

# Breeding birds of “Nomentum” nature reserve (central Italy): a forest remnant landscape surrounded by an agro-urbanized matrix

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**Abstract** - We carried out a standardized breeding bird atlas of “Nomentum” nature reserve (central Italy), located in a fragmented hilly forest near a large urbanized area (Rome). In order to obtain information about local composition, occurrence, distribution and richness, we correlated data with environmental heterogeneity and vegetation structure variables. We recorded 58 species in 48 500x500 m-wide atlas units, with *Parus major*, *Corvus cornix*, *Turdus merula*, *Sylvia atricapilla*, *Sylvia melanocephala*, as the most occurring in frequency (> 80%). Although synanthropic species represent only slightly more than 20% in number and urban environments are relatively reduced in size, these species show a higher mean occurrence when compared to mosaic species, despite the fact that these last are higher in species number and mosaic habitats are widely diffused. Local urbanization may disrupt communities, facilitating opportunistic species linked to these environments (i.e. synanthropic) and inducing a decline in mosaic species. Moreover, the homogenization induced by anthropization could, at least partially, explain the lack of correlation between habitat diversity and species richness, at local scale. Finally, tree density and diameter do not affect total bird richness at this spatial grain/scale. In this regard, further analyses could test for possible correlations between habitat variables and single ecological guilds.

**Keywords** urbanization, synanthropic species, forest species, mosaic species, homogenization, habitat heterogeneity.

**Riassunto** - Uccelli nidificanti della Riserva naturale “Nomentum”: un paesaggio forestale residuale inserito in una matrice agricola in fase di urbanizzazione.

Si riportano i dati ottenuti da un atlante standardizzato degli uccelli nidificanti nella riserva naturale “Nomentum” (Italia centrale), collocata in un paesaggio collinare a dominanza forestale ad elevato grado

di frammentazione, in prossimità di una vasta area urbanizzata (Roma), al fine di ottenere dati sulla composizione, presenza, distribuzione e ricchezza specifica. Sono state registrate 58 specie in 48 unità di rilevamento di ampiezza 500x500. *Parus major*, *Corvus cornix*, *Turdus merula*, *Sylvia atricapilla* e *Sylvia melanocephala* hanno mostrato la frequenza di copertura più elevata (> 80%). Sebbene le specie sinantropiche rappresentino solo poco più del 20% in numero e gli ambienti urbani siano di dimensioni relativamente ridotte, queste specie mostrano una presenza media più elevata rispetto alle specie legate ai mosaici ambientali, nonostante il fatto che queste ultime siano in maggior numero e gli ambienti a mosaico mostrino una ampia distribuzione. L’urbanizzazione a scala locale può perturbare le comunità, facilitando specie opportunistiche e sinantropiche legate a questi ambienti e favorendo un declino delle specie di mosaico. Inoltre, l’omogeneizzazione indotta dall’antropizzazione potrebbe, almeno in parte, spiegare la mancanza di correlazione tra diversità di habitat e ricchezza di specie, osservata a scala locale. La densità e il diametro degli alberi non influenzano la ricchezza totale degli uccelli nidificanti a questa grana/scale spaziale. A questo proposito, ulteriori analisi potrebbero testare possibili correlazioni tra variabili di habitat e single guilds (corporazioni) ecologiche.

**Keywords** urbanizzazione, specie sinantropiche, specie forestali, specie di mosaico ambientale, omogeneizzazione, eterogeneità ambientale.

## INTRODUCTION

Forest ecosystems of the plains and hilly areas of central Italy are markedly fragmented and embedded in a heterogeneous and anthropized landscape matrix: this can have effects on the bird communities both at faunal and structural level (Battisti, 2001; Bianconi *et al.*, 2003; Frank & Battisti, 2005; Lorenzetti & Battisti, 2006; Mortelliti *et al.*, 2010; Arca *et al.*, 2012). A large number of these remnant ecosystems are now included in protected areas: therefore, it is of relevant interest to study the local bird communities, obtaining quali-quantitative and spatially-referred data. In this regard, the Atlas of breeding birds – providing systematized information on the species occurrence, distribution and richness – can be a useful tool at different scales (Araújo *et al.*, 2005). This knowledge can be used to define appropriate planning, management and conservation actions and strategies at species-, community- and ecosystem-level.

In central Italy, in the last decade, the number of such local atlases has been increasing with many examples available for protected areas (e.g., Guidi & Battisti, 2010; Tafon *et al.*, 2011; Quatrini *et al.*, 2012; Marini *et al.*, 2014;

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Brunelli *et al.*, 2016; Sorace *et al.*, 2017; Muratore *et al.*, 2018; Ceccarelli *et al.*, 2019; Sorace *et al.*, 2019; Battisti *et al.*, 2020). However, one of the most frequent biases of atlases is represented by the non-uniform research effort, which leads to a data unreliability, such as a over- or underestimated patterns of species distribution (see Sutherland, 2006). For this reason, it has been highlighted the need to standardize the research effort per sampling unit (Donald & Fuller, 1998; Sutherland, 2006). Consequently, the sampling protocols followed standardized approaches in order to obtain reliable data, for example, using the same number of researchers for sampling units, as well as standards at spatial (cells of equal size) and temporal level (uniform time per detection units; see Taffon *et al.*, 2011; Marini *et al.*, 2014; Battisti *et al.*, 2020).

