or have larger territories might be missed. However, this standardised method allows the possibility to compare between all the green spaces equally. Bird counts were conducted twice in 2012: the first in April and the second at the end of May/beginning of June (Bibby et al. 2000). The counts were only conducted when there was no wind or rain to avoid any detection problems. In total, 39 points were selected across Ljubljana. Locations were distributed as uniformly as possible across the city and included urban and peri-urban green spaces (resp. 25 and 14 locations), large and small green spaces (resp. 23 and 16 locations), and different types of green spaces (parks and forests) (6 locations in parks and 33 locations in forests). Urban forests were defined as larger patches of forest ecosystems in an urban landscape - within the city and its immediate surroundings. Parks on the other hand were defined as a (public) open green space with grass fields and individual trees, bushes and in some cases rich horticultural arrangements and blue infrastructure (water bodies) primarily intended for the citizens to restore their health and well-being on a daily basis. The type of urban area was defined based on whether it is located inside the motorway ring road around the city (urban area) or outside of it (peri-urban areas). Inside the ring, the urban area is more densely built up (18.5 % forest area inside the ring and 40 % outside the ring), and therefore the motorway ring is often used to delineate between Ljubljana's urban and peri-urban areas (Gojčič 2019). The area of the green spaces was measured via orthophoto. The patch size was divided into small and large patches (resp. < 9 ha and > 18 ha), because it is easier to determine the difference in species. The cut off was determined on basis of the average and there was gradually increase of patch size till 9 ha with exponential increase in patch size afterwards.

<u>Analysis</u>

For the analysis, the maximum number of individuals per species per the two counts were used. The number of species per location was the species richness, while the abundance was the number of individuals per location. This was done because it was expected that the same species would be sampled in both counts, as most of the species are territorial and therefore remain in the same area. Species that were not considered to breed in forests or parks, such as the barn swallow, were not taken into account in the analysis. The territorial species and the species which are known to breed in forests or parks were included. The proportion of the locations where the species occurred was calculated. Also, the influence of the different environmental variables (urban type, green space type and the area of the green space) on species composition was analysed.

To assess the influence of the environmental variables on species richness (number of species per location), a GLMM was used with a Poisson error structure. The dependent variable was the species richness. The independent variables were the type of urban area (urban area or peri-urban area), type of green space (park or forest) and the area of the green space patch. Patch identity and the observer were included into the model as random effects. A full model was prepared with all the variables. First the residuals of the full model were tested for spatial autocorrelation with the Moran test. Only for the species richness, spatial autocorrelation was observed in the residuals and a Moran's Eigenvector was included in the model (Dray et al. 2006). For the model selection, the Akaike Information Criterion (AIC) was used (Burnham and Anderson 2002). The model within 2 AIC units of the most explanatory model was chosen.

The change in species composition was analysed by the species dissimilarity, which was subdivided into species turnover and species nestedness. We prepared a data matrix with the rows showing the locations and the columns the species and the different explanatory variables. Species dissimilarity we defined as the difference in absence and presence of species between two locations. Species turnover is the difference in species between two different species assemblages. Species nestedness is a measure of the extent to which one location has a subgroup of bird species from another location. For the influence of the urban type, green space type and the green space size (difference between small and large patches) on species dissimilarity, species turnover and species nestedness (Baselga 2010; Baselga 2012), an NMDS and a permutational MANOVA analysis was done (Anderson 2001) with 999 permutations. For dissimilarity, the Jaccard index was used. The independent variable contained the species composition with species presence within a 25-m radius from the point count. The environmental variables were the same as those used in the GLMM analysis.

In the indicator analysis, the species which are indicative for certain explanatory variables. For this analysis we used the community data matrix and the explanatory factors. IndVal index is association between a species and site group. First the IndVal index is calculated for every site group and the group with the highest IndVal index is chosen. The relationship is tested with a permutation test (Dufrene and Legendre 1997). The indicator analysis was done with the IndVal method with 999 permutations. The method was used for every environmental variable separately. The classes for patch size were used because the method does only allow comparison between groups. All analyses were performed in R (R Core Team 2018) with the vegan (Oksanen et al. 2013), lme4 (Bates et al. 2014), indicspecies (De Caceres and Legendre 2009) and betapart (Baselga et al. 2013) packages.

