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How do habitat variability and management regime shape the spatial heterogeneity of birds within a large Mediterranean urban park?

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Abstract

Large urban parks can support a diverse bird community. However, the effects of variability among habitats and of park management on bird assemblages are poorly understood. We studied bird communities within the Yarkon Park, Tel Aviv, the largest urban park in Israel. We examined species richness, abundance and community composition across 20 locations that differ in levels of park management to identify habitat variables responsible for variation in bird richness and composition. Of 91 recorded bird species, 13 were aliens (14%), 4 were urban exploiters (4%), 54 were urban adapters (60%) and 20 were migrants (22%). Management had a significant effect on native bird richness and bird community structure varied among areas with different management regimes. Species richness of all the above species' groups was lowest in intensively managed areas. Areas with intermediate levels of management had higher or equal richness compared to unmanaged areas. The majority of urban exploiters were found at all locations within the park reaching their highest abundances in intensively managed areas. Species richness of alien birds did not vary across levels of management. Bird species richness was negatively associated with lawn cover and with distance from nearest water source and was positively associated with the number of woody plant species. We suggest that urban parks should be designed such that the heterogeneity of native vegetation is preserved, if we aim to maintain native bird species diversity and minimize urban exploiter and alien species. When lightly managed or unmanaged, urban parks can retain large remnants of sub-natural habitats and can serve as important contributors to the conservation of native biodiversity within a large urban metropolis.

Keywords: Urban ecology; Urban parks; Urban exploiters; Alien species; Bird communities; Israel

1. Introduction

Urban population growth that contributes to the conversion of natural ecosystems into agricultural and urbanized areas (Vitousek and Mooney, 1997) leads to the loss of natural habitat and native biodiversity (Czech et al., 2000; McKinney, 2002). However, as the proportion of urban residents increases, urban nature plays an increasingly crucial role in the standard of living within cities (Miller, 2005) and in shaping people's approach towards natural ecosystems and conservation (Tilghman, 1987; Savard et al., 2000; Clergeau et al., 2001a). Reflecting a new interest in urban landscapes by conservation biologists (Collins et al., 2000; Marzluff et al., 2001; Miller and Hobbs, 2002), much recent research has examined changes in biodiversity across rural-urban gradients (e.g. Blair, 1996; Savard et al., 2000; Fernandez-Juricic and Jokimäki, 2001; Melles et al., 2003; Lim and Sodhi, 2004; Bino et al., in press).

Urban parks are usually the most heterogeneous green spaces in the urban ecosystem and show high vegetation diversity (Gilbert, 1989; Hadidian et al., 1997; Rottenborn, 1999), making them an interesting and important subject of research within the urban ecosystem. The majority of studies conducted on urban parks found park area to be an important variable in explaining bird diversity and richness (Tilghman, 1987; Jokimäki, 1999; Fernandez-Juricic, 2000; Cornelis and Hermy, 2004). Many studies view the park as a homogenous entity (Cornelis and Hermy, 2004; Fernandez-Juricic, 2004), but parks of larger areas are apt to be composed of several

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different habitat types (Solecki and Welch, 1995; Hermy and Cornelis, 2000), often deliberately planned for multiple uses such as sports, recreation areas and more sub-natural areas for walking and touring. Effects of urbanization on bird communities (Emlen, 1974; Beissinger and Osborne, 1982; Marzluff, 2001; Chace and Walsh, 2004) within larger parks may vary depending on habitat factors, home range sizes and interactions between species. Such variation and the underlying processes contributing to it may have important implications for the design of parks that aims to maintain native biodiversity within an urban environment.

Previous research has shown a positive relationship between the overall biodiversity in parks and the number of sub-habitats in the park (Hermy and Cornelis, 2000). However, there has been little effort to examine variation in bird community structure over small local spatial scales within a park. A potentially important factor influencing the diversity of avian communities in parks is the level or intensity of park management (Jokimäki, 1999; Lim and Sodhi, 2004). This can range from intensively managed to unmanaged areas within the park. This study had two main objectives. First, we aimed to investigate the variation in bird communities among different levels of management within the park. Compared to areas with little or no management, i.e. more sub-natural areas, those areas with intensive management should have impoverished bird communities (Connell, 1978) dominated by species able to exploit urban habitats (urban exploiters, see Blair, 1996; Kark et al., 2007).

Second, we investigated to what extent plant community characteristics produced by varying park management regimes explain variation in bird community structure within a large park. Bird species diversity in urban landscapes is associated with habitat complexity (Lancaster and Rees, 1979; Tilghman, 1987; Clergeau et al., 1998; Fernandez-Juricic, 2000; Hermy and Cornelis, 2000; Cornelis and Hermy, 2004), and bird community patterns should be explained largely by differences in the structural diversity and species richness of the associated plant communities (Clergeau et al., 2001b; Jokimäki and Kaisanlahti-Jokimäki, 2003). In particular, we expected bird species richness to be positively associated with woody species richness and cover and negatively associated with lawn cover based on previous work in urban environments (Beissinger and Osborne, 1982; Mills et al., 1989; Germaine et al., 1998; White et al., 2005).

2. Methods

2.1. Study area and site selection

We investigated variation in bird communities within the largest urban park in Israel. Located on the passage between Europe, Asia and Africa, Israel serves as an important bird migration route (Shirihai, 1996). This location and the variety of zoogeographical regions within the small country (~22,000 km^2) create a particular mosaic of bird species (Yom-Tov, 1988). The country has high bird richness with a total of approximately 520 species observed throughout the area (Shirihai, 1996).

The study was conducted in the city of Tel Aviv, Israel (32°02′ N, 34°47′ E). Tel Aviv and the cities that encircle it create the biggest metropolis in Israel (henceforth known as Tel Aviv metropolis). The Tel Aviv metropolis is stretched next to the Eastern Mediterranean Sea on a low altitude plateau (coastal plain). This metropolis, covering about 50.6 km^2 and containing 2.99 million people, is one of the densest urban areas in the world with an average human population density of 7170 people per km^2 in the urban core (Central Bureau of Statistics, 2005, http://www1.cbs.gov.il, accessed February 25, 2007).

The study was carried out in the Yarkon Park, the largest urban park in Israel (named after the main river that crosses the park). The Yarkon Park, with an area of 262 ha, was established in 1973 and forms part of a green narrow corridor stretching from east to west, from the Judean Mountains to the seashore of Tel Aviv. We focused on the eastern side of the park, an area of 181 ha composed of several different habitats: open lawns, botanical gardens, ponds, a small agricultural farm, several small groves of trees which vary in species composition, tree and lawn cover, and small artificial ponds. The Yarkon river flows through the centre of the park and is bordered by Eucalyptus trees (*Eucalyptus* sp.) and *Phragmites* sp. creating a unique ecosystem.

We visually distinguished between four management regimes in the park based on the level of landscape management, human activity and apparent vegetation characteristics (Table 1, Fig. 1). These included: intensively managed, moderately managed, lightly managed and unmanaged areas. Intensively managed areas are highly modified habitats with low habitat structure comprised of mostly lawn and uniformly planted exotic gar-

Table 1
Description of the management regimes, number of sampling points in each regime and habitat in Yarkon Park, Tel Aviv

Management regime	Number of points	Management intensity[a]	Habitat description	Plant understory	Irrigation	Human activity[b]
Intensive	6	++++	Open grass lawn, scattered trees	Mainly exotic	Yes	High
Moderate	4	+++	Gardens, orchards, agricultural farm	Partly exotic	Yes	Moderate
Light	5	++	Syrian Ash, Pine, Tamarisk coppices, fallow fields with annuals	Mainly native	No	Low
Unmanaged	5	+	Eucalyptus groves, fallow fields, annual ground cover	Mainly native	No	Low

[a] Landscaping maintenance operations such as grass cutting, pruning, fertilizing levels range from high (++++) to low (+).
[b] As estimated by the quantity and development of trails (paved versus unpaved), number of people observed eating or playing within a 100-meter radius during five sampling minutes in each location (means: 5 for low, 17 for moderate and 37 for high) and the number of garbage bins (relative rankings of high, moderate, low).