As part of the management of a regional protected natural area (Nomentum nature reserve), we carried out a standardized breeding bird atlas in order to obtain data about local occurrence, distribution and richness. Although this reserve has already been thoroughly investigated for many animal taxa (terrestrial molluscs: Crucitti *et al.*, 2003; insects: Crucitti *et al.* 2004b; Crucitti *et al.*, 2015; amphibians, reptiles and mammals: Crucitti *et al.*, 2004a, 2005b; Crucitti & Bufalieri, 2012; Doglio *et al.*, 2013; see also Crucitti *et al.*, 2013a), a quali-quantitative analysis of the composition and distribution of the breeding bird is not yet available, with the exception of some studies focused on the effects of forest fragmentation on sensitive species and guilds (Battisti *et al.*, 2003, 2004, 2009; Lorenzetti & Battisti, 2005, 2006, 2007; Taffon & Battisti, 2003).

Since the patterns of frequency distribution of species could be deeply affected by the agricultural and urban anthropization, we obtained information both on the composition and distribution of breeding species and on the relationship between species richness vs. environmental heterogeneity and vegetation structure. More in particular, our aims were: 1) to describe the bird community and guilds of the nature reserve and 2) to assess how landscape and habitat features affect the composition of communities and guilds. In addition to providing local information, it may also have a more general interest since this nature reserve is located in a fragmented hilly forest near a large urbanized area of central Italy.

## STUDY AREA

The “Nomentum” nature reserve (Regional Law n.29 / 1997), about 850 hectares wide, is sited in the north east sector of Rome metropolitan area (Mentana and Fonte Nuova Municipalities; IGM 144 III SE). The Reserve is located in a hilly clay system (between 60 and 200 meters a.s.l.), between the Campagna Romana, the Tiber river and pre-Apennines mountans (Lucretili, Cornicolani mts.; Crucitti, 2013). The Reserve is characterized by a landscape mosaic including remnant fragments of deciduous broad-leaved forests, embedded in an anthropized matrix with olive groves, cultivated and urbanized areas. In the last decades, the progressive expansion of the urban settlements has occurred to the detriment of the natural areas, which are reduced – especially the woods – in isolated patches (Rosati *et al.*, 2010).

The soils are mainly of sandy-clayey type (Paolini & Capecci, 2004). From the phytoclimatic point of view, the “Nomentum” nature reserve is located in the Mediterranean transitional belt (Tiber valley and the system of foothills of the Apennines; Blasi, 1994; Vannicelli Casoni, 2004). For the vegetation aspects, the following typologies are noted: (i) the mesophilic forests (in the northern area, Macchia Trentani and Selva Cavaliere), consisting of *Quercus cerris*, *Quercus robur*, and *Carpinus orientalis*; (ii) patches of hygrophilous vegetation along the ditches and impluvium lines, characterized by the presence of *Ulmus minor*, *Salix alba* and *Populus nigra* and, locally, by reed bed patches at *Phragmites australis* and *Arundo donax*; (iii) the mixed thermophilic coppiced woods (in the southern area, Macchia Mancini) with *Quercus cerris*, *Q. frainetto*, *Q. pubescens*, *Fraxinus ornus*, *Acer campestre* and *Ostrya carpinifolia*; (iv) uncultivated areas and pastures, with *Crataegus monogyna*, *Rubus ulmifolius*, *Ulmus minor*, *Ulmus glabra*; finally, (v) in the urbanized areas ornamental, cultivated and hedges species occur, such as *Olea europaea*, *Malus domestica*, *Prunus persica*, *Nerium oleander*, *Platanus x acerifolia*, *Cedrus deodara*, *Cupressus sempervirens*, *Pinus pinea* and *Thuja orientalis* (Guidi, 2004). Further details on the area in Crucitti *et al.* (2000, 2001).

## METHODS

### Protocol

A squared grid was over-imposed on the whole of study area (and on the immediately adjacent contexts). This grid was made up of 48 500x500 m-wide survey units (S.U.) obtained by dividing each UTM unit 1x1 km of the Regional Technical Map (scale 1: 10,000; Lazio Region, 1990; Fig. 1). In the 2019 spring period (from 7 March to 27 June), we randomly walked the sector of each S.U. twice during the breeding season (the first in March and April, the second in May and June). In each of the two times a 20-minute non-linear transect was performed, as representative as possible of the entire S.U. (Bibby *et al.*, 2000; total effort: 40 minutes/S.U.; total research effort: approx. 1,900 minutes).

