



ATTI
DELLA
SOCIETÀ TOSCANA
DI
SCIENZE NATURALI

MEMORIE • SERIE B • VOLUME CXXXIII • ANNO 2026



Edizioni ETS

ATTI DELLA SOCIETÀ TOSCANA DI SCIENZE NATURALI

MEMORIE

Via Santa Maria, 53 - 56126 Pisa

Rivista di proprietà della Società Toscana di Scienze Naturali. Fondata nel 1875, la rivista pubblica Memorie e Note originali, recensioni, corrispondenze e notiziari nel campo delle Scienze Naturali. È inviata ai soci e depositata in biblioteche corrispondenti. Tutti i contenuti dei volumi a stampa (articoli originali, comunicazioni brevi, notizie e recensioni) sono liberamente disponibili in rete, in conformità all'Open Access, sulle pagine <http://www.stsn.it/en/memorie-serie-a.html> (Serie A) e <http://www.stsn.it/en/memorie-serie-b.html> (Serie B).

Journal owned by Società Toscana di Scienze Naturali. Founded in 1875, the journal publishes original papers, short communications, news and book reviews on Natural Sciences. The Journal is sent to Società Toscana di Scienze Naturali members and deposited in selected libraries. All content of the printed version (original papers, short communications, news and book reviews) is freely available online in accordance with the Open Access at <http://www.stsn.it/en/memorie-serie-a.html> (Serie A) and <http://www.stsn.it/en/memorie-serie-b.html> (Serie B).

Gli Atti sono pubblicati in due volumi (Serie A - Abiologica, ISSN 0365-7655; Serie B - Biologica, ISSN 0365-7450) all'anno nel mese di dicembre. Possono essere pubblicati ulteriori volumi, definiti Supplementi, su temi specifici.

Atti are published yearly in two Issues (Serie A - Abiological, ISSN 0365-7655; Serie B - Biological, ISSN 0365-7450) in December. Some monographic volumes may be published as Supplementi.

Le lingue usate dalla rivista sono l'inglese o l'italiano // *The languages of the journal are English or Italian.*

Comitato scientifico (Editorial Board)

Serie A: G. Bianucci (Pisa, Italia), R. Blanco Chao, (Santiago de Compostela, Spagna), L. Disperati (Siena, Italia), W. Finsinger, (Montpellier, Francia), C. Montomoli (Torino, Italia), A. Oros Sršen (Zagabria, Croazia), E. Pandeli (Firenze, Italia), S. Richiano (Puerto Madrin, Argentina), E. Starnini (Pisa, Italia).

Serie B: A. Aguilera (Valencia, Spain), N.E. Baldaccini (Pisa, Italy), B. Foggi (Firenze, Italy), E. Palagi (Pisa, Italy), G. Paradis (Ajaccio, France), L. Peruzzi (Pisa, Italy), M. Zuffi (Pisa, Italy).

Direttore scientifico (*Editor in Chief*): Paolo Roberto Federici

Comitato di redazione (*Editorial Office*)

Serie A: A. Chelli (*Segretario agli Atti / Editor*)

Serie B: D. Ciccarelli (*Segretario agli Atti / Editor*)

La corrispondenza deve essere inviata ai Segretari agli Atti (per la Serie A: A. Chelli, Dipartimento di Chimica, Scienze della Vita e della Sostenibilità Ambientale, Parco Area delle Scienze, 157/A - 43124 Parma, email: attia@stsn.it; per la Serie B: D. Ciccarelli, Dipartimento di Biologia, via Derna, 1 - 56126 Pisa, e-mail: attib@stsn.it).

The correspondence must be sent to Editors (for Serie A: A. Chelli, Dipartimento di Scienze Chimiche, della Vita e della Sostenibilità Ambientale, Parco Area delle Scienze, 157/A - 43124 Parma, email: attia@stsn.it; for Serie B: D. Ciccarelli, Dipartimento di Biologia, via Derna, 1 - 56126 Pisa, e-mail: attib@stsn.it).

Per ulteriori informazioni / *For further information:* <http://www.stsn.it/>

Per informazioni editoriali / *For editorial information:* Edizioni ETS - <https://www.edizioniets.com/>

SOCIETÀ TOSCANA DI SCIENZE NATURALI

Fondata nel (*founded in*) 1874

Via Santa Maria, 53 - 56126 Pisa

Consiglio Direttivo (*Executive Committee*)

(2025-2026)

Presidente

Vice Presidenti

Segretario generale

Segretari agli Atti (Editors)

Bibliotecario

Economo-Cassiere

G. Bedini

M. Pappalardo, G. Petroni

J. Gennai

A. Chelli (Serie A),

D. Ciccarelli (Serie B)

M. Zuffi

R. Narducci

Autorizzazione n. 17/56 del 26 luglio 1956, Trib. di Pisa

Direttore responsabile (Editor in Chief): Paolo Roberto Federici

© Copyright 2025-2026 by Società Toscana di Scienze Naturali.

Per tutti gli articoli pubblicati (articoli originali, comunicazioni brevi, notizie e recensioni)
gli autori trasferiscono i diritti d'autore e di pubblicazione alla rivista.

*For all published articles (original papers, short communications, news and book reviews)
the authors transfer copyright and publishing rights to the Journal.*

Tutti gli articoli pubblicati sugli Atti (articoli originali, comunicazioni brevi, notizie e recensioni) sono rilasciati con licenza CC BY 4.0. Essi possono essere condivisi e adattati, a condizione che venga dato credito adeguato, e possono essere utilizzati anche per scopi commerciali.