Results

In total, 36 bird species were observed during the survey of the different types of urban forests and other green spaces in Ljubljana (Table 1). The three most abundant species were the European robin , Common blackbird and Eurasian blackcap. The species found in the highest proportion of locations were the European robin, Common blackbird, Great tit and Eurasian blackcap.

Factors affecting species richness and abundance

The abundance showed a decreasing trend with the area of the green space (z=-3.956, P<0.001) and parks (average= 6.5, SD=1.87) had a lower abundance than the forests (average=7.88, SE= 3.85) (z=-2.254, P=0.02) (Fig 1, Table 1). No spatial autocorrelation was observed in the residuals (Moran I statistic standard deviate = 0.267, P = 0.39). Bird species richness was affected by the size of the green space (Fig 2). For the species richness, there was spatial autocorrelation observed in the residuals (Moran I statistic standard deviate = 3.3372, P < 0.001). The model selection procedure showed that patch size, urbanization type and the green space type were out selected, indicating that they were not important variables influencing bird species richness (Fig 1, Table 2).

Factors affecting the change in species composition

In general, difference in species composition between parks and urban forests was not significant as shown by the Jaccard index (PERMANOVA: $F = 1.533$, $P = 0.068$) (Figure 2a; Table 3). Furthermore, the species composition was influenced by the area of the green space (Figure 2b, Table 3). The change in species turnover was also statistically significant affected by the area of the green space. The R^2 was low, which might be due to exclusion of other environmental variables from the analysis.

Indicator species

There were several indicator species observed for the different investigated green spaces (Table 4). In peri-urban areas, the blue tit was the most characteristic species, while in urban areas the hawfinch was more abundant. Regarding green space type, only parks had some species which were more indicative of parks, such as the domestic pigeon and black bird. There were no unique species only found within forest patches. The area of the green space was important for most species. The coal tit was most indicative of larger forest patches. The blackbird and nuthatch were more specialized in smaller forest patches.

Discussion

The results showed that the bird species richness and composition of birds in green spaces is influenced by the area of the green space. Abundance was negatively affected by green space area and type. There were fewer birds in parks than in forest. Green space area affected species turnover, while there were no differences between urban and peri-urban areas and green space type with respect to species composition. The species composition of the peri-urban areas was similar to that of the urban areas, which was unexpected. For the different environmental variables, different indicator species were identified.

The area of the green space affected most of the components of the bird species assemblage. Surprisingly, the smaller green spaces contained higher abundance than the larger green spaces and species richness was equal over the patch sizes. This is counterintuitive as larger species richness and abundance is expected in larger areas (Leveau et al. 2019); however, in this study we standardized the plots to a 25-m radius. This standardization made it possible to compare between the different locations. This result is probably due to greater habitat variability in the smaller patches which allows the coexistence of forest birds and bird species occurring in surrounding areas. The larger patches were mostly forest of the same type, and species and abundances were likely more spread out over the entire larger area. The indicator species were mainly typical forest species (Roberge and Angelstam 2006).

Surprisingly, the type of green space affected species abundance, but not species richness or species dissimilarity. The number of birds per location was lower in parks than in forests. Another study showed that the presence of forest in the green space increased the number of species (Dale 2018), but it was not directly compared to parks. The lack of difference in species richness was possibly due to the surroundings of the parks and the composition of trees in the forest. Many of the parks contain large trees with many species also including specialists like woodpeckers (Catalina-Allueva and Martín 2021); however, there are also meadows without birds. This makes a suitable environment for both forest species and open land species (Korányi et al. 2020; Oliver et al. 2011), although missing more specialized species, this accounts for the equal species richness between the two types of green spaces. Forests contain many habitat types that can sustain a larger abundance of birds. Also, the species composition between these two different green space types contained different species (Katoh and Matsuba 2021), which is logical, because species typical of more open areas, such as the serin and feral pigeon, were more prevalent in parks. Although urban areas have different habitats for birds (Korányi et al. 2020; Tryjanowski et al. 2017), difference between forests and parks was not well investigated.