During each sampling every direct and indirect sighting of each presumably breeding species was recorded, obtaining a data of occurrence in any S.U. We have considered a species occurring in a S.U. whether at least one direct or indirect contact of the species was obtained in at least one session. We then accumulated the occurrence data obtained from the two sessions for each S.U. Species abundance data were not obtained. Nikon 8x40 and Leica 10x42 binoculars were used for bird species detection.

## DATA ANALYSIS

### Distribution maps, frequencies of occurrence and guild characterization

We obtained local distribution maps both for each breeding species and for the total species richness. For each species we obtained the number of S.U. occupied and the frequency on the total occurrences (fr occ, that is, n. S.U./48), a proxy of the local distribution of the species. The relative frequency of species occurrence was

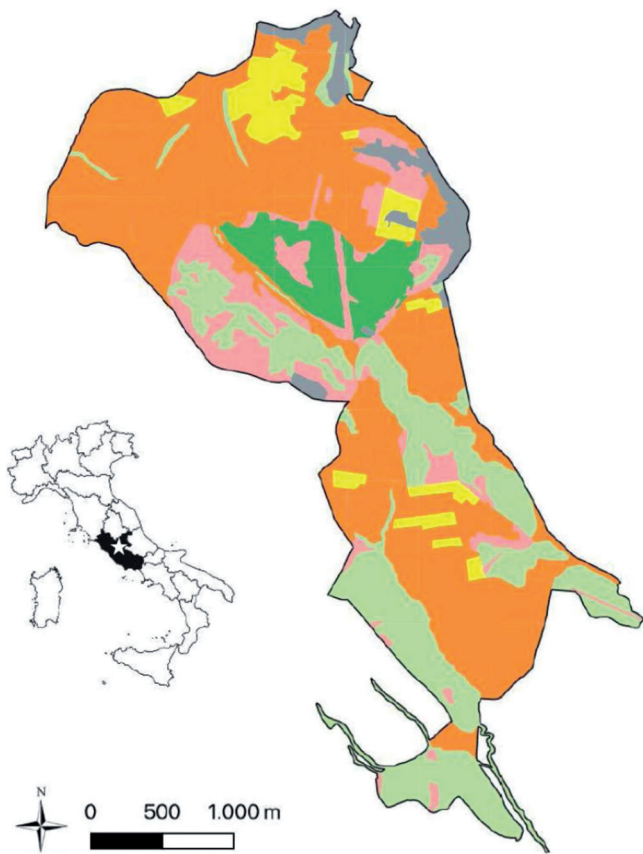


Fig. 2 - Map of the study area. Colors represent the different habitat types. In green: woods (dark green: high forests; light green: coppiced woods, characterized by mixed oak species including *Q. cerris*, *Q. pubescens*, *Q. frainetto*); orange: woody agricultural crops (olive groves, vineyards, orchards); yellow: arable land *sensu lato* (annual and/or perennial and with the presence of pastures); pink: shrunby-edge areas (ecotonal habitats with isolated trees and shrubs such as *Rubus ulmifolius*); grey: urban environments (included road infrastructures and recreational areas). Star represents the location of study site at regional scale. / Cartografia dell'area di studio. I colori rappresentano le diverse tipologie di habitat. In verde: aree forestali (verde scuro: fustaia; verde chiaro: boschi cedui, caratterizzati da querceti misti con *Q. cerris*, *Q. pubescens* e *Q. frainetto*); arancio: ambienti agricoli con legnose agrarie (oliveti, vigneti, frutteti); giallo: aree coltivate in senso lato (a diverso regime agricolo, anche con presenza di pascoli e incolti); rosa: aree marginali e arbustive (ambienti ecotonali con alberi isolati e arbusteti con *Rubus ulmifolius*); grigio: ambienti urbani (incluse infrastrutture stradali e aree classificate come a scopo ricreativo). La stella indica la collocazione dell'area di studio a scala nazionale.

also calculated (fr, i.e. the ratio between the number of S.U. occupied by a species and the total number of species occurrences). This frequency data was used to obtain preliminary information on the spatial structure of the breeding community in the study area.

The breeding bird species were coarse-grained characterized grouping them into the following ecological categories (guilds): forest species (*sensu lato*: FOR); edge-mosaic, open-habitat and crop-land species (MOS); synanthropic species (SYN; see Tab. 1); following the ecological preferences reported in Fornasari *et al.* (2010) and, for Latium, in Brunelli *et al.* (2011). For each guild, the average number of S.U. occupied and the frequency of the total occurrences were calculated. For the nomenclature and systematic order, reference was made to the recent check list of Italian birds (Baccetti *et al.*, 2019).