All published articles in Atti (original papers, short communications, news and book reviews) are released under CCL BY 4.0. They can be shared and adapted, provided that adequate credit is given, for any purpose, even commercially.

Maurizio Maggiorotti ⁽¹⁾, Francesca Marini ⁽¹⁾, Francesco Zullo ⁽²⁾, Corrado Battisti ⁽¹⁾

BREEDING BIRDS IN THE SAN LODOVICO ESTATE (SCANSANO, GROSSETO, CENTRAL ITALY): A PRELIMINARY SURVEY

Abstract - M. Maggiorotti, F. Marini, F. Zullo, C. Battisti, *Breeding birds in the San Lodovico Estate (Scansano, Grosseto; central Italy): A preliminary survey.*

We obtained an occurrence data set from a local breeding bird atlas in a private Estate of Maremma (Tuscany, central Italy; extent: 79 hectares). Thirty-seven species were recorded with a standard method (21.6% were long distance migrants). Forest and mosaic species were dominant both in local distribution and in number of occurrences when compared to farmland and synanthropic species. Local atlases may constitute a useful tool for conservation and management strategies, also aimed at promoting sustainable tourism at local level.

Key words - occurrences, atlas dataset, species richness, long-distance migrants, agro-mosaic landscape

Riassunto - M. Maggiorotti, F. Marini, F. Zullo, C. Battisti, *Gli uccelli nidificanti nella Tenuta di San Lodovico (Scansano, Grosseto; Italia centrale): un inquadramento preliminare.*

Abbiamo ottenuto un set di dati di presenza/assenza realizzando un atlante locale degli uccelli nidificanti in una tenuta privata della Maremma grossetana (Toscana, Italia centrale; 79 ettari). Sono state registrate 37 specie (il 21,6%, migratori a lungo raggio) utilizzando un campionamento standardizzato. Le specie forestali e di mosaico sono risultate dominanti sia nella distribuzione a scala locale che nel numero di records di presenza/assenza, rispetto alle specie di ambiente agricolo e legate ad ambienti antropizzati. Gli atlanti locali possono costituire un utile strumento per strategie di conservazione e gestione, anche finalizzate alla valorizzazione turistico-sostenibile del sito.

Parole chiave - presenza/assenza, atlante, ricchezza di specie, migratori a lunga distanza, paesaggio agro-forestale

Introduction

The Maremma region (southern Tuscany, central Italy) has long been the subject of ornithological research, primarily focused on coastal and lowland ecosystems (Farina, 1998; Pezzo, 2012; Giovacchini, 2019). However, fine-scale studies addressing specific local contexts within this area remain scarce and, when available, are generally limited to individual species (e.g., Monti *et al.*, 2014) or to occasional records documented in ornithological chronicles (e.g., Arcamone & Puglisi, 2008) or citizen-science surveys (see Sforzi *et al.*, 2019).

This study presents preliminary data collected through intensive sampling based on a survey unit approach (a “local atlas” focused on breeding bird species; Sutherland, 2006; see also Taffon & Battisti, 2003; Taffon *et al.*, 2008; Guidi & Battisti, 2010; Marini *et al.*, 2014; Battisti *et al.*, 2020, 2022). The survey covered the entire agro-forestry mosaic of a private estate located in the Maremma Grossetana, within a sector that remains poorly studied from an ornithological perspective.

Materials and methods

The San Lodovico Estate (Scansano, Grosseto; geographical coordinates: 42°44'01.0"N, 11°21'58.4"E; 42.733596, 11.366225), covering an area of 79 hectares, comprises a landscape mosaic situated in the Italian Tyrrhenian coastal sub-province (Blasi & Biondi, 2017). The estate features predominantly wooded areas dominated by *Quercus cerris* L., *Q. pu-*

⁽¹⁾ Accademia Wilderness - maggiorotti@gmail.com, franmarini50@gmail.com, corradobattisti01@gmail.com

⁽²⁾ Department of Civil, Construction-Architectural and Environmental Engineering (University of L'Aquila), Piazzale Ernesto Pontieri, Monteluco di Roio L'Aquila, CA 67100 - francesco.zullo@univaq.it

Corresponding author: Corrado Battisti (corradobattisti01@gmail.com)

bescens Willd., *Q. robur* L., and *Fraxinus ornus* L. – some of which are managed as coppice-with-standards with rotation cycles of approximately 15 years. The understory includes *Ostrya carpinifolia* Scop., with ecotonal zones characterized by *Phillyrea latifolia* L., *Erica arborea* L., and *Arbutus unedo* L. The vegetation includes acidophilous associations such as *Erico arboreae–Quercetum cerridis* Arrigoni, related to the thermophilous alliance *Lonicero–Quercion pubescentis* Arrig. et Foggi, and meso-hygrophilous formations like *Melico uniflorae–Quercetum cerridis* Arrigoni, belonging to the more mesophilous order *Carpino–Melicetalia* Ubaldi *et al.* (Arrigoni *et al.*, 1990). These wooded areas alternate with open pasturelands and rural buildings, at elevations ranging between 248 and 480 meters a.s.l. The Estate also includes watersheds with seasonal streams bordered by riparian vegetation (*Salix* sp. pl., *Alnus glutinosa* L., *Populus* sp. pl.), on soils derived from diverse geological substrates. Many of the formerly cultivated or abandoned areas are currently undergoing progressive natural reforestation (Petrini *et al.*, 2013). Further information on the vegetation of this part of the Maremma, including floristic and forestry aspects, can be found in Moggi (1972), Arrigoni *et al.* (1990), Angiolini *et al.* (2005), and Selvi (2010).