The fact that there was no difference between the urban and peri-urban areas was probably due to how the areas were defined. One would expect more species to occur in the forest in the outskirts of the city or just outside the city. However, in the urban areas there are large patches of urban forests. The city area has many green spaces with many forested ridges reaching into the centre. Also, there are many natural forest remnants within the urban matrix of Ljubljana. As a result, many species occur here. Interestingly, the species assemblage of the peri-urban area was similar to that of the urban area. This is surprising given that for various bird groups there is a homogenization of generalists expected along an urban gradient towards more built-up areas (Devictor et al. 2007). However, for the green spaces in the City of Ljubljana this is not the case. In the peri-urban areas, the study focused mainly on forests since parks are not found there, while the urban areas contain parks and urban forests (Beninde et al. 2015). The urban forests were sufficiently large that the diversity of bird species was not reduced, while other species occurring in parks were added. The species that was mainly found in peri-urban areas was the blue tit. The species that was found to be indicative of urban areas was the hawfinch. This is probably because it is a typical breeding bird in deciduous forests, but also in parks and urban areas. In the area of Ljubljana, there is a large amount of deciduous forest, which is probably why this species is more prevalent there. The reason that the blue tit is indicative of peri-urban areas is more difficult to explain. More research is needed to ascertain why there was no obvious difference in bird species richness and composition between the urban and peri-urban areas.

<u>Lessons learned for urban green management planning</u>

The study provides several important indications on how bird diversity can be used as a proxy for biodiversity and reflect the habitat quality of urban green areas. The area of green spaces, the matrix surrounding them and type of green spaces are very important with regard to different aspects of urban green management planning.

The study touches a problem which is already heavily debated: the SLOSS debate, single large or several small reserves (Fahrig 2020; Fahrig et al. 2019; Fletcher et al. 2018; Godefroid and Koedam 2003; Lindenmayer et al. 2015; Niemelä 1999; Saunders et al. 1991; Shafer 1995; Tjørve 2010). For this study the question arises whether it would be better to have one large patch of forest or several smaller patches of forest creating a network across the city (Niemelä 1999). The advantage of one large forest is that species that need large continuous habitat could also survive in larger cities. The downside of large forest areas is that they would be difficult to create or preserve in many cities. However, certain parks could be transformed into more natural-like wooded areas in order to provide forested habitats for bird species specialized in larger wooded areas. Concerning bird diversity, an equal number of species per location was found in the larger patches compared to smaller patches. However, if all species for one patch were taken into account, the number of species would probably be higher. In the smaller forest patches, however, the species assemblage contains more species from habitats other than forests (Godefroid and Koedam 2003). Species specialized in forest habitats do not occur in smaller forest patches (Godefroid and Koedam 2003). If the smaller patches were placed in a network so that interpatch colonization would be possible, species could easily establish in non-colonized areas (Wang and Altermatt 2019). However Leveau showed that cities with small green areas have lower bird species richness (Leveau 2021). The main problem with this approach is that smaller forest patches are prone to disturbances of different kinds, such as garbage dumping, logging, invasive alien species and disturbance from the surrounding urban matrix. Therefore, it is not clear whether there should be only one large forest or many small forest patches. Probably the most useful compromise would be a combination of larger and smaller wooded patches so birds from larger forest patches could function as source populations for smaller forest patches (Lomolino 1994).