Fig. 1. Photos showing representative areas of different management regimes in Yarkon Park in Tel Aviv: (a) intensively managed, (b) moderately managed, (c) lightly managed, (d) unmanaged.

den trees, and are associated with high human activity at sports and picnic areas with several developed trails, and many people and garbage bins. Moderately managed areas are dominated by native trees and shrubs as well as annual cover. They are associated with moderate levels of human activity, i.e. few developed trails, garbage bins and people present. Lightly managed areas are those with little management except that understory annuals are cut back each spring. Unmanaged areas are similar to lightly managed areas, but with no management at all (i.e. no cutting of annuals). The two latter management regimes are characterized by lower human use and activity, i.e. only undeveloped trails with low numbers of people present.

Overall, 21 locations representing the various environments of the park were selected for surveys with one location later excluded (see Section 2.3). Identification of these locations in the park was performed in two stages; initially, we analysed an aerial ortho-photo of the park to identify possible locations. Next, we surveyed the park and selected locations within the four management regimes mentioned above (Table 1) ensuring that there was no spatial overlap between sampling points. The centres of the sampling points were located at least 200 m apart and at least 150 m from the park edge.

2.2. Bird surveys

We carried out bird point count surveys following Buckland et al. (1993, 2004). We used fixed 100 m radius circular plots. Before beginning each survey, we waited for five minutes at the point as a “calming period”. Following this, we sampled all the birds seen or heard for 10 min. For each observation we recorded species, number of individuals, and the distance from the observer using small flags positioned every 10 m from the centre point and a rangefinder (Leica Rangemaster LRF 900). Our survey assembled observations from two phases: intensive surveys conducted several times on weekdays between August 3 and September 14, 2003 by three observers, continued with longer term surveys conducted several times from April 2004 to January 2006 by 15 skilled birders. Each point was sampled from 12 to 23 times, with surveys at all locations being distributed approximately equally in number between the two survey phases. Census location and times of the different observers were varied to avoid observer bias, with surveys done in teams of pairs, including one qualified birder and one notekeeper. The points in the first phase in 2003 were censused mornings 3 h after sunrise and evenings three hours before dark, coinciding with peak bird activity. Analysis of this data revealed that more birds are observed during morning counts ($t = 2.448$, d.f. = 42, $P = 0.019$), so the second phase surveys were conducted during the first three hours after sunrise. Altogether, data included in the analyses were based on 490 bird surveys throughout the study period.

To further assess the independence of sampling points over this small spatial scale, we tested the relationship between community similarity and distance between all pairs of points. Community similarity was not significantly related to distance between points ($r_s = 0.132$, d.f. = 190, $P = 0.069$) suggesting that bird communities at a given point are not strongly influenced by other points nearby.

2.3. Bird groups

Blair (1996) divided the urban bird community into three groups regarding their relation to the urban ecosystem: urban exploiters, suburban adapters and urban-avoiders. Although we used Blair’s (1996) terminology as a basis, we modified the categorization of “suburban adapters” to “urban adapters” following Kark et al. (2007) and separated alien species into an additional group. We defined five bird groups to characterize the Yarkon Park bird community. Urban exploiters were defined as those native species that adapt to exploit the urban environment, often reaching their greatest densities in highly urbanized areas (Kark et al., 2007). Alien species are species that were deliberately or accidentally set free in a location where they are not native (Richardson et al., 2000). While it is possible that an alien species could also be an urban exploiter, e.g. Rock Dove in North America, this was not the case at present in this study area (Kark et al., 2007). Urban adapters are native species that can exploit some of the urban resources such as ornamental vegetation typical of intermediate levels of urbanization (see Kark et al., 2007). Migrating species are native species that pass through the park during the migration season. At each site, locally rare species were defined as those species that were seen in less than 5% of the total surveys. We based our classification on data gathered from the published literature (Shirihai, 1996; Kark et al., 2007) supplemented by expert opinion from experienced bird watchers (Table 2).

2.4. Sampling effort

Sampling effort was estimated for each of the 21 locations using a sample-based rarefaction curve (Colwell et al., 2004). The expected species accumulation curve for each location was calculated using the Sobs (Mao Tau) estimator in the software EstimateS 7.5 (Colwell, 2005). We built the accumulation curves based on the accumulation of species per sighting (a sighting indicated either a single bird or a flock of birds). This analysis was first carried out for all species, excluding migrants (see below). For each of the 21 sites we then calculated the minimal slope reached by the accumulation curve. We found that of the 21 sites, 20 sites reached saturation with a minimal slope lower or equal to 0.04. The one site with insufficient sampling was subsequently excluded from the analyses. In order to avoid a survey effort bias we standardized the sampled richness for all the sites to the richness estimated at the minimal slope. Species richness was then estimated in a similar way for each bird group: Urban adapters (min slope 0.05), urban exploiters (min slope 0.02) and alien species (min slope 0.05). Migrants, for which the sampling design was likely insufficient, had a high minimal slope (0.55) and were therefore excluded from all further analyses of species richness.

2.5. Environmental and vegetation factors

For the area around each of the 20 sampling points, plant species richness was measured, as well as percentage cover of all (total) plants, woody plants, annual plants, and lawn. During spring 2004, we established four 100 m transects starting from each point (east–west, north–south, northeast–southwest, southeast–northwest). We measured the length covered by the four vegetation cover variables as specified above using a meter tape and calculated percentage cover as the proportion covered by the vegetation variable summed over the total 400 m distance (following Bino et al., in press). Because we recorded both the ground and canopy cover, total cover values greater than 100% could be attained. Plant species richness was sampled by Avinoam Danin, a well-known botanist specializing in Mediterranean plants, counting all the woody species in a 50 m radius from the point.

We calculated three habitat parameters as follows using the Geographical Information System ArcGIS 9.0 (ESRI Institute, 2004). We created a layer containing the points, and another digitized layer of all park and trail borders. We measured the distance from each point to the closest permanent water source (including pond, lake or river), distance to the nearest walking trail and to the nearest park border. Distance from trail and park border are two parameters that are indicative of anthropogenic activity, with human activity increasing close to trails and towards the border of the park (Orchan, 2007).

2.6. Data analyses

For each point, we calculated bird species richness and abundance as the number of species or individuals , respectively, observed averaged over all survey periods. We compared species richness and abundances across management regimes for all bird species combined, species groups (see Section 2.4), and the number of locally rare species using a one-way ANOVA and post-hoc Tukey comparisons. We used ANOSIM (analysis of similarity), a randomization program in Primer 5.1.2 (Primer-E Ltd., 2000, http://www.primer-e.com/), to compare community composition across management regimes with 999 iterations. Similarity was calculated for abundance data using the Bray Curtis similarity measure. We used the SIMPER procedure in Primer to identify those species contributing most to dissimilarity between management regimes.

We compared means of several vegetation variables across management regimes using a one-way ANOVA and post-hoc Tukey comparisons. Assumptions of normality and equal variance of the data for both bird and vegetation analyses were assessed using the Shapiro-Wilks and the Levene statistics, respectively (Zar, 1999). Where assumptions of equal variance or normality were not met, we log transformed the data or used the analogous non-parametric Kruskal–Wallis and multiple comparisons tests (Zar, 1999). We compared habitat associations between selected vegetation variables and total bird species and species-groups with multiple linear regression using SPSS 14.0 (2005). The variables were examined for multicollinearity and variables showing significant collinearity from the model were removed. The significance level for results was set at 0.05.