In this study area, we carried out a bird atlas at a local scale, focused on breeding species. To obtain a standardized percentage coverage value for each species, intensive sampling was carried out across the entire surface of the private Estate. For this purpose, a square-grid mesh was overlaid on the entire study area (including immediately adjacent zones). The resulting grid consisted of 34 survey units (SU), each measuring 200×200 meters, defined using aerial photogrammetric data (fig. 1). Specifically, starting from the cartographic base of the “San Lodovico” Estate, a 200-meter resolution fishnet grid (the unit used for sampling) was created. Non-surveyed cells were excluded, and the remaining ones were assigned a unique identifier using the same alpha-numerical coding system applied to the sampling (e.g., A1, A2, etc.).

This allowed for the creation of a primary key, which was used to link field data with spatial data in a geographic database (gpkg format). The geodatabase was subsequently used to generate species-specific thematic maps (presence/absence) as well as a

composite species richness map (see fig. 1). All operations were carried out within a GIS environment (QGIS, version 3.34).

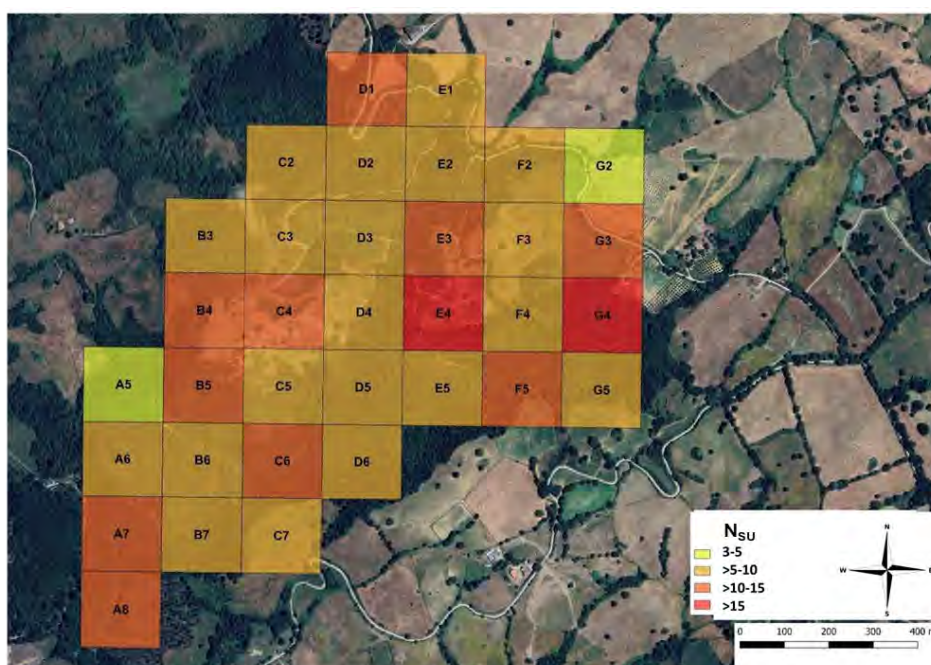
During the spring of 2025 (May 10-11), each SU was intensively and randomly surveyed using a non-linear transect walk lasting 15 minutes, aiming to represent the entire SU as comprehensively as possible (510 minutes of standardized sampling). Further records obtained outside the sampling time have been used only for the qualitative checklist (not in data analysis based on standard method: a total of 15 hours). During each survey, every direct (observational sighting of an individual) or indirect contact (singing, drumming, tracks) with a presumably breeding species was recorded, resulting in a presence (occurrence) value per SU. To minimize bias due to the “observer effect” (e.g., Donald & Fuller, 1998), which may arise from varying effort and observer skill across survey units, we standardized the methodology by ensuring the same number of surveyors and applying consistent spatial and temporal protocols across all equally sized units.

For graphical representation in the atlas, a species was considered “present” in an SU if at least one direct or indirect contact was recorded. No data on species abundance was collected. The methodology did not allow for a reliable estimation of the local distribution of nocturnal and crepuscular bird pairs, which are therefore likely to be underestimated. All observations were conducted using professional Leica 8×42 binoculars.

Presence/absence data were recorded in binary format (1 = presence; 0 = pseudo-absence) in an Excel matrix. Based on this matrix, a local-scale distribution map was created for each species, along with a composite species richness map per SU (fig. 1). For each species, we calculated the number of occupied SUs (N_{SU}) and the percentage frequency of occurrences (Fr_{SU}), expressed as the number of SUs where the species was detected out of the total 34 SU. This frequency provides insight into the local-scale distribution pattern of each species.

We also calculated the relative frequency of occurrences (Fr), defined as the ratio between the number of SUs occupied by a species and the total number of species occurrences across all units ($Fr = n/N$). Species with a relative frequency greater than 0.05 ($Fr > 0.05$) were considered dominant. This

Figure 1 - Map of species richness of breeding birds in the San Lodovico Estate (Scansano, Grosseto; central Italy) recorded in survey units (SU). Number of species in each survey unit (N_{SU}) has been subdivided into classes of richness (see legend).



frequency metric was used to gain preliminary insights into the spatial structure of the breeding bird community within the study area.