### Habitat heterogeneity, vegetation structure and breeding bird richness

For each S.U., the percentage frequency (fr) of land use was calculated using the Qgis software (version 2.14.22), selecting the following coarse-grained categories: coppice woods (characterized by mixed oak species including *Q. cerris*, *Q. pubescens*, *Q. frainetto*); woody agricultural crops (olive groves, vineyards, orchards); arable land (annual and / or perennial and with the presence of pastures); ecotonal habitats (isolated trees and shrubs such as *Rubus ulmifolius*, *Crataegus* sp., and *Prunus spinosa*); urban environments (included road infrastructures and recreational areas; see Fig. 2).

From the land use/cover frequencies, an habitat heterogeneity index was obtained using the Shannon-Wiener diversity (entropy) index:  $H' = -\sum fr \ln fr$ , where fr = percentage frequency of land use of the i-th category (Shannon & Weaver, 1949; Magurran, 2004).

In a sub-sector, corresponding to the forest core of the protected area reserve ("Trentani wood" and surrounding, classified as "A" zone of nature reserve of high conservation concern: centroid: 42°01'12.0"N 12°38'01.9"E) and including a representative sample of any habitat type (high forests, coppiced woods, and shrunby-edge areas; details in AA. VV., 1999; Buccomino *et al.*, 2017), we also carried out a fine-grained analysis of the vegetation structure, selecting 13 S.U.). In each S.U. we randomly selected

Tab. 1 - Structural characteristics of tree vegetation (mean tree density and diameter and number of tree species) for the sub-area (see Methods, for details). High forest and coppiced woods: characterized by mixed oak species including *Q. cerris*, *Q. pubescens*, *Q. frainetto*; ecotones (shrunby-edge areas): ecotonal habitats (isolated trees and shrubs such as *Rubus ulmifolius*). / Caratteristiche strutturali della vegetazione arborea (densità media di alberi, diametro e numero di specie arboree) per la sub-area (vedi Metodi per i dettagli). Le fustaie e i boschi cedui sono caratterizzati da querceti misti con *Q. cerris*, *Q. pubescens*, *Q. frainetto*; gli ecotoni (ambienti arbustivi marginali) includono alberi isolati e arbusteti con *Rubus ulmifolius*.

	High forest	Coppiced wood	Ecotones	KW test
Mean tree density	17.5 ± 4.78	20.64 ± 10.23	14.36 ± 12.73	7.030, p=0.019
Mean tree diameter	32.98 ± 11.79	24.71 ± 14.35	27.77 ± 17.29	64.780, p<0.001
Tree species	8	13	15	