3. Results

3.1. Bird community composition in Yarkon Park

Throughout the study, we observed 108 bird species in the Yarkon Park. During point counts, we recorded 91 bird species belonging to 33 families (Table 2), with another 17 species observed between surveys. Of the 91 species, 13 were alien species (14%), four were urban exploiters (4%), 54 were urban adapters (60%) and 20 were migrants (22%).

Table 2
Classification of bird species and mean abundance (±S.E.) across all surveys per point count within each management regime in Yarkon Park, Israel in descending order of overall occurrence across sites

Common name	Latin name	Urban association	Intensive ($n=6$)	Moderate ($n=4$)	Light ($n=5$)	Unmanaged ($n=5$)	Incidence (% sites)
Common Myna	*Acridotheres tristis*	Alien	5.90 (1.27)	5.09 (2.24)	1.58 (0.54)	0.74 (0.43)	100
Rock Pigeon	*Columba livia*	Urban exploiter	22.33 (14.02)	1.44 (0.68)	1.14 (0.62)	0.77 (0.25)	100
Hooded Crow	*Corvus corone cornix*	Urban exploiter	12.57 (4.51)	4.90 (1.15)	2.44 (0.56)	2.57 (0.97)	100
House Sparrow	*Passer domesticus*	Urban exploiter	6.25 (1.54)	3.90 (0.67)	3.76 (2.29)	5.15 (1.30)	100
Rose-ringed Parakeet	*Psittacula krameri*	Alien	1.60 (0.56)	2.32 (0.80)	1.84 (0.43)	3.44 (1.80)	100
Spur-winged Lapwing	*Vanellus spinosus*	Urban adapter	1.59 (0.57)	4.08 (1.59)	1.79 (0.56)	0.71 (0.47)	100
White-throated Kingfisher	*Halcyon smyrnensis*	Urban adapter	0.27 (0.08)	0.53 (0.21)	0.22 (0.07)	0.45 (0.12)	95
White Wagtail	*Motacilla alba*	Urban adapter	1.10 (0.23)	0.95 (0.24)	0.24 (0.09)	0.16 (0.07)	95
White-spectacled Bulbul	*Pycnonotus xanthopygos*	Urban adapter	1.12 (0.46)	2.49 (1.40)	3.61 (1.25)	4.28 (1.05)	95
Eurasian Collared Dove	*Streptopelia decaocto*	Urban adapter	0.48 (0.24)	0.69 (0.18)	1.23 (0.46)	0.66 (0.17)	95
Laughing Dove	*Streptopelia senegalensis*	Alien	0.41 (0.27)	0.73 (0.21)	0.39 (0.13)	0.39 (0.12)	95
European Turtle Dove	*Streptopelia turtur*	Urban adapter	0.16 (0.02)	0.23 (0.13)	0.37 (0.10)	0.40 (0.11)	95
Syrian Woodpecker	*Dendrocopos syriacus*	Urban adapter	0.08 (0.05)	0.25 (0.00)	0.50 (0.08)	0.19 (0.03)	90
Graceful Prinia	*Prinia gracilis*	Urban adapter	0.23 (0.09)	1.42 (0.60)	1.33 (0.20)	2.30 (0.50)	90
Eurasian Blackbird	*Turdus merula*	Urban adapter	0.46 (0.23)	0.51 (0.24)	0.39 (0.11)	0.36 (0.18)	90
Cattle Egret	*Bubulcus ibis*	Urban adapter	4.05 (2.17)	0.99 (0.34)	0.18 (0.04)	0.12 (0.10)	85
Great Tit	*Parus major*	Urban adapter	0.16 (0.09)	0.18 (0.07)	0.34 (0.12)	0.35 (0.07)	85
Eurasian Hoopoe	*Upupa epops*	Urban adapter	0.61 (0.19)	0.23 (0.07)	0.23 (0.12)	0.20 (0.07)	85
European Greenfinch	*Carduelis chloris*	Urban adapter	0.17 (0.07)	0.30 (0.13)	0.41 (0.14)	0.80 (0.44)	80
Eurasian Jay	*Garrulus glandarius*	Urban adapter	0.03 (0.02)	0.38 (0.09)	0.44 (0.14)	0.25 (0.09)	80
Monk Parakeet	*Myiopsitta monachus*	Alien	1.31 (0.46)	3.05 (1.09)	3.84 (1.34)	0.94 (0.74)	80
Palestine Sunbird	*Nectarinia osea*	Urban adapter	0.14 (0.09)	0.59 (0.20)	0.46 (0.14)	0.56 (0.09)	80
Eurasian Jackdaw	*Corvus monedula*	Urban adapter	2.37 (1.63)	0.61 (0.10)	0.68 (0.44)	0.07 (0.03)	75
Barn Swallow	*Hirundo rustica*	Urban adapter	1.19 (0.53)	0.66 (0.45)	0.39 (0.14)	0.09 (0.07)	75
European Goldfinch	*Carduelis carduelis*	Urban adapter	0.01 (0.01)	0.12 (0.06)	0.31 (0.06)	0.60 (0.42)	70
Willow Warbler	*Phylloscopus trochilus*	Migrant	0.04 (0.02)	0.17 (0.10)	1.05 (0.66)	0.09 (0.02)	70
Vinous-breasted Starling	*Sturnus burmannicus*	Alien	0.06 (0.03)	0.88 (0.14)	1.45 (0.59)	0.02 (0.01)	70
Common Swift	*Apus apus*	Urban exploiter	0.35 (0.23)	0.82 (0.30)	0.16 (0.15)	0.25 (0.15)	60
Pied Kingfisher	*Ceryle rudis*	Urban adapter	0.40 (0.28)	0.24 (0.14)	0.61 (0.54)	0.83 (0.63)	60
Chaffinch	*Fringilla coelebs*	Urban adapter	0.02 (0.02)	0.30 (0.13)	0.32 (0.18)	0.15 (0.10)	55
Masked Shrike	*Lanius nubicus*	Migrant	0.06 (0.03)	0.28 (0.10)	0.26 (0.11)	0.02 (0.02)	55
Common Kestrel	*Falco tinnunculus*	Urban adapter	0.18 (0.09)	0.08 (0.03)	0.03 (0.03)	0.03 (0.02)	50
Spotted Flycatcher	*Muscicapa striata*	Urban adapter	0.00 (0.00)	0.10 (0.02)	0.09 (0.04)	0.04 (0.03)	50
Common Chiffchaff	*Phylloscopus collybita*	Urban adapter	0.01 (0.01)	0.14 (0.07)	0.18 (0.10)	0.15 (0.07)	50
Blackcap	*Sylvia atricapilla*	Migrant	0.01 (0.01)	0.08 (0.05)	0.11 (0.08)	0.09 (0.05)	50
Eurasian Hobby	*Falco subbuteo*	Urban adapter	0.04 (0.03)	0.06 (0.03)	0.03 (0.01)	0.02 (0.01)	45
Little Egret	*Egretta garzetta*	Urban adapter	0.22 (0.18)	0.03 (0.03)	0.09 (0.09)	0.21 (0.18)	40
Olivaceous Warbler	*Hippolais pallida*	Migrant	0.02 (0.01)	0.04 (0.02)	0.02 (0.01)	0.01 (0.01)	40
Black-crowned Night-Heron	*Nycticorax nycticorax*	Urban adapter	0.21 (0.13)	0.09 (0.07)	0.02 (0.02)	0.31 (0.22)	40
Common Kingfisher	*Alcedo atthis*	Urban adapter	0.13 (0.12)	0.06 (0.06)	0.01 (0.01)	0.20 (0.10)	35
Mallard	*Anas platyrhynchos*	Urban adapter	1.79 (1.79)	0.14 (0.14)	0.05 (0.04)	0.80 (0.62)	35
European Robin	*Erithacus rubecula*	Urban adapter	0.03 (0.03)	0.02 (0.02)	0.04 (0.03)	0.03 (0.01)	35
Grey Heron	*Ardea cinerea*	Urban adapter	0.14 (0.11)	0.01 (0.01)	0.04 (0.03)	0.05 (0.05)	30
Chukar	*Alectoris chukar*	Urban adapter	0.00 (0.00)	0.91 (0.87)	0.49 (0.49)	0.29 (0.27)	25
Egyptian Goose	*Alopochen aegyptiacus*	Alien	0.08 (0.06)	0.01 (0.01)	0.00 (0.00)	0.15 (0.12)	25
Armenian Gull	*Larus armenicus*	Urban adapter	0.15 (0.14)	0.29 (0.27)	0.00 (0.00)	0.01 (0.01)	25
Common Moorhen	*Gallinula chloropus*	Urban adapter	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	0.28 (0.13)	20
Red-backed Shrike	*Lanius collurio*	Migrant	0.00 (0.00)	0.02 (0.02)	0.02 (0.02)	0.05 (0.03)	20
Common Black-headed Gull	*Larus ridibundus*	Urban adapter	0.31 (0.31)	0.11 (0.11)	0.06 (0.05)	0.00 (0.00)	20
European Bee-eater	*Merops apiaster*	Urban adapter	0.00 (0.00)	0.00 (0.00)	0.03 (0.03)	0.31 (0.19)	20
Great Cormorant	*Phalacrocorax carbo*	Urban adapter	0.22 (0.22)	0.08 (0.08)	0.01 (0.01)	0.11 (0.11)	20
Glossy Ibis	*Plegadis falcinellus*	Urban adapter	0.03 (0.02)	0.04 (0.03)	0.00 (0.00)	0.00 (0.00)	20
Common Starling	*Sturnus vulgaris*	Urban adapter	0.00 (0.00)	0.02 (0.02)	0.26 (0.26)	0.14 (0.09)	20
Lesser Whitethroat	*Sylvia curruca*	Migrant	0.01 (0.01)	0.02 (0.02)	0.01 (0.01)	0.01 (0.01)	20
Eurasian Sparrowhawk	*Accipiter nisus*	Urban adapter	0.00 (0.00)	0.00 (0.00)	0.03 (0.01)	0.00 (0.00)	15
Eurasian Thick-knee	*Burhinus oedicnemus*	Urban adapter	0.01 (0.01)	0.06 (0.06)	0.01 (0.01)	0.00 (0.00)	15
Ortolan Bunting	*Emberiza hortulana*	Migrant	0.00 (0.00)	0.10 (0.08)	0.00 (0.00)	0.01 (0.01)	15
Lesser Grey Shrike	*Lanius minor*	Migrant	0.00 (0.00)	0.03 (0.02)	0.00 (0.00)	0.01 (0.01)	15
Common Stonechat	*Saxicola torquata*	Urban adapter	0.00 (0.00)	0.17 (0.17)	0.00 (0.00)	0.15 (0.10)	15
Black-collared Starling	*Sturnus nigricollis*	Alien	0.11 (0.11)	0.02 (0.02)	0.02 (0.02)	0.00 (0.00)	15
Sardinian Warbler	*Sylvia melanocephala*	Urban adapter	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	0.07 (0.04)	15
Song Thrush	*Turdus philomelos*	Urban adapter	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	0.02 (0.01)	15