To assess potential differences in distribution patterns between sedentary (including short- and medium-distance migrants) and long-distance migratory species, we calculated the mean N_{SU} value for each of the two phenological groups. For the phenological classification of the species, we referred to Puglisi *et al.* (2023). Analogously, we calculated mean N_{SU} value for each of the three different ecological guilds (i.e., forest and mosaic species: mos; open habitats species: ape; synanthropic species, sin) following Lardelli *et al.* (2023).

The collected data were analyzed to obtain the following community-level parameters: species richness (S), normalized species richness (i.e., the number of species normalized to the number of records: Margalef index, calculated as $Dm = (S-1)/\ln N$ where N is the total number of records; Magurran, 2004), mean species richness per SU (mean S, with standard deviation, s.d.); Shannon diversity index ($H' = -\sum fr \ln[fr]$; Shannon & Weaver, 1963); and the evenness index ($J = H'/H'_{max}$ where $H'_{max} = \ln S$; Lloyd & Ghelardi, 1964; Pielou, 1966; see also Magurran, 2004 for further details). To illustrate the frequency distribution of species, a rank/occurrence plot (Whittaker plot; Magurran, 2004) was generated.

To estimate the actual species richness in the study area based on the sampling effort, a non-parametric estimator was applied (Chao2 Estimator; Magurran, 2004): $S_{Chao2} = S + Q_1^2/2Q_2$, where S is the observed species richness, Q_1 is the number of species occurring in only one sampling unit, and Q_2 is the number of species occurring in exactly two units.

The Mann-Whitney U test was applied to compare the median values of N_{SU} occupied between the two phenological groups, while the Kruskal-Wallis test was used to compare medians across more than two groups. Statistical analyses were conducted using PAST 4.01 (Hammer *et al.*, 2001), with the significance level set at $\alpha = 0.05$. Species nomenclature followed Baccetti *et al.* (2021), except for the genera *Curruca* and related Sylviidae updates, for which Gill *et al.* (2025) was adopted consistently throughout.

Results

During the sampling period, a total of 321 occurrences were recorded, corresponding to 37 breeding bird species within the private Estate. The species richness map is presented in fig. 1, while the local distribution maps for each species are provided in Appendix. The estimated total spe-

cies richness, based on the Chao2 estimator, was 43. In addition to these, three vagrant species were also observed: two in high-altitude flight (*Merops apiaster*, *Bubulcus ibis*), and one that could not be precisely localized due to nocturnal flight (*Burhinus oedicnemus*). Two species require confirmation – *Anthus campestris* and *Saxicola rubetra* – as, this last, was observed during migration. One introduced species (*Anas platyrhynchos*), with individuals of domestic origin, was not included in the analysis.

Seven species (*Sylvia atricapilla*, *Erithacus rubecula*, *Luscinia megarhynchos*, *Cyanistes caeruleus*, *Turdus merula*, *Parus major*, *Fringilla coelebs*) were widely distributed, with a percentage occurrence frequency greater than 50%. Nineteen species showed a percentage frequency of occurrence lower than 20% (i.e., species with a locally restricted distribution; see tab. 1).

The frequency difference between the dominant species group and the others is clearly visible in the Whittaker plot (fig. 2). The number of species per survey unit ranged from 3 to 18 (mean $S = 9.44 \pm 3.29$ s.d.). Eight species (21.6% of the total) and 65 records (20.2%) correspond to occurrences of long-distance migratory species.

No significant difference was detected between the local distributions of sedentary/short-medium-distance migratory species vs. the long-distance migratory species (mean N_{SU} for long-distance migrants: 8.13 ± 6.85 s.d.; sedentary/short-medium-distance migrants: 8.90 ± 8.16 s.d.; $U = 115$, $p > 0.05$; Mann-Whitney U test; fig. 3).

Species associated with forest and mosaic habitats were the most widely distributed across the Estate ($N_{SU} = 10.3 \pm 8.43$ s.d.), showing a tendency toward significance ($H = 5$, $p = 0.08$; Kruskal-Wallis test) when compared to species from agricultural and ecotonal environments ($N_{SU} = 5.75 \pm 4.35$ s.d.) and synanthropic species ($N_{SU} = 3.67 \pm 2.66$ s.d.).

In terms of occurrence frequency, species associated with agricultural/ecotonal habitats and synanthropic species were recorded significantly less frequently (7.2% and 6.9%, respectively) compared to species associated with forest and mosaic habitats ($\chi^2 = 471.18$ and $\chi^2 = 478.06$; both $p < 0.001$; fig. 4). The Shannon diversity index (H') is 3.25, the evenness (J) is 0.9, and the normalized species richness is 6.24.

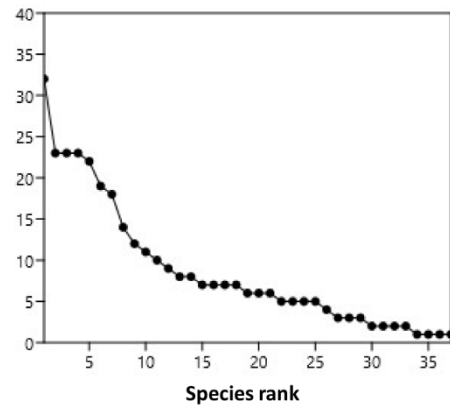


Figure 2 - Whittaker plot (frequency distribution of breeding birds in decreasing order). X-axis: species rank (1 to 37), y-axis: number of survey units where any species occurs (N_{SU}).