Another important factor which should be taken into account is the urban matrix around green spaces. Many studies of urbanization gradients show that there is a decline in species diversity and homogenization towards city centres (Meffert and Dziock 2013). In peri-urban areas, there are often many gardens or even larger forest patches that contain higher species diversity, while in the highly urbanized city centres, there is a much lower number of species due to the lack of proper habitat. The interaction between forest patches and the matrix goes both ways. Forest patches in highly urbanized areas are under a great deal of stress because of heat and pollution, which affect the habitat quality for breeding birds. Additionally, colonization could be hindered because of the lack of corridors. However, our results show that this is not the case in Ljubljana, as the heavily urbanized centre does not contain many parks or forest. In peri-urban areas the number of gardens is generally very high, which provides habitats for certain species. In this case the forest patches would be a source population for the gardens. However, these forest patches can be used for foraging habitat. In any case, these forest fragments will have a strong impact on the surrounding urbanized area.

Another question that arises is whether establishing parks is sufficient for enriching bird species diversity. Our results showed that there was a difference between forest patches and parks. Parks contained species that forests did not have and vice versa. Parks also had species which preferred open land, such as the serin, but this species occurs in many parts of Ljubljana and does not necessarily depend on parks. Other studies showed that parks had a higher bird species richness than compared to garden allotments (Korányi et al. 2020), as shown this does not necessarily extent to forests. Parks with old trees and undergrowth could equalize the number of species (Canedoli et al. 2018) compared to forests as shown in our study, but not the abundance of species. It should be noted, however, that without forest patches, forest bird species would be absent and consequently general bird species richness much lower.

Conclusions

Our study found that different characteristics of urban green spaces affect bird species diversity and assemblage. However, the differences in bird communities are not straightforward and are not only dependent on diversity, but also on differences in bird species composition. Under the EMoNFUr project, we established a monitoring system for assessing the status of artificial and natural urban and peri-urban forests, focusing on plant and animal biodiversity, in which we prepared a baseline study. However, Southeastern European cities such as Ljubljana are dealing with the pressure of climate change, urbanization (Nastran et al. 2019; Ogrin and Krevs 2015), and invasive alien species and therefore sound planning and the management of urban green spaces and corridors will be necessary to mitigate the effects (Nastran and Regina 2016). Long-term monitoring of bird populations is needed for a better understanding of the influence of urban green spaces on bird assemblages in a changing world. Bird monitoring could serve as a proxy for biodiversity and support developing strategies for optimized management of urban forests and other green spaces.

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Tables

Table 1: Abundance of the bird species observed within a 25-m radius from the centre of the point count.

Species name	**Scientific name**	**within a 25-m radius**	
		total number of birds	**proportion of locations present**
Long-tailed tit	*Aegithalos caudatus*	4	0.10
European goldfinch	*Carduelis carduelis*	3	0.08
European greenfinch	*Carduelis chloris*	5	0.10
Eurasian treecreeper	*Certhia familiaris*	3	0.08
Hawfinch	*Coccothraustes coccothraustes*	11	0.21
Domestic pigeon	*Columba livia f. domestica*	2	0.05
Common wood pigeon	*Columba palumbus*	5	0.13
Hooded crow	*Corvus corone cornix*	20	0.15
Eurasian blue tit	*Cyanistes caeruleus*	15	0.38
Great spotted woodpecker	*Dendrocopos major*	6	0.15
Yellowhammer	*Emberiza citrinella*	1	0.03
European robin	*Erithacus rubecula*	30	0.62
Common chaffinch	*Fringilla coelebs*	19	0.46
Eurasian jay	*Garrulus glandarius*	9	0.23
Common nightingale	*Luscinia megarhynchos*	1	0.03
Spotted flycatcher	*Muscicapa striata*	2	0.05
Eurasian golden oriole	*Oriolus oriolus*	2	0.05
European crested tit	*Parus cristatus*	1	0.03
Great tit	*Parus major*	24	0.56
House sparrow	*Passer domesticus*	7	0.08
Eurasian tree sparrow	*Passer montanus*	2	0.03
Coal tit	*Periparus ater*	13	0.31
Common chiffchaff	*Phylloscopus collybita*	8	0.21
Grey-headed woodpecker	*Picus canus*	1	0.03
European green woodpecker	*Picus viridis*	1	0.03
Marsh tit	*Poecile palustris*	7	0.15
Eurasian bullfinch	*Pyrrhula pyrrhula*	1	0.03
Goldcrest	*Regulus regulus*	6	0.15
European serin	*Serinus serinus*	1	0.03
Eurasian nuthatch	*Sitta europaea*	13	0.33
Common starling	*Sturnus vulgaris*	14	0.21
Eurasian blackcap	*Sylvia atricapilla*	26	0.56
Eurasian wren	*Troglodytes troglodytes*	4	0.10
Common blackbird	*Turdus merula*	26	0.62
Song thrush	*Turdus philomelos*	6	0.13
Mistle thrush	*Turdus viscivorus*	1	0.03