Table 2 (*Continued*)

Common name	Latin name	Urban association	Intensive (n = 6)	Moderate (n = 4)	Light (n = 5)	Unmanaged (n = 5)	Incidence (% sites)
Tree Pipit	*Anthus trivialis*	Migrant	0.00 (0.00)	0.00 (0.00)	0.04 (0.04)	0.04 (0.04)	10
Great Egret	*Casmerodius alba*	Urban adapter	0.00 (0.00)	0.03 (0.03)	0.01 (0.01)	0.00 (0.00)	10
Muscovy Duck	*Cairina moschata*	Alien	0.95 (0.95)	0.00 (0.00)	0.00 (0.00)	0.03 (0.03)	10
Collared Flycatcher	*Ficedula albicollis*	Migrant	0.00 (0.00)	0.00 (0.00)	0.03 (0.02)	0.00 (0.00)	10
Woodchat Shrike	*Lanius senator*	Migrant	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	0.01 (0.01)	10
Grey Wagtail	*Motacilla cinerea*	Urban adapter	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.03 (0.02)	10
Eurasian Golden Oriole	*Oriolus oriolus*	Migrant	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	0.01 (0.01)	10
Southern Masked-Weaver	*Ploceus velatus*	Alien	0.00 (0.00)	0.01 (0.01)	0.00 (0.00)	0.02 (0.02)	10
Common Sandpiper	*Tringa hypoleucos*	Urban adapter	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.14 (0.11)	10
Common Redshank	*Tringa totanus*	Urban adapter	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	0.01 (0.01)	10
Blue Magpie	*Urocissa erythrorhyncha*	Alien	0.00 (0.00)	0.03 (0.02)	0.00 (0.00)	0.00 (0.00)	10
Eurasian Reed Warbler	*Acrocephalus scirpaceus*	Urban adapter	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	5
Greylag Goose	*Anser anser*	Alien	0.04 (0.04)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5
Red-throated Pipit	*Anthus cervinus*	Migrant	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	5
Eurasian Nightjar	*Caprimulgus europaeus*	Migrant	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	0.00 (0.00)	5
Cetti’s Warbler	*Cettia cetti*	Urban adapter	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.02 (0.02)	5
European Pied Flycatcher	*Ficedula hypoleuca*	Migrant	0.00 (0.00)	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	5
Common Coot	*Fulica atra*	Urban adapter	0.03 (0.03)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5
Hill Myna	*Gracula religiosa*	Alien	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	0.00 (0.00)	5
Red-rumped Swallow	*Hirundo daurica*	Urban adapter	0.00 (0.00)	0.06 (0.06)	0.00 (0.00)	0.00 (0.00)	5
Purple Glossy-Starling	*Lamprotornis purpureus*	Alien	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.05 (0.05)	5
Bluethroat	*Luscinia svecica*	Urban adapter	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	5
Black Redstart	*Phoenicurus ochruros*	Urban adapter	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	5
Bonelli’s Warbler	*Phylloscopus bonelli*	Migrant	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.02 (0.02)	5
Sand Martin	*Riparia riparia*	Migrant	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	5
Whinchat	*Saxicola rubetra*	Migrant	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	5
European Serin	*Serinus serinus*	Migrant	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.18 (0.18)	5
Green Sandpiper	*Tringa ochropus*	Urban adapter	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	5
Northern Lapwing	*Vanellus vanellus*	Migrant	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5

Common and Latin names based on Sibley and Monroe (1996) (http://www.fact-index.com/s/si/sibley_monroe_checklist_1.html).

The most abundant bird species in the park community were the urban exploiters and the alien species. Of 16,541 individuals recorded in the point counts, 40% were classified as urban exploiters, 38% as urban adapters and 21% as aliens. The seven most abundant species (in order of decreasing abundance) were the Rock Pigeon (*Columba livia*), Hooded Crow (*Corvus corone cornix*), House Sparrow (*Passer domesticus*), Common Myna (*Acridotheres tristis*), Monk Parakeet (*Myiopsitta monachus*), White-spectacled Bulbul (*Pycnonotus xanthopygos*) and the Rose-Ringed Parakeet (*Psittacula krameri*). Altogether these seven species (all of them occurring at least in 80% of sites) constitute 63% of all observed individuals (Table 2).