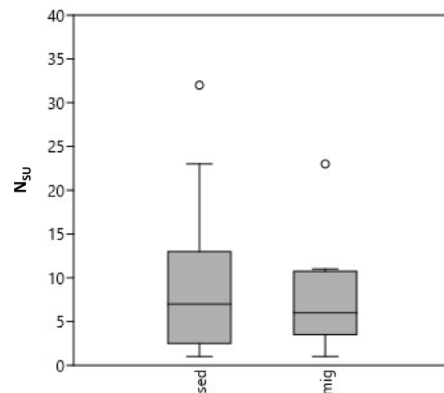


Figure 3 - Box plots comparing the number of survey units (N_{SU} ; y-axis) occupied by sedentary-medium and short-range migratory (sed) vs. long-range migratory (mig) breeding bird species. The minimum and maximum values are shown with vertical bars, and the 25-75 percentile range is indicated by the box. The horizontal line in the box represents the median value. Outliers (white dots) are also reported.

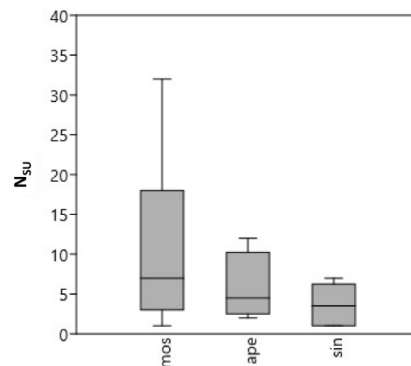


Figure 4 - Box plots comparing the number of survey units (N_{SU} ; y-axis) occupied by bird species associated with forest and mosaic habitats (mos), open habitats (ape), and anthropogenic habitats (synanthropic species, sin). The minimum and maximum values are shown with vertical bars, and the 25-75 percentile range is indicated by the box. The horizontal line in the box represents the median value.

Table 1 - Breeding bird species in the San Lodovico Estate (Scansano; Grosseto; central Italy). For each species, the scientific name, the number of survey units occupied (N_{SU}), and the relative frequency both of total occurrences (Fr) and of total survey units (Fr_{SU} ; $n = 34$) have been reported. In bold, the dominant species with Fr and $Fr_{SU} > 0.05$.

Species	N_{SU}	Fr	Fr_{SU}	Species	N_{SU}	Fr	Fr_{SU}
<i>Sylvia atricapilla</i>	32	0.100	0.941	<i>Pica pica</i>	6	0.019	0.176
<i>Erithacus rubecula</i>	23	0.072	0.676	<i>Curruca cantillans/subalpina</i>	6	0.019	0.176
<i>Luscinia megarhynchos</i>	23	0.072	0.676	<i>Cisticola juncidis</i>	5	0.016	0.147
<i>Cyanistes caeruleus</i>	23	0.072	0.676	<i>Phasianus colchicus</i>	5	0.016	0.147
<i>Turdus merula</i>	22	0.069	0.647	<i>Streptopelia decaocto</i>	5	0.016	0.147
<i>Parus major</i>	19	0.059	0.559	<i>Upupa epops</i>	5	0.016	0.147
<i>Fringilla coelebs</i>	18	0.056	0.529	<i>Emberiza calandra</i>	4	0.012	0.118
<i>Columba palumbus</i>	14	0.044	0.412	<i>Otus scops</i>	3	0.009	0.088
<i>Emberiza cirlus</i>	12	0.037	0.353	<i>Sitta europaea</i>	3	0.009	0.088
<i>Streptopelia turtur</i>	11	0.034	0.324	<i>Certhia brachydactyla</i>	3	0.009	0.088
<i>Oriolus oriolus</i>	10	0.031	0.294	<i>Passer italiae</i>	2	0.006	0.059
<i>Phylloscopus collybita</i>	9	0.028	0.265	<i>Dendrocopos major</i>	2	0.006	0.059
<i>Curruca melanocephala</i>	8	0.025	0.235	<i>Buteo buteo</i>	2	0.006	0.059
<i>Picus viridis</i>	8	0.025	0.235	<i>Lullula arborea</i>	2	0.006	0.059
<i>Carduelis carduelis</i>	7	0.022	0.206	<i>Strix aluco</i>	1	0.003	0.029
<i>Corvus cornix</i>	7	0.022	0.206	<i>Athene noctua</i>	1	0.003	0.029
<i>Garrulus glandarius</i>	7	0.022	0.206	<i>Sturnus vulgaris</i>	1	0.003	0.029
<i>Troglodytes troglodytes</i>	7	0.022	0.206	<i>Jynx torquilla</i>	1	0.003	0.029
<i>Cuculus canorus</i>	6	0.019	0.176				
					321		

Discussion

The breeding bird community of the San Lodovico Estate is characterized by species typical of the agro-forestry mosaics of central Italy's hills (e.g., Ukmar *et al.*, 2007; Marini *et al.*, 2014; Morelli *et al.*, 2014). The species richness map shows a relatively uniform distribution of the number of species/SU, as expected based on the relatively homogeneous landscape mosaic. Among the species recorded, some are of conservation interest due to their threatened status and numerical decline, or because they are geographically restricted (e.g., *Jynx torquilla*, *Burhinus oedicnemus*) at the national and regional scale (Gustin *et al.*, 2021; Puglisi *et al.*, 2023). The study area lies in a zone of overlaps between the ranges of two species of the genus *Curruca* (i.e., *C. subalpina* and *C. cantillans*), and it was not possible to differentiate between the taxa (Lardelli *et al.*, 2022). Probably, nocturnal and crepuscular species have been underestimated.