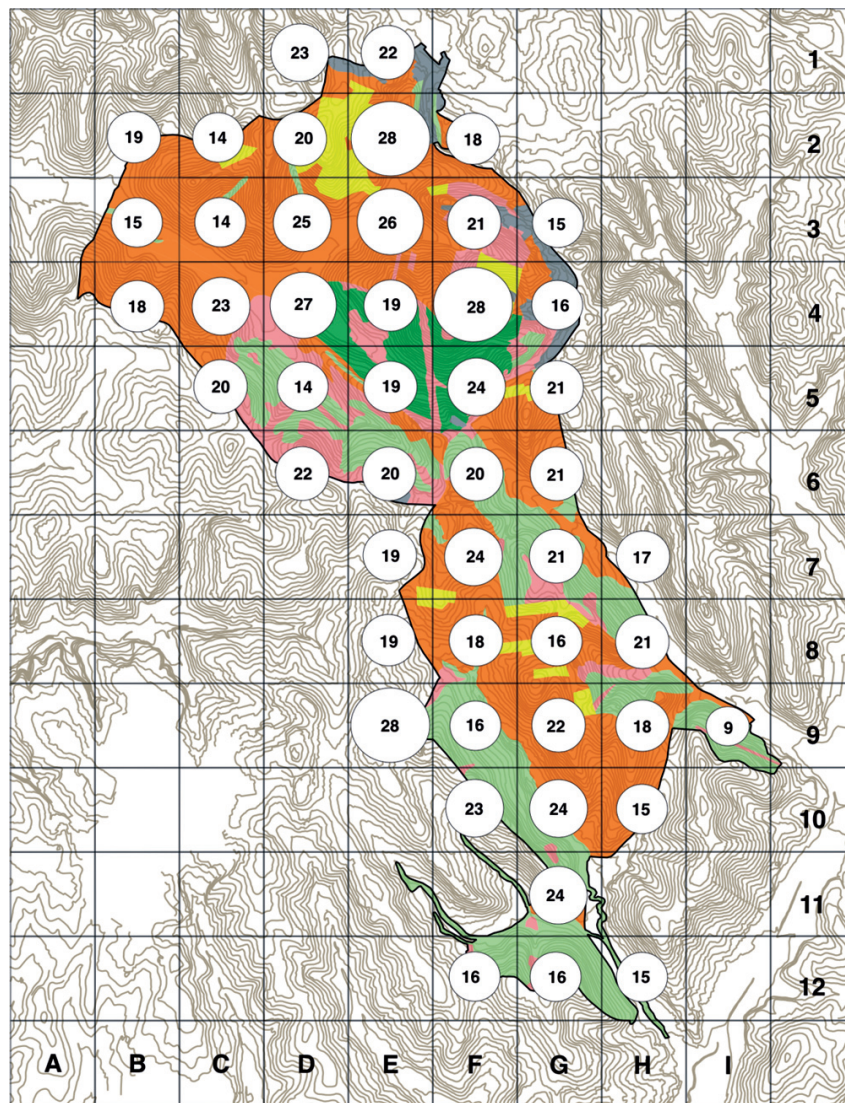


Fig. 2 - Map of breeding bird species richness for the “Nomentum” nature reserve. / Mappa della ricchezza di specie di uccelli nidificanti nella Riserva naturale “Nomentum”.

five circular 400m<sup>2</sup>-wide plots (James & Shugart, 1970; Deonchat & Balent, 2001; total: 65 plots). In each plot all tree plants with a diameter > 7 cm were taxonomically identified and counted. For each of them, the diameter to the breast height (1.30 m from the ground) was measured. From these measurements, the following parameters were obtained for each S.U.: tree species richness, mean tree density (n. plants/plot) and mean tree diameter (in cm; Table 1). We used this sub-set of data to assess the role of vegetation structure in predict the bird species richness.

### Statistical analyses

To test for differences among frequencies in both species number of different guilds and different habitat types, we used the  $\chi^2$  test. Data on the structural variables of vegetation and land use cover were compared and correlated with data on breeding birds (both total and divided by guilds). To test for differences both in averaged values of number of occurrences and structural variables of vegeta-

tion (plant density and diameter) among different guilds, we performed non-parametric comparison tests between un-paired mean values (2 cases: U Mann-Whitney test; > 2 cases: Kruskal-Wallis test). Habitat diversity indices have been correlated to the breeding species richness using a non-parametric test (Spearman's rank test, 2 tail; Dytham, 2011). We used the SPSS 13.0 software for Windows. Alpha level was set at 0.05 level.

## RESULTS

### Distribution maps and frequency of occurrences

We obtained 951 occurrences relating to 58 species of breeding birds (Table 2). The number of species/S.U. ranged from 9 to 28 (see map of species richness in Fig. 2). Five species (*Parus major*, *Corvus cornix*, *Turdus merula*, *Sylvia atricapilla*, *Sylvia melanocephala*) were the most widely distributed (percentage frequency of occurrence > 80%). Localized species (<20%) show the highest percentages in species number (n=25; >40%).

Tab. 2 - Breeding bird species of the "Nomentum" nature reserve. Number of occurrences (n occ) and frequencies both on the total of occurrences (Fr tot) and on the total of S.U (FrSU; in bold: FrSU>0.50). Among brackets, the ecological guilds (FOR: forest species; MOS: mosaic species; SYN: synanthropic species). / Uccelli nidificanti nella Riserva naturale "Nomentum". Numero di presenze (n occ) e frequenze sia sul totale delle presenze (Fr tot) e sul totale delle Unità di rilevamento standard (S.U.; FrSU; in grassetto: FrSU>0.50). Tra parentesi, le corporazioni ecologiche (FOR: specie forestali; MOS: specie di mosaico ambientale; SYN: specie sinantropiche).