3.2. *Influence of park management regime on bird communities*

3.2.1. *Species richness*

Total bird species richness varied between the four management regimes (Table 3). Overall, moderately managed areas were richer habitats for all species groups. They were significantly richer for all bird species combined and for urban adapters, followed by unmanaged, lightly and intensively managed areas. Species richness in intensively managed habitats was significantly lower than that in moderately managed and unmanaged habitats (Table 3). Lightly managed areas had species richness similar to unmanaged. Urban exploiter and alien species

Table 3
Species richness (mean ± S.E.) for all species combined and richness of urban adapters, aliens, urban exploiters and locally rare species across management regimes in the Yarkon Park, Israel

	Intensive (n = 6)	Moderate (n = 4)	Light (n = 5)	Unmanaged (n = 5)	ANOVA $F_{3,16}$	P
All species	21.75 ± 2.01[a]	32.09 ± 2.44[b]	28.14 ± 1.07[b]	31.43 ± 1.51[b]	7.33	0.003
Urban adapters	16.69 ± 1.87[a]	25.02 ± 2.23[b]	21.69 ± 1.35[b]	24.06 ± 1.57[b]	4.69	0.016
Alien species	3.85 ± 0.37[a]	4.93 ± 0.42[a]	4.71 ± 0.27[a]	4.41 ± 0.35[a]	1.75	0.197
Urban exploiters	2.92 ± 0.04[a]	3.42 ± 0.19[a]	3.23 ± 0.18[a]	3.15 ± 0.19[a]	1.17	0.206
Locally rare species	1.36 ± 0.10[a]	2.27 ± 0.07[b]	1.55 ± 0.07[a,b]	1.89 ± 0.01[b]	5.99	0.006

[a,b] A difference between letters within each row (a vs. b) indicates pairs of means that significantly differ at the 0.05 level based on the Tukey test for multiple pairwise comparison of means.

richness did not vary among management regimes (Table 3). The number of locally rare species varied with the level of management (Table 3) with equal numbers found in the unmanaged and moderately managed habitats and a significantly lower number found in the intensively managed areas.

3.2.2. Abundance

Abundance of all species combined varied among management regimes (ANOVA, $F_{3,16} = 4.79$, $P = .014$). Abundance in intensively managed areas was significantly higher than in lightly managed or unmanaged areas (Tukey, $P = 0.032$ and Tukey, $P = 0.019$, respectively). Abundances of urban exploiters were significantly higher in intensively managed areas compared to all other areas (ANOVA, $F_{3,16} = 10.79$, $P < 0.001$). Urban adapters, alien species and locally rare species abundances were similar across management regimes (all P values > 0.15).

3.2.3. Community composition

Community composition based on presence or absence of species varied among the management regimes (ANOSIM, *Global rho* = 0.155, $P = 0.028$). Intensively managed areas had a significantly different species composition from unmanaged areas (ANOSIM, *Global rho* = 0.248, $P = 0.039$) and showed a trend for different compositions from moderately managed areas (ANOSIM, *Global rho* = 0.243, $P = 0.050$). The proportion of locally rare species ranged from 89% to 92% of species and did not vary across management categories. The five most common species in each category ranged from 49% of observations in the lightly managed areas to 71% of observations in the unmanaged areas. House Sparrow and Hooded Crow were among the five most numerous species at all sites. White-spectacled Bulbul and the alien Monk Parakeet were also the most abundant species at most sites. Among the locally rare species, most were urban adapters (65–71%) and migrant species (13% in intensively managed areas up to 21% in the unmanaged areas).

In six pairwise comparisons between the management regimes, between 19 and 24 species accounted for approximately 50% of the dissimilarity in bird assemblages. Species that were rare or absent within intensively managed habitats compared to other habitats included: Blackcap (*Sylvia atricapilla*), Chaffinch (*Fringilla coelebs*), European Bee-eater (*Merops apiaster*), European Goldfinch (*Carduelis carduelis*), Eurasian Jay (*Garrulus glandarius*), Spotted Flycatcher (*Muscicapa striata*), and Willow Warbler (*Phylloscopus trochilus*).

3.3. Vegetation and habitat factors

Several vegetation and habitat factors varied between management regimes (Table 4). Intensively managed areas had high lawn cover compared to the less managed ones (Table 4). Conversely, less managed habitats had higher annual cover compared to those that are highly managed. Lightly managed areas had the highest annual cover (Table 4). Unmanaged areas showed a trend towards lower distance from the park edge although the difference was not significant (Table 4).

3.4. Bird/habitat relationships

Several vegetation variables were significant in predicting total species richness and richness of the different species groups (Table 5). Bird richness of all species combined was negatively correlated with lawn cover and was positively correlated with woody plant richness, with these factors explaining 37% and 10% of the variation in richness respectively. Sixty-two percent of the total variation in urban adapter richness was explained by the negative effect of lawn cover ($R^2 = 31\%$) and the distances from water source ($R^2 = 18\%$) and trails ($R^2 = 13\%$) (Table 5). There was no significant effect of any of the explanatory variables (Table 4) on the richness of urban exploiters. Together, woody plant richness and distance from nearest water source explained 60% of the variation in alien species richness. Alien bird richness increased with increasing woody plant richness ($R^2 = 45\%$) while it decreased with increasing distance from water source ($R^2 = 15\%$).

4. Discussion

4.1. Relationship between park management regimes and bird communities

Bird communities varied among different management regimes. As predicted, species richness was lower in intensively managed areas characterized by a structurally and floristically

Table 4
Vegetation and habitat attributes (mean ± S.E.) in Yarkon Park, Israel

Attribute	Park management regime				ANOVA $F_{3,16}$	P
	Intensive ($n = 6$)	Moderate ($n = 4$)	Light ($n = 5$)	Unmanaged ($n = 5$)		
Woody plant % cover	21.25 ± 7.14	26.46 ± 8.95	31.58 ± 10.99	44.34 ± 11.90	1.06	0.392
Annual % cover	0.00 ± 0.00[a]	20.19 ± 9.84[a]	90.70 ± 3.96[c]	55.65 ± 8.28[b]	47.27	<0.001
Lawn % cover	85.08 ± 6.52[a]	25.09 ± 13.05[b]	0.00 ± 0.00[b]	0.00 ± 0.00[b]	43.85	<0.001
Plant species richness	10.33 ± 2.99	8.25 ± 7.30	10.80 ± 1.53	16.60 ± 2.56	1.16	0.358
Distance to park border	271.50 ± 69.14	341.75 ± 23.74	267.60 ± 45.85	120.60 ± 43.50	2.82	0.072
Distance to nearest trail	65.00 ± 13.83	155.75 ± 45.82	53.60 ± 14.10	161.60 ± 95.37	1.20	0.339
Distance to nearest water source	166.00 ± 51.94	100.25 ± 56.96	78.60 ± 12.40	213.60 ± 123.40	0.70	0.565

The sample size (n) is the number of points sampled in each management regime.
[a,b,c] A difference between letters within each row (a, b, c) indicates pairs of means that significantly differ at the 0.05 level based on the Tukey test for multiple pairwise comparison of means

Table 5
Results of multiple regressions between selected vegetation and habitat variables and bird richness (for all species combined, urban adapters and aliens)

Model	Variables[a]	Sign	$R^2_{adjusted}$	P
All			0.47	0.002
	Lawn cover	−	0.37	0.002
	Woody plant richness	+	0.10	0.048
Urban adapter			0.62	0.001
	Lawn cover	−	0.31	0.010
	Distance from water source	−	0.18	0.003
	Distance from trails	+	0.13	0.040
Alien			0.60	<0.001
	Woody plant richness	+	0.45	0.001
	Distance from water source	−	0.15	0.020