The areas with the highest species richness correspond to more structurally complex habitats in terms of vertical stratification (complex vegetation layering) or spatial heterogeneity (environmental mosaics). All the study area is characterized by forest stands of different age (mosaic of coppice forest areas, partly active and partly progressively ageing, alternating with high forests and mature riparian woodland strips) and patches in progressive re-naturalization (due to abandonment of crops; Petrini *et al.*, 2013). The role of forest complexity and landscape patchiness in explaining high values and turnovers in species richness have been largely evidenced in literature (Tews *et al.*, 2004; Shaw *et al.*, 2024), also for birds in central Italy (Florenzano, 2004; de Gasperis *et al.*, 2016; Mentil *et al.*, 2018; Amori *et al.*, 2021).

Although the number of sedentary species or short/medium-distance migrants is much higher than that of long-distance migrants, no differences in their local distribution were observed (when comparing the mean number of SU occupied). This

finding contrasts with what is generally known at the Palaearctic level, where long-distance migrants are typically more localized and rarer in abundance (Alerstam, 1990; see also Battisti & Guidi, 2010). This discrepancy is likely due to the relatively broad local distribution of long-distance migrants such as *Luscinia megarhynchos*, *Streptopelia turtur*, and *Oriolus oriolus*, which influenced the mean values. Probably, also the limited research effort carried out in this explorative study could affect these results.

The dominant species are all closely associated with forest or agroforestry mosaic habitats. These species are also the ones recorded with a significantly higher number of occurrences compared to those characteristics of open or synanthropic environments. Both latter two groups (associated with open or anthropogenic habitats) also show a more restricted distribution compared to forest and mosaic species, highlighting the characteristics of this environmental mosaic dominated by oak forests of varying maturity. In this preliminary survey, many species (including some common and widespread ones) were not recorded in this sector of the Maremma, although they have been reported in the surrounding area and adjacent regions (Lardelli *et al.*, 2022; Puglisi *et al.*, 2023): *Coturnix coturnix*, *Alectoris rufa*, *Caprimulgus europaeus*, *Apus apus*, *Tyto alba*, *Asio otus*, *Circus gallicus*, *Circus pygargus*, *Accipiter nisus*, *Milvus milvus* (Ceccolini *et al.*, 2014), *Coracias garrulus* (Pezzo & Puglisi, 2015), *Falco subbuteo*, *F. peregrinus*, *Lanius* spp., *Corvus monedula* (reported in Scansano; pers. obs.), *Poecile palustris*, *Alauda arvensis*, *Galerida cristata*, *Hippolais polyglotta*, *Delichon urbicum*, *Hirundo rustica*, *Aegithalos caudatus*, *Curruca communis*, *C. undata*, *Muscicapa striata*, *Phoenicurus* spp., *Monticola solitarius*, *Saxicola torquatus*, *Regulus ignicapilla*, *Passer montanus*, *Motacilla* spp., *Chloris chloris*, *Linaria cannabina*, *Serinus serinus*. Their presence, for many of these species confirmed in the nearby Torrente Trasubbie (Sforzi *et al.*, 2019), may be confirmed in the future for the Estate with additional surveys, possibly using specific methods and improving the research effort.

Other species (e.g., *Milvus milvus*, *Pernis apivorus*, *Falco tinnunculus*, *Falco biarmicus*, *Accipiter gentilis*; the latter also reported in the nearby Special Area of Conservation 'Monte Labbro e Alta Valle dell'Albegna'; Giovacchini, 2003) have been observed prior to this study (P.P. Fondi, pers. comm.).

Although preliminary, this study has provided fine-grained data on a context that is still poorly studied from an ornithological perspective. For similar areas, it is recommended to adopt the approach used here (bird atlas with a grid system), which, if carried out following standardized protocols (same surveyors, units of similar size, comparable research effort), can represent an opportunity for in-depth qualitative and quantitative knowledge of actively managed forest/mosaic areas (both private and public) and for future comparisons through monitoring. This knowledge base can also initiate processes for the enhancement of these areas through communication, education, and tourism promotion actions (Bimonte & Faralla, 2012).

In this work we used a non-parametric estimate of species richness to process field data (Magurran, 2004), useful when the representativeness of the samples is low (Balestrieri *et al.*, 2017), as in this exploratory field study. Moreover, it could be interesting to apply the richness estimators to the different ecological guilds (e.g., forest vs. edge mosaic species) stratifying for the different environments of the landscape mosaic (e.g., Wagner & Wildi, 2002). However, in our study there are some points of weaknesses that should be evidenced. First, given the spatial characteristics of this fine-grained atlas grid (with small, adjacent units), it is not unlikely that the same singing individuals could be assigned to multiple neighboring cells. This may lead to overestimation of the presence of some species. Second, in this preliminary study, the survey period is limited, and it is probable that early-nesting or late-spring species may be underestimated or, on the contrary, other species may be overestimated due to the presence (in May) of mixed breeding and migrating individuals. These and other sources of bias should be controlled to improve the reliability of the resulting dataset in future studies. Finally, further investigations could include analysis on the relationships between species and specific environmental characteristics (e.g., vegetation type, degree of naturalness, hydrological network, species turnover between sites, etc.), to identify the factors and processes responsible for the current local distribution patterns of species, and emphasizing the possible role of some forest/mosaic species as indicators of environmental quality and disturbance sensitivity (Roberge & Angelstam, 2006; Mikusiński *et al.*, 2001; Battisti & Fanelli, 2016).