Table 2: model selection table including all different models for bird abundance and species richness with the independent variable. The models are selected on basis of the AICc and the weight.

model	Intercept	forest type	log(1+size)	type	Moran's eigenvector	df	logLik	AICc	delta	weight
abundance	3.399		-0.1059	+		5	-92.291	196.4	0	0.58
	3.099		-0.08717			4	-94.832	198.8	2.44	0.171
	3.449	+	-0.1078	+		6	-92.239	199.1	2.7	0.15
	3.262	+	-0.094			5	-94.511	200.8	4.44	0.063
	2.022					3	-98.384	203.5	7.05	0.017
	2.104			+		4	-97.652	204.5	8.08	0.01
	1.915	+				4	-98.233	205.6	9.24	0.006
	2.027	+		+		5	-97.388	206.6	10.19	0.004
species richness	1.854				-1.133	4	-80.122	169.4	0	0.392
	2.113		-0.02062		-1.019	5	-79.833	171.5	2.06	0.14
	1.838			+	-1.197	5	-79.997	171.8	2.39	0.119
	1.888	+			-1.127	5	-80.033	171.9	2.46	0.114
	2.194	+	-0.02339		-1	6	-79.676	174	4.56	0.04
	1.832					3	-83.775	174.2	4.81	0.035
	1.885	+		+	-1.215	6	-79.812	174.2	4.83	0.035
	2.076		-0.01821	+	-1.058	6	-79.818	174.3	4.84	0.035
	2.407		-0.04305			4	-82.686	174.5	5.13	0.03
	2.539		-0.05147	+		5	-82.235	176.3	6.87	0.013
	2.51	+	-0.04639			5	-82.43	176.7	7.26	0.01
	1.827			+		4	-83.773	176.7	7.3	0.01
	1.826	+				4	-83.774	176.7	7.3	0.01
	2.136	+	-0.01906	+	-1.075	7	-79.617	176.8	7.43	0.01
	2.587	+	-0.05242	+		6	-82.132	178.9	9.47	0.003
	1.822	+		+		5	-83.773	179.4	9.94	0.003

Table 3: Species dissimilarity for birds in green spaces with respect to different environmental variables using nestedness, species turnover and the Jaccard index.

	Species turnover			Species nestedness			Jaccard index		
	F	R^2	P	F	R^2	P	F	R^2	P
Green space area	2.989	0.072	**0.006**	-3.512	-0.106	0.854	2.404	0.060	**0.002**
Green space type	1.873	0.045	0.061	0.359	0.011	0.544	1.533	0.038	0.068
Urban type	1.591	0.038	0.119	1.150	0.034	0.420	1.340	0.033	0.154
Residuals		0.844			1.061			0.869	
Total		1			1			1	

Table 4: Bird species that are indicative of different types of green spaces in urban areas. , we indicate the group that obtained the highest correlation, the value of the correlation (r_{pb}), and the statistical significance of the association (p-value)

variables	group	species	r_{pb}	P
Urban type	peri-urban	Blue tit	0.684	0.026
	urban	Hawfinch	0.566	0.034
Green space type	park	domestic pigeon	0.577	0.014
		Common blackbird	0.804	0.049
Green space area	large	Coal tit	0.650	0.015
	small	Common blackbird	0.765	0.005
		Eurasian nuthatch	0.655	0.022

Figures

Figure 1: map with the different locations of the point counts in Ljubljana and surrounding.