Only significant variables are shown.
[a] Variables entered in model include: distance from nearest water source, distance from park edge, distance from nearest trail, woody species cover, lawn cover, plant richness.

simplified plant community. This reflects a loss or decline of several urban adapters that are likely more sensitive to human-induced changes. Our expectation that decreases in these species would be compensated by increases in the species richness of urban exploiters (Turner et al., 2004) was not met. For all bird groups, the highest species richness was found in the moderately managed areas which represent a "mid-point" along the management intensity spectrum. Our results agree with those of Jokimäki and Suhonen (1993) and Blair (1996) who found that moderate levels of development increase bird species richness. However, unlike Blair (1996), increases in richness found here were not due to a replacement of native species by widely distributed species such as aliens or urban exploiters. These results are consistent with patterns generally predicted by the intermediate disturbance hypothesis (Connell, 1978), and that extend to communities affected by human land use whereby areas of intermediate human development exhibit the highest diversity (McDonnell et al., 1993; Blair, 1996). Here, the similarity in urban exploiters spatial pattern across the range of management regimes can probably be explained by the shape of the Yarkon Park, which forms a long narrow strip along the Yarkon River, surrounded by highly urbanized areas on either side which enable a permanent diffusion of urban exploiters in all areas of the park. However, while the numbers of urban exploiter species did not increase with increasing human influence (Marzluff, 2001; Turner et al., 2004), communities in intensively managed areas had, as expected, higher abundances of urban exploiters. The widespread occurrence patterns of three of these urban exploiters (Hooded Crow, Rock Pigeon, and House Sparrow) were mostly similar to those found along an urbanization gradient in Jerusalem (Bino et al, in press; Kark et al., 2007). Both the Rock Pigeon and House Sparrow are ubiquitous in urbanized areas worldwide (Clergeau et al., 1998, 2006; Blair, 2001).

Contrary to our prediction and to some previous studies (Mills et al., 1989; Lim and Sodhi, 2004), richness and abundance of alien species were similar among levels of management. Alien species are typically habitat generalists (Cassey, 2002; Duncan et al., 2003) and are able to exploit a variety of nesting sites and food resources in the park (A. Shwartz, unpublished data) and therefore were found throughout the park. These species have been shown to aggressively compete among themselves over nesting and foraging resources (Orchan, 2007). This may lead to their exploitation of larger portions of the park.

Of the estimated 228 bird species that have been reported in the entire costal plain of Israel, 108 were observed in the Yarkon Park in this study. Thus, despite its narrow shape and its location within a large urban metropolis, the Yarkon Park seems to support a diverse and rich avifauna. The highly urbanized environment surrounding the park may provide a hotspot for urban exploiters, as well as humans that can alter the park ecosystem through their activities. The greatest human pressure is likely to occur in those areas of the park most closely resembling urban areas and providing the greatest access and amenities for humans and their exploiter commensals and in areas close to the park edge. However, our expectation that species richness of urban adapters would increase with increasing distance from the park edge, while urban exploiters would respond in the opposite way, was not met. This might suggest that the availability of resources may play a more crucial role here. Nevertheless, urban adapters were negatively affected by the distance from trails, in contrast to urban exploiters (Table 5), emphasizing that these species are influenced by humans and their commensals (Kark et al., 2007).

At a local scale, we found a positive association between bird diversity and the habitat structure complexity provided by high richness of woody plant species and decreased lawn cover, consistent with other studies in urbanized environments (Beissinger and Osborne, 1982; Mills et al., 1989; Clergeau et al., 1998; Germaine et al., 1998). Other specific habitat attributes found to be important in shaping bird diversity are large tree patches and old trees with cavities (Rottenborn, 1999; Hostetler and Holling, 2000). Proximity to water sources was found to be important in shaping richness patterns of urban adapters and alien species. This may simply reflect the addition of bird species associated with water, such as Pied Kingfisher (*Ceryle rudis*), Mallard (*Anas platyrhynchos*) and Common Sandpiper (*Tringa hypoleucos*) for urban adapters, and Egyptian Goose (*Alopochen aegyptiacus*) and Muscovy Duck (*Cairina moschata*) for alien species. Nevertheless, additional factors may be acting here. For example, urban adapters may prefer the constant and unlimited drinking source, while the exploiters may more readily use localized and human-related anthropogenic water resources (e.g. drinking fountains).

4.2. The scale of urban influence

Our study is among the first to explicitly examine the spatial variability of bird communities within a large urban park and, in particular, the range of influence of urban exploiter and adapter species. Importantly, the pattern of peak bird diversity at intermediate levels of human development described by Blair (1996) among sites compared at a regional scale is retained at the local park scale suggesting that birds may respond also to variation in habitat characteristics at a finer local scale, e.g. vegetation composition, water source and habitat edges such as walking trails.

Our results differ, however, in some important ways from those of previous studies that focused on urbanization gradients (Blair, 2004; Clergeau et al., 2006). While there are similarities along management regimes that may be considered analogous to the process of urbanization, e.g. simplification of vegetation structure, there remains a high level of species diversity and coexistence between urban exploiters and urban adapters. At present, there is little evidence of biotic homogenization due to urban exploiter and alien species (see also Beissinger and Osborne, 1982; McKinney, 2002; Clergeau et al., 2006) except for the intensively managed habitats. We suggest that changes in the natural bird community structure are buffered by the large contiguous area of the park within the urban environment. Park area is a major factor in maintaining biodiversity and large parks containing a variety of habitats including both native and exotic plant species can maintain higher levels of natural biodiversity compared to smaller parks (Fernandez-Juricic and Jokimäki, 2001; Cornelis and Hermy, 2004; Fernandez-Juricic, 2004; Bino et al., in press). Further, the area of the various sub-habitats within the park is likely to be important. Parks with high proportions of natural or semi-natural areas with high plant heterogeneity and water sources can maintain higher levels of native biodiversity compared with those highly managed and dominated by recreation lawns.

In contrast to the hypothesis that large urban remnants with high native species richness may be more resistant to invasion by alien species (Antos et al., 2006), Yarkon Park also contains a high number of alien species, reflecting the increasing influence of alien species in urban landscapes (White et al., 2005). This supports the findings of Kark and Sol (2005) that found high success of introduced species around the Mediterranean Basin. It is important to note that several alien species are in the early stages of establishment and these may contribute to greater biotic homogenization in later establishment stages and following various invasion and extinction scenarios (Olden and Poff, 2003; McKinney, 2004).

Although bird communities varied among park habitats, the urban influence extended throughout the park with seven dominant species found at all sites, indicating a wide range of habitats used and/or the tendency for home-range movements to cover the entire park. Distinguishing between these two possibilities will require the collection of demographic and movement data, a direction we are currently exploring for several species. Several of these species such as the Hooded Crow, Common Myna and Rose-ringed Parakeet are capable of covering large areas (A. Shwartz, unpublished data). Others, such as the House Sparrow and Rock Pigeon, have more restricted home ranges (Sol and Senar, 1995; Shochat et al., 2004).

4.3. Management implications for large parks

Because urban and alien bird species have potentially negative effects on other species, especially at high densities, through competition for nesting sites or nest predation, consideration should be given to ways to minimize their densities in the design of urban parks. For example, several urban species are omnivorous and incorporate human foods from garbage into their diet (Jokimäki, 1996). The influence of the human presence and an incremental urban food supply on the bird community and particularly on densities of urban species is an important question that has yet to be addressed (Blanco and Velasco, 1996; Shochat, 2004; Shochat et al., 2004). Making garbage less available by using closable garbage bins may reduce population sizes and the distribution of exploiters and aliens.