Author's contributions

MM, FM and CB carried out field study; FZ developed the GIS analysis and provided the species-specific (and richness) maps.

Acknowledgments

We would like to thank Pietro Giovacchini and Pier Paolo Fondi for providing additional historical data and bibliographic references for the area, as well as Arianna and Lorenzo Maggiorotti for their warm hospitality at the San Lodovico Estate's accommodation facility. This work was carried out as part of the technical-scientific activities of the Wilderness Academy. Two anonymous reviewers and Editor provided useful comments and suggestions.

Conflict of interest statement

The authors declare that they have no conflict of interest, neither known competing financial interests nor personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

- Alerstam T., 1990. *Bird migration*. Cambridge University Press, Cambridge.
- Amori G., Mazzei A., Storino P., Urso S., Luzzi G., Aloise G. *et al.*, 2021. *Forest management and conservation of faunal diversity in Italy: A review*. Plant Biosystems, 155 (6), 1226-1239.
- Angiolini C., Arrigoni P.V., Selvi F., 2005. *Stato attuale e progressi delle conoscenze floristiche in Toscana dal 1978 ad oggi*. In: Scoppola A., Blasi C. (Eds), *Stato attuale delle conoscenze sulla flora vascolare d'Italia*, 141-145. Palombi Editore, Roma.
- Arcamone E., Puglisi L., 2008. *Cronaca ornitologica toscana. Osservazioni relative agli anni 2005-2007*. Alula, 15 (1-2), 3-121.
- Arrigoni P.V., Mazzanti A., Ricceri C., 1990. *Contributo alla conoscenza dei boschi della Maremma grossetana*. Webbia, 44 (1), 121-149.
- Baccetti N., Fracasso G., Commissione Ornitologica Italiana (COI), 2021. *CISO-COI Check-list of Italian birds - 2020*. Avocetta, 45, 21-82.
- Balestrieri R., Basile M., Posillico M., Altea T., Matteucci G., 2017. *Survey effort requirements for bird community assessment in forest habitats*. Acta Ornithologica, 52 (1), 1-9.
- Battisti C., Barucci V., Concettini V., Dodaro G., Marini F., 2022. *Breeding birds of "Nomentum" nature reserve (central Italy): a forest remnant landscape surrounded by an agro-urbanized matrix*. Rivista Italiana di Ornitologia, 92 (1), 3-12.
- Battisti C., Dodaro G., Vannuccini M., 2020. *A fine-grained Atlas as tool for spatial monitoring: A case study from a remnant wetland during the breeding period (Torre Flavia, central Italy)*. Rivista italiana di ornitologia, 90, 41-50.
- Battisti C., Fanelli G., 2016. *Applying indicators of disturbance from plant ecology to vertebrates: The hemeroby of bird species*. Ecological Indicators, 61, 799-805.
- Battisti C., Guidi A., 2010. *Comparing spatial rarity between long distance migrant and sedentary bird species using atlas data and diversity/dominance diagrams*. Vie et Milieu – Life and Environment, 60, 321-326.
- Bimonte S., Faralla V., 2012. *Tourist types and happiness a comparative study in Maremma, Italy*. Annals of Tourism Research, 39 (4), 1929-1950.
- Blasi C., Biondi E., 2017. *La flora in Italia*. Ministero dell'Ambiente e della Tutela del Territorio e del Mare. Sapienza Università Editrice, Roma.
- Ceccolini G., Cenerini A., Baini M., Falchi V., Passalacqua L., Vignali S., 2014. *Restocking del Nibbio reale Milvus milvus in Toscana meridionale. Metodi e primi risultati*. In: Tinarelli R., Andreotti A., Baccetti N., Melega L., Roscelli F., Serra L., Zenatello M. (Eds), *Atti XVI Convegno Italiano di Ornitologia. Cervia (RA), 22-25 settembre 2011. Scritti, Studi e Ricerche di Storia Naturale della Repubblica di San Marino*, 255-260.
- de Gasperis S.R., Redolfi De Zan L., Battisti C., Reichegger I., Carpaneto G.M., 2016. *Distribution and abundance of hole-nesting birds in Mediterranean forests: impact of past management patterns on habitat preference*. Ornis Fennica, 93 (2), 100-110.
- Donald P.F., Fuller R.J., 1998. *Ornithological atlas data: A review of uses and limitations*. Bird Study, 45, 129-145.
- Farina A., 1998. *Bird diversity in a changing landscape (Tuscany, Italy)*. In: Rundel P.W., Montenegro G., Jaksic F.M. (Eds), *Landscape Disturbance and Biodiversity in Mediterranean type Ecosystems*, 349-367. Springer, Berlin.
- Florenzano G.T., 2004. *Birds as indicators of recent environmental changes in the Apennines (Foreste Casentinesi National Park, central Italy)*. Italian Journal of Zoology, 71 (4), 317-324.
- Gill F., Donsker D., Rasmussen P., 2025. *IOC World Bird List (v15.1)*. [https:// www.worldbirdnames.org/new/](https://www.worldbirdnames.org/new/)
- Giovacchini P., 2003. *L'avifauna del sito di Importanza Comunitaria del «Monte Labbro e alta valle dell'Albegna» (Grosseto, Toscana meridionale)*. Atti della Società Toscana di Scienze Naturali, Memorie, Serie B, 110, 71-82.
- Giovacchini P., 2019. *Gli uccelli del Parco Regionale della Maremma e aree limitrofe (Grosseto, Toscana, Italia)*. Rivista Italiana di Ornitologia, 89 (1), 7-99.
- Gustin M., Nardelli R., Brichetti P., Battistoni A., Rondinini C., Teofili C., 2021. *Lista Rossa IUCN degli uccelli nidificanti in Italia 2021*. Comitato Italiano IUCN e Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Roma.
- Hammer Ø., Harper D.A., Ryan P.D., 2001. *PAST: paleontological statistics software package for education and data analysis*. Palaeontologia Electronica, 4, 9. https://palaeo-electronica.org/2001_1/past/issue1_01.htm
- Lardelli R., Bogliani G., Brichetti P., Caprio E., Celada C., Conca G. *et al.* (Eds.), 2022. *Atlante degli uccelli nidificanti in Italia*. Edizioni Belvedere, Latina.
- Lloyd M., Ghelardi R.J., 1964. *A table for calculating the equitability component of species diversity*. Journal of Animal Ecology, 33, 217-225.
- Magurran A., 2004. *Measuring Biological Diversity*. Blackwell Publishing, Malden, MA.