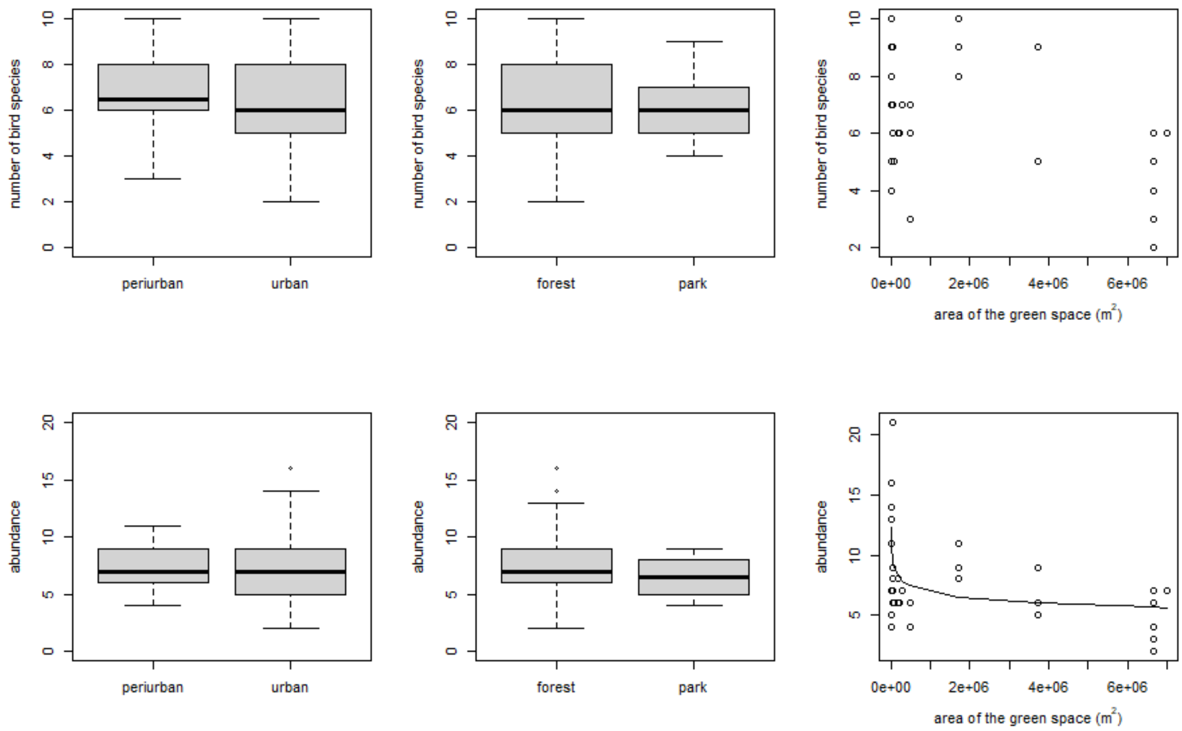

Figure 2: Factors influencing bird species richness and abundance in urban green spaces: a) urban type (periurban vs. urban); b) green space type (forest vs. park); c) the area of the green space.

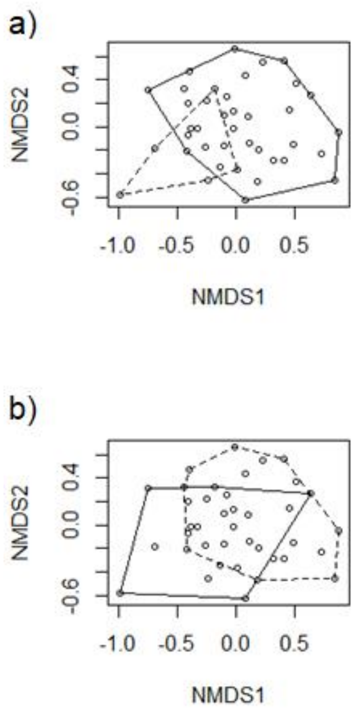

Figure 3: Factors influencing bird composition in urban forests and other green areas: a) difference between forests (continuous line) and parks (stippled line) and b) the area of the green space – small (continuous line) or large (stippled line)