Species (and guilds)	n occ	Fr tot	Fr SU	Species (and guilds)	n occ	Fr tot	Fr SU
<i>Parus major</i> (FOR)	46	0.048	<b>0.96</b>	<i>Cuculus canorus</i> (FOR)	12	0.013	0.25
<i>Corvus cornix</i> (SYN)	45	0.047	<b>0.94</b>	<i>Regulus ignicapilla</i> (FOR)	11	0.012	0.23
<i>Turdus merula</i> (FOR)	44	0.046	<b>0.92</b>	<i>Pica pica</i> (MOS)	10	0.011	0.21
<i>Sylvia atricapilla</i> (FOR)	44	0.046	<b>0.92</b>	<i>Oriolus oriolus</i> (FOR)	10	0.011	0.21
<i>Sylvia melanocephala</i> (MOS)	43	0.045	<b>0.9</b>	<i>Falco tinnunculus</i> (MOS)	9	0.009	0.19
<i>Cyanistes caeruleus</i> (FOR)	38	0.04	<b>0.79</b>	<i>Luscinia megarhynchos</i> (MOS)	8	0.008	0.17
<i>Serinus serinus</i> (MOS)	36	0.038	<b>0.75</b>	<i>Emberiza calandra</i> (MOS)	8	0.008	0.17
<i>Passer domesticus</i> (SYN)	36	0.038	<b>0.75</b>	<i>Streptopelia turtur</i> (FOR)	7	0.007	0.15
<i>Troglodytes troglodytes</i> (FOR)	33	0.035	<b>0.69</b>	<i>Hippolais polyglotta</i> (MOS)	7	0.007	0.15
<i>Fringilla coelebs</i> (FOR)	33	0.035	<b>0.69</b>	<i>Garrulus glandarius</i> (FOR)	7	0.007	0.15
<i>Carduelis chloris</i> (MOS)	32	0.034	<b>0.67</b>	<i>Sitta europaea</i> (FOR)	6	0.006	0.13
<i>Hirundo rustica</i> (SYN)	30	0.032	<b>0.63</b>	<i>Monticola solitarius</i> (SYN)	6	0.006	0.13
<i>Erithacus rubecula</i> (FOR)	27	0.028	<b>0.56</b>	<i>Saxicola torquatus</i> (MOS)	5	0.005	0.1
<i>Streptopelia decaocto</i> (SYN)	26	0.027	<b>0.54</b>	<i>Psittacula krameri</i> (SYN)	4	0.004	0.08
<i>Columba palumbus</i> (FOR)	26	0.027	<b>0.54</b>	<i>Motacilla alba</i> (SYN)	4	0.004	0.08
<i>Dendrocopos major</i> (FOR)	25	0.026	<b>0.52</b>	<i>Passer montanus</i> (SYN)	3	0.003	0.06
<i>Carduelis carduelis</i> (SYN)	24	0.025	0.5	<i>Corvus monedula</i> (SYN)	3	0.003	0.06
<i>Picus viridis</i> (FOR)	22	0.023	0.46	<i>Carduelis cannabina</i> (MOS)	3	0.003	0.06
<i>Certhia brachydactyla</i> (FOR)	22	0.023	0.46	<i>Apus apus</i> (SYN)	3	0.003	0.06
<i>Phasianus colchicus</i> (MOS)	21	0.022	0.44	<i>Upupa epops</i> (MOS)	2	0.002	0.04
<i>Columba livia dom.</i> (SYN)	21	0.022	0.44	<i>Merops apiaster</i> (MOS)	2	0.002	0.04
<i>Aegithalos caudatus</i> (FOR)	21	0.022	0.44	<i>Dendrocopos minor</i> (FOR)	2	0.002	0.04
<i>Sturnus vulgaris</i> (SYN)	20	0.021	0.42	<i>Buteo buteo</i> (MOS)	2	0.002	0.04
<i>Cettia cetti</i> (MOS)	20	0.021	0.42	<i>Sylvia communis</i> (MOS)	1	0.001	0.02
<i>Emberiza cirlus</i> (MOS)	17	0.018	0.35	<i>Phoenicurus ochruros</i> (MOS)	1	0.001	0.02
<i>Phylloscopus collybita</i> (FOR)	16	0.017	0.33	<i>Jynx torquilla</i> (FOR)	1	0.001	0.02
<i>Cisticola juncidis</i> (MOS)	16	0.017	0.33	<i>Coturnix coturnix</i> (MOS)	1	0.001	0.02
<i>Sylvia cantillans</i> (MOS)	15	0.016	0.31	<i>Alauda arvensis</i> (MOS)	1	0.001	0.02
<i>Delichon urbicum</i> (SYN)	12	0.013	0.25	<i>Accipiter nisus</i> (FOR)	1	0.001	0.02

The local distribution maps of the species have been shown in Supporting information. Occasional observations outside the standard method were also obtained for *Lanius collurio*, *Athene noctua*, *Myiopsitta monachus*, all probably nesting in the Reserve. Vagrant (not locally breeding) species were also recorded during this study: *Larus michaellis*, *Bubulcus ibis*, *Milvus migrans*, *Falco peregrinus* (nesting in the surrounding; Pozzo del Merro near Sant'Angelo Romano; Battisti *et al.*, 2017) and *Phylloscopus sibilatrix* and *P. trochilus*, these last using the Reserve as a stop-over site during migratory pass.

The guilds of forest and mosaic habitats showed the highest number of species (both  $n = 22$ ; 37.9%) when compared to the guild of synanthropic species ( $n = 14$ ; 24.1%). At the frequency level, forest species showed the highest significant values (about the 50%; Table 3). Despite forest and mosaic habitats are largely more represented (they are found in 70% and 90% of SUs, respectively) in the Reserve, mosaic species showed the lowest values of mean distribution of occurrences (frequency <30% on the total occurrences; Table 3). Differently, synanthropic species showed a larger averaged

distribution when compared to mosaic species, although S.U. hosting urbanized habitats are low in frequency (about 20%).

### Habitat heterogeneity, vegetation structure and breeding bird richness

Habitat diversity indices  $H'$  in S.U. ranged from 0 to 1.512. There was no significant correlation between bird species richness and habitat diversity ( $r_s = 0.252$ ,  $p = 0.084$ ; Spearman rank correlation test, 2 tail) with data showing a high variance (regression line:  $S = 2.66H' + 18.03$ ;  $R^2 = 0.064$ ).