In this study, we could not detect any urban exploiter- or alien-free habitat in the park, which might be due to the shape of the park (high perimeter to area ratio) and its human facilities design (e.g., picnic areas and trails). Creating a buffer zone near the edge of the park by planning the more natural habitats in the centre of the park and designing the intensively managed areas at the outskirts can create a local urbanization gradient within the park (Fox and Madsen, 1997; Löfvenhaft et al., 2002). This may reduce the urban exploiter and alien diffusion to the central parts. Walking trails show a negative impact on sensitive species (see also Fernandez-Juricic, 2004) and should be designed to minimize interactions between humans and areas with high densities of native bird diversity. Ponds and small lakes, however, provide suitable habitat for water birds and can provide a suitable drinking sources for shyer species. Therefore their presence may well increase total bird diversity, especially that of the urban adapters. Planning the park while considering these factors might increase native species diversity, while providing pleasure for the visitor by exploration of the urban park "nature".

The introduction of exotic plant species is common practice and may sometimes contribute to high species richness in moderately managed areas by increasing resources and niches available to birds along with the addition of nutrients (Beissinger and Osborne, 1982). However, because exotic vegetation is also associated with high abundances of alien bird species (White et al., 2005), and negative effects on native bird species at high densities (Ortega et al., 2006), further understanding of bird species interactions with exotic vegetation is needed. Lawn cover had a strong negative impact on the richness of all species and of urban adapters, but it did not affect alien or urban exploiters. Replacement of lawns and other exotic ground cover with native woody plant species could enhance habitat for native species. Our findings imply that such a change might also help to displace exploiters and alien birds, replacing them with native avifauna.

Despite the urban influence, there was a diversity of species among the locations, due both to resident species and those species present during migration. Israel is located on a major migratory pathway and Yarkon Park is likely an important stopover point for migratory birds while crossing the large metropolis. The use of habitats by migratory and breeding species may differ from those of residents, focusing on different limiting habitat attributes (Hostetler and Holling, 2000). Because migrant activity can change dramatically during the season, and our data of the migrant species was insufficient we did not include the migratory species in some of our analyses. However, we believe that this group of species is important and future research efforts should focus on understanding habitat use of migrants and breeding birds in urban parks. Learning more about the contribution of the urban park to the unique mosaic of birds in the region may help in conserving bird communities around this dynamic metropolis and others.

The maintenance of species interactions characteristic of natural areas is necessary to preserve communities in the longer term (Janzen, 1983). Given the prevalence of urban species, an altered balance of species interactions from natural habitats between food supply and predation is also likely (Lim and Sodhi, 2004; Faeth et al., 2005) so priority should be given to understanding the mechanisms underlying these changes to reduce negative impacts. Our study represents a complementary approach to the study of urbanization gradients among several parks and contributes new insights into the impacts of urbanization on small-scale spatial variation of bird communities. These insights provide evidence that management regime and vegetation design should be included in future plans if we aim to maintain high native biodiversity in urban parks.

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References

Antos, M.J., Fitzsimons, J.A., Palmer, G.C., White, J.G., 2006. Introduced birds in urban remnant vegetation: does remnant size really matter? Austral. Ecol. 31, 254–261.

Beissinger, S.R., Osborne, D.R., 1982. Effects of urbanization on avian community organization. Condor 84, 75–83.

Bino, G., Levin, N., et al., in press. Landsat derived NDVI and spectral unmixing accurately predict bird species richness patterns in an urban landscape. Int. J. Remote Sens.

Blair, R., 2004. The effects of urban sprawl on birds at multiple levels of biological organization. Ecology and Society 9, 2 (Online). URL: http://www.ecologyandsociety.org/vol9/iss5/art2.

Blair, R.B., 1996. Land use and avian species diversity along an urban gradient. Ecol. Appl. 6, 506–519.

Blair, R.B., 2001. Creating a homogenous avifauna. In: Marzluff, J.M., Bowman, R., Donnelly, R. (Eds.), Avian Ecology and Conservation in an Urbanizing World. Kluwer Academic Publishers, Norwell, Massachusetts, pp. 459–486.

Blanco, G., Velasco, T., 1996. Bird habitat relationships in an urban park during winter. Folia Zool. 45, 35–42.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman & Hall, London.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L., Thomas, L., 2004. Advanced Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, London.

Cassey, P., 2002. Life history and ecology influences establishment success of introduced land birds. Biol. J. Linn. Soc. 76, 465–480.

Chace, J.F., Walsh, J.J., 2004. Urban effects on native avifauna: a review. Landscape Urban Plan. 74, 46–69.

Clergeau, P., Croci, S., Jokimäki, J., Kaisanlahti- Jokimäki, M.L., Dinetti, M., 2006. Avifauna homogenisation by urbanisation: analysis at different European latitudes. Biol. Conserv. 127, 336–344.

Clergeau, P., Mennechez, G., Sauvage, A., Lemoine, A., 2001a. Human perception and appreciation of birds: a motivation for wildlife conservation in urban environments of France. In: Marzluff, J.M., Bowman, R., Donnelly, R. (Eds.), Avian Ecology and Conservation in an Urbanizing World. Kluwer Academic Publishers, Norwell, Massachusetts, pp. 19–48.

Clergeau, P., Jokimäki, J., Savard, J.P.L., 2001b. Are urban bird communities influenced by the bird diversity of adjacent landscapes? J. Appl. Ecol. 38, 1122–1134.

Clergeau, P., Savard, J.P.L., Mennechez, G., Falardeau, G., 1998. Bird abundance and diversity along an urban–rural gradient: a comparative study between two cities on different continents. Condor 100, 413–425.

Collins, J.P., Kinzig, A., Grimm, N.B., Fagan, W.F., Hope, D., Wu, J.G., Borer, E.T., 2000. A new urban ecology. Am. Sci. 88, 416–425.

Colwell, R.K., 2005. EstimateS: Statistical Estimation of Species Richness and Shared Species from Samples. User's Guide and Application, Version 7.5.

Colwell, R.K., Mao, C.X., Chang, J., 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. Ecology 85, 2717–2727.

Connell, J.H., 1978. Diversity in tropical rain forests and coral reefs. Science 199, 1302–1310.

Cornelis, J., Hermy, M., 2004. Biodiversity relationships in urban and suburban parks in Flanders. Landscape Urban Plan. 69, 385–401.

Czech, B., Krausman, P.R., Devers, P.K., 2000. Economic associations among causes of species endangerment in the United States. Bioscience 50, 593–601.

Duncan, R.P., Blackburn, T.M., Sol, D., 2003. The ecology of bird introductions. Annu. Rev. Ecol. Syst. 34, 71–98.

Emlen, J.T., 1974. An urban bird community in Tucson, Arizona: derivation, structure, regulation. Condor 76, 184–197.

Faeth, S.H., Warren, P.S., Shochat, E., Marussich, W.A., 2005. Trophic dynamics in urban communities. Bioscience 55, 399–407.

Fernandez-Juricic, E., 2000. Bird community composition patterns in urban parks of Madrid: the role of age, size and isolation. Ecol. Res. 15, 373–383.

Fernandez-Juricic, E., 2004. Spatial and temporal analysis of the distribution of forest specialists in an urban-fragmented landscape (Madrid, Spain) – implications for local and regional bird conservation. Landscape Urban Plan. 69, 17–32.

Fernandez-Juricic, E., Jokimäki, J., 2001. A habitat island approach to conserving birds in urban landscapes: case studies from southern and northern Europe. Biodivers. Conserv. 10, 2023–2043.