At vegetation structural level (1128 measured plants with dominance of *Quercus cerris*, *Q. robur*, *Q. frainetto*), we obtained a significant difference in the tree density among paired habitat types (high wood, coppiced wood, shrubby-edge areas; Table 1), with shrubby-edges showing a significantly lower density than both high forests ( $U = 136$ ;  $z = -2.119$ ;  $p = 0.034$ ) and coppiced woods ( $U = 134$ ;  $z = -2.539$ ;  $p = 0.011$ ). Coppiced woods and high forests were not significantly different ( $U = 183$ ;  $z = 0.934$ ;  $p = 0.350$ ; Mann-Whitney U test). As expected, mean tree diameter was significantly higher in high woods when compared to coppiced woods ( $U = 52638.5$ ;  $z = -8.214$ ;  $p < 0.001$ ) and with shrubby-edge areas ( $U = 43089$ ;  $z = -4.926$ ;  $p < 0.001$ ); differences between coppiced woods and shrubby-edge areas were not significant ( $U = 66418$ ;  $z = -1.751$ ;  $p = 0.080$ ).

Bird species richness was not correlated neither to mean tree density ( $r_s = 0.101$ ,  $p = 0.742$ ) nor to mean tree diameter ( $r_s = -0.061$ ,  $p = 0.843$ , 2 tail).

### DISCUSSION

“Nomentum” nature reserve hosts breeding bird communities typical of agroforestry mosaics of central

Italy (e.g., Sarrocco *et al.*, 2002; Frank & Battisti, 2005; Lorenzetti & Battisti, 2006) and this atlas improves previous published and unpublished knowledge (Battisti, 2001; Taffon & Battisti, 2003; Giardini, 2004; Battisti, 2006; Brunelli *et al.*, 2011; Giardini & Battisti, 2012; Crucitti *et al.*, 2013) and unpublished sources (Ornitho.it, iNaturalist.it and BioLazio - Società Romana di Scienze Naturali).

However, when grouping species in ecological guilds, our original data evidence how landscape urbanization greatly affected their spatial occurrence. Indeed, although synanthropic species represent only slightly more than 20 % in number and urban environments are relatively reduced in size (approximately the 20 % of S.U.), these species show a higher mean occurrence than mosaic ones, although the latter are more numerous and mosaic habitats are more widespread (> 90 % of S.U.).

The role of urbanization in disrupt bird communities and facilitating opportunistic species has been worldwide evidenced (e.g. Seress & Liker, 2015), with several authors suggesting a role of these species as indicator of ongoing urbanization process (Guetté *et al.* 2017). As is known, urbanization is one of the main causes of biotic homogenization and change in the structure and functionality of bird communities (Blair, 2001; McKinney, 2006; Devictor *et al.*, 2008). The results of our study seem to indicate that a similar process has begun in the Nomentum Reserve as well. Urban sprawl, which has caused the loss of rural and forest habitats and increased fragmentation, is favoring the spread of a few robust and widespread species (“adapters”, “exploiters” and “urbanophiles”, sensu Johnston, 2001) at the expense of many more specialized and less common species (Crooks *et al.*, 2004; Blair, 2004; Blair & Johnson, 2008).

Also, the decline of mosaic species has been largely underlined, both a local, national and continental level. In particular, many studies have highlighted the strong

Tab. 3 - Guild analysis (FOR: forest species, MOS: mosaic edge species; SYN: synanthropic species). N SU and Fr SU: respectively, number and frequency of SU (Standard Units) with at least 1 ha with the specific habitat type (FOR, MOS o SYN); n occ and fr occ: respectively, total number of occurrences and relative frequency for each habitat guild; Mean occ: mean number of occurrences for each habitat guild, and s.d. standard deviation). Statistics: (1)  $\chi^2$  test (d.f. 2), (2) Kruskal-Wallis test (d.f. 2). / Analisi a livello di corporazioni ecologiche: (FOR: specie forestali; MOS: specie di mosaico e di ambienti marginali; SYN: specie sinantropiche). N SU e Fr SU: rispettivamente, numero e frequenza delle SU (Unità di rilevamento standard) con almeno 1 ha ricadente negli specifici tipi di habitat selezionati (FOR, MOS o SYN); n occ e fr occ: rispettivamente, numero totale di presenze e frequenza relativa per ogni guild (corporazione ecologica); Mean occ: numero medio di presenze per ogni guild ecologica, e deviazione standard, s.d.). Statistiche: (1) test del  $\chi^2$  test (2 gradi di libertà), (2) test di Kruskal-Wallis test (2 gradi di libertà).

	Guilds				test	p
	FOR	MOS	SYN	Tot		
<b>N UR</b>	34	44	10	48		
<b>Fr UR</b>	70.83	91.67	20.83		$\chi^2=53.53$ (1)	<0.001
<b>N occ</b>	454	260	237	951		
<b>Fr occ</b>	47.74	27.34	24.92	1	$\chi^2=134.47$ (1)	<0.001
<b>Mean occ (s.d.)</b>	20.64 (14.54)	11.82 (12.18)	16.93 (13.98)	16.40 (13.87)	H=5.22 (2)	0.073

decrease of farmland species in Italy (e.g. Gustin *et al.*, 2010; Nardelli *et al.*, 2015; Calvi *et al.*, 2018; Brambilla, 2019; see also Gustin *et al.*, 2019). The latest data from the longest-running farmland species monitoring program nationwide (Rete Rurale Nazionale & Lipu, 2021) show that in the period 2000-2020 there was a drastic reduction in the overall value of the Farmland Bird Index (Gregory *et al.*, 2005; Gregory & van Strien, 2010) and in the populations of 16 of the 28 species typical of agricultural areas used in Italy for calculation of the index (Campebelli *et al.*, 2012).

An even worse situation is found at the regional level, where the overall value of the index has decreased in the last 20 years by more than 40 % and more than 50 % of the species monitored are in decline, particularly those related to mosaics. Our data reflects this condition: although agricultural areas are widespread in almost 60 % of the study area, some of the typical farmland species have never been contacted, although habitat types are suitable for them (e.g. *Calandrella brachydactyla*, *Galerida cristata*, *Lanius senator*) and two species have been detected in a single S.U. (*Alauda arvensis* and *Lanius collurio*, occasional observations, the last outside the standard method).

The few occurrences of farmland species in the Nomentum Reserve certainly depend on national dynamics and also on specific local conditions, such as the disturbance caused by land use change and the strong anthropization of the surrounding areas, a particularly incisive and much investigated factor (e.g. Szép *et al.*, 2012; Filippi-Codaccioni *et al.*, 2008; Havlíček *et al.* 2021; for Italy: La Mantia *et al.*, 2014; Velatta *et al.*, 2016). For some field-nesting species (e.g. *Alauda arvensis*) another limiting factor may be the strong heterogeneity of the territory, as these birds tend to avoid vertical structures such as forest edges (Berg *et al.*, 2015).

One of the main predictors of species richness is environmental heterogeneity, i.e. habitat diversity, and this pattern was widely recognized worldwide in bird communities at local/regional scales (e.g. Rafe *et al.*, 1985; Böhning-Gaese, 1997; Tews *et al.*, 2004; Stein *et al.*, 2014; see also the 'habitat heterogeneity hypothesis: Connor & McCoy, 1979). However, although a large proportion of the Reserve is characterized by mosaics with a large range in habitat diversity, we obtained only a weak correlation between habitat diversity and species richness, also controlling for the area effect. Probably (i) the narrow range in species richness, (ii) the fine-grained scale of atlas units when compared to bird-perceived scale of heterogeneity and, (iii) the role of anthropization and disturbances in homogenize the differences among sites, could locally affected our pattern. Last but not least, the variable used to describe habitat heterogeneity (i.e. habitat diversity by Shannon-Wiener index), as it does not consider any spatially explicit attribute (patch shape and configuration, patchiness, edge ratio, etc.), may be a further factor affecting our results.

Although expected differences in tree density and diameter occur among habitat types due to different forest management (coppicing leads to the production of multiple suckers from each plant, so improving tree density

in coppiced woods; Mattioli *et al.*, 2008; del Río *et al.*, 2014), these structural variables do not affect bird species richness at this spatial grain/scale. Probably at level of total number of species significant patterns are not evident, since different forest ecological guilds (e.g. shrub species, hole-nesting birds, forest generalists, edge species, etc.), here not considered, may be sensitive each one to specific ranges in mean tree density and mean tree diameter. Further analyses are necessary to analyze these guild-based relationships.

Local bird atlases, if made according to rigorous and effective protocols, represent a tool that protected areas must equip themselves with: in fact they provide an important qualitative and quantitative knowledge base useful for understanding spatial distribution of species and also specific phenomena such as biotic homogenization, helping to understand how and in which areas anthropogenic activities affect biodiversity (Devictor *et al.*, 2007). Therefore, they are useful tools to define specific management and restoration actions at community, guild or species level.

Further investigations may include a more in-depth analyses of relationships among ecological guilds (considering other criteria as trophic level, phenology, spatial niche, etc) and further fine-grained environmental variables (e.g., type of vegetation, degree of anthropization, etc.), so overcoming this first explorative spatial approach.

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CB, FM, GD, VC defined the atlas design, carried out the field sampling and performed the statistical analyses, VB developed the species maps. All the authors discussed the results and commented on the manuscript. An anonymous reviewer (and Editor) provided useful comments and suggestions which improved the first draft of the manuscript.

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## SUPPORTING INFORMATION / INFORMAZIONI SUPPLEMENTARI

Additional supporting information may be found online for this article. / Per questo articolo sono disponibili informazioni supplementari online.

S1 - Maps of the single breeding bird species. / Mappe delle singole specie di uccelli nidificanti.