Fox, A.D., Madsen, J., 1997. Behavioural and distributional effects of hunting disturbance on waterbirds in Europe: implication for refuge design. J. Appl. Ecol. 34, 1–13.

Germaine, S.S., Rosenstock, S.S., Schweinsburg, R.E., Richardson, W.S., 1998. Relationships among breeding birds, habitat, and residential development in Greater Tucson, Arizona. Ecol. Appl. 8, 680–691.

Gilbert, O.L., 1989. The Ecology of Urban Habitats. Chapman and Hall, London.

Hadidian, J., Sauer, J., Swarth, C., Handly, P., Droege, S., Williams, C., Huff, J., Didden, G., 1997. A citywide breeding bird survey for Washington, DC. Urban Ecosyst. 1, 87–102.

Hermy, M., Cornelis, J., 2000. Towards a monitoring method and a number of multifaceted and hierarchical biodiversity indicators for urban and suburban parks. Landscape Urban Plan. 49, 149–162.

Hostetler, M., Holling, C.S., 2000. Detecting the scales at which birds respond to structure in urban landscapes. Urban Ecosyst. 4, 25–54.

Janzen, D.H., 1983. No park is an island: increase in interference from outside as park size decreases. Oikos 41, 402–410.

Jokimäki, J., 1996. Patterns of bird communities in urban environments. PhD Thesis, University of Lapland, Arctic Centre Reports 16, Finland.

Jokimäki, J., 1999. Occurrence of breeding bird species in urban parks: effect of park structure and broad-scale variation. Urban Ecosyst. 3, 21–34.

Jokimäki, J., Suhonen, J., 1993. Effects of urbanization on the breeding bird species richness in Finland: a biogeographical comparison. Ornis Fenn. 70, 71–77.

Jokimäki, J., Kaisanlahti- Jokimäki, M.L., 2003. Spatial similarity of urban bird communities: a multiscale approach. J. Biogeogr. 30, 1183–1193.

Kark, S., Sol, D., 2005. Establishment success across convergent Mediterranean ecosystems: an analysis of bird introductions. Conserv. Biol. 19, 1519–1527.

Kark, S., Iwaniuk, A., Schalimtzek, A., Banker, E., 2007. Living in the city: can anyone become an "urban exploiter"? J. Biogeogr. 34, 638–651.

Lancaster, R.K., Rees, W.E., 1979. Bird communities and the structure of urban habitat. Can. J. Zool. 57, 2358–2368.

Lim, H.C., Sodhi, N.S., 2004. Responses of avian guilds to urbanisation in a tropical city. Landscape Urban Plan. 66, 199–215.

Löfvenhaft, K., Björn, C., Ihse, M., 2002. Biotope patterns in urban areas: a conceptual model integrating biodiversity issues in spatial planning. Landscape Urban Plan. 58, 223–240.

Marzluff, J.M., 2001. Worldwide urbanization and its effects on birds. In: Marzluff, J.M., Bowman, R., Donnelly, R. (Eds.), Avian Ecology and Conservation in an Urbanizing World. Kluwer Academic Publishers, Norwell, Massachusetts, pp. 19–48.

Marzluff, J.M., Bowman, R., Donnelly, R., 2001. A historical perspective on urban bird research: trends, terms, and approaches. In: Marzluff, J.M., Bowman, R., Donnelly, R. (Eds.), Avian Ecology and Conservation in an Urbanizing World. Kluwer Academic Publishers, Norwell, Massachusetts, pp. 1–18.

McDonnell, M.J., Pickett, S.T.A., Pouyat, R.V., 1993. The application of the ecological gradient paradigm to the study of urban effects. In: McDonnell, M.J., Pickett, S.T.A. (Eds.), Humans as Components of Ecosystems. Springer-Verlag, New York, pp. 175–189.

McKinney, M.L., 2002. Urbanization, biodiversity, and conservation. Bioscience 52, 883–890.

McKinney, M.L., 2004. Do exotics homogenize or differentiate communities? Roles of sampling and exotic species richness. Biol. Invasions 6, 495–504.

Melles, S., Glenn, S., Martin, K., 2003. Urban bird diversity and landscape complexity: species-environment associations along a multiscale habitat gradient. Conserv. Ecol. 7, 5 (Online). URL: http://www.consecol.org/vol7/iss1/art5.

Miller, J.R., 2005. Biodiversity conservation and the extinction of experience. Trends Ecol. Evol. 20, 430–434.

Miller, J.R., Hobbs, R.J., 2002. Conservation where people live and work. Conserv. Biol. 16, 330–337.

Mills, G.S., Dunning, J.B., Bates, J.M., 1989. Effects of urbanization on breeding bird community structure in south-western desert habitats. Condor 91, 416–428.

Olden, J.D., Poff, N.L., 2003. Toward a mechanistic understanding and prediction of biotic homogenization. Am. Nat. 162, 442–460.

Orchan, Y., 2007. The cavity nesting bird community in the Yarkon Park: spatial, temporal interactions and breeding success in a community being invaded in recent decades. M.Sc. thesis, The Hebrew University of Jerusalem, Jerusalem (in Hebrew with English abstract).

Ortega, Y.K., McKelvey, K.S., Six, D.L., 2006. Invasion of an exotic forb impacts reproductive success and site fidelity of a migratory songbird. Oecologia 149, 340–351.

Richardson, D.M., Pysek, P., Rejmanek, M., Barbour, M.G., Panetta, F.D., West, C.J., 2000. Naturalization and invasion of alien plants: concepts and definitions. Diversity Distrib. 6, 93–107.

Rottenborn, S.C., 1999. Predicting the impacts of urbanization on riparian bird communities. Biol. Conserv. 88, 289–299.

Savard, J.P.L., Clergeau, P., Mennechez, G., 2000. Biodiversity concepts and urban ecosystems. Landscape Urban Plan. 48, 131–142.

Shirihai, H., 1996. The Birds of Israel. Princeton University Press, Princeton.

Shochat, E., 2004. Credit or debit? Resource input changes population dynamics of city-slicker birds. Oikos 106, 622–626.

Shochat, E., Lerman, S.B., Katti, M., Lewis, D.B., 2004. Linking optimal foraging behaviour to bird community structure in an urban–desert landscape: field experiments with artificial food patches. Am. Nat. 164, 232–243.

Sol, D., Senar, J.C., 1995. Urban pigeon populations – stability, home-range, and the effect of removing individuals. Can. J. Zool. 73, 1154–1160.

Solecki, W.D., Welch, J.M., 1995. Urban parks – green spaces or green walls. Landscape Urban Plan. 32, 93–106.

SPSS Inc., 2005. SPSS 14.0 for Windows. Chicago.

Tilghman, N.G., 1987. Characteristics of urban woodlands affecting breeding bird diversity and abundance. Landscape Urban Plan. 14, 481–495.

Turner, W.R., Nakamura, T., Dinetti, M., 2004. Global urbanization and the separation of humans from nature. Bioscience 54, 585–590.

Vitousek, P.M., Mooney, H.A., 1997. Human domination of Earth's ecosystem. Science 277, 494–499.

White, J.G., Antos, M.J., Fitzsimons, J.A., Palmer, G.C., 2005. Non-uniform bird assemblages in urban environments: the influence of streetscape vegetation. Landscape Urban Plan. 71, 123–135.

Yom-Tov, Y., 1988. The zoogeography of the birds and mammals of Israel. In: Yom-Tov, Y., Tchernov, E. (Eds.), The Zoogeography of Israel. Dr. W. Junk, Dordrecht, Netherlands, pp. 389–410.

Zar, J.H., 1999. Biostatistical Analysis. Prentice Hall, Upper Saddle River, New Jersey.