- Marini F., Battisti C., Ranchelli E., Ciambotta M., Ventura A., 2014. *L'avifauna nidificante nella Riserva naturale di Monte Soratte (Lazio, Italia centrale): check-list, status di conservazione e atlante locale*. Bollettino del Museo Civico di Storia Naturale di Verona, Botanica Zoologia, 38, 161-179.
- Mentil L., Battisti C., Carpaneto G.M., 2018. *The older the richer: Significant increase in breeding bird diversity along an age gradient of different coppiced woods*. Web Ecology, 18 (2), 143-151.
- Mikusiński G., Gromadzki M., Chylarecki P., 2001. *Woodpeckers as indicators of forest bird diversity*. Conservation Biology, 15 (1), 208-217.
- Moggi G., 1972. *La flora e la vegetazione della Toscana meridionale: dati storico-bibliografici*. Atti della Società Toscana di Scienze Naturali, Memorie, Serie B, 79, 107-120.
- Monti F., Dominici J.M., Choquet R., Duriez O., Sammuri G., Sforzi A., 2014. *The Osprey reintroduction in Central Italy: dispersal, survival and first breeding data*. Bird Study, 61 (4), 465-473.
- Morelli F., Jerzak L., Tryjanowski P., 2014. *Birds as useful indicators of high nature value (HNV) farmland in central Italy*. Ecological Indicators, 38, 236-242.
- Petrini R., Angeli L., Costantini R., 2013. *Evoluzione del paesaggio agrario del comune di Scansano (GR) dal 1954 al XXI secolo*. Atti 17^a Conferenza Nazionale ASITA - Riva del Garda 5-7 novembre 2013, 1099-1104.
- Pezzo F., 2012. *La comunità ornitica nidificante nella "Pineta Granducale di Alberese" (Toscana). Composizione, struttura e indicazioni gestionali per la conservazione*. Atti del Museo di Storia Naturale della Maremma, 23, 91-101.
- Pezzo F., Puglisi L., 2015. *Aumento ed espansione della ghiandaia marina Coracias garrulus in Toscana*. Atti del I Convegno nazionale sulla Ghiandaia marina Coracias garrulus. Alula, 22 (1-2), 133-135.
- Pielou E.C., 1966. *The measurement of diversity in different types of biological collections*. Journal of Theoretical Biology, 13, 131-144.
- Puglisi L., Arcamone E., Franchini M., Giunchi D., Meschini E., Sacchetti A. et al., 2023. *Atlante degli uccelli nidificanti e svernanti in Toscana 2. Distribuzione, abbondanza e distribuzione*. Centro Ornitologico Toscano, Regione Toscana, ETS Edizioni, Pisa.
- Roberge J.M., Angelstam P., 2006. *Indicator species among resident forest birds. A cross-regional evaluation in northern Europe*. Biological Conservation, 130 (1), 134-147.
- Selvi F., 2010. *A critical checklist of the vascular flora of Tuscan Maremma (Grosseto province, Italy)*. Flora Mediterranea, 20, 47-139.
- Sforzi A., Bastianini M., Benocci A., Bonari G., Canovai R., Cantini D. et al., 2019. *Bioblitz 2015 Torrente Trasubbie*. Atti del Museo di Storia naturale della Maremma, 24, 45-76.
- Shannon C.E., Weaver W., 1963. *Mathematical Theory of Communication*. University of Illinois Press, Urbana, Illinois.
- Shaw T., Scherer-Lorenzen M., Müller S., 2024. *Forest structural heterogeneity positively affects bird richness and acoustic diversity in a temperate, central European forest*. Frontiers in Ecology and Evolution, 12, 1387879.
- Sutherland W.J., 2006. *Ecological Census Techniques*. Blackwell, London.
- Taffon D., Battisti C., 2003. *L'Atlante locale degli uccelli nidificanti di un settore della provincia di Roma (area Mentanese-Cornicolana): considerazioni faunistiche, ecologiche, applicative*. Alula, 10, 3-48.
- Taffon D., Giucca F., Battisti C., 2008. *Atlante degli uccelli nidificanti nel Parco regionale dell'Appia antica*. Provincia di Roma, Assessorato alle politiche dell'agricoltura e dell'ambiente, Gangemi, Roma.
- Tews J., Brose U., Grimm V., Tielbörger K., Wichmann M.C., Schwager M. et al., 2004. *Animal species diversity driven by habitat heterogeneity/diversity: The importance of keystone structures*. Journal of Biogeography, 31 (1), 79-92.
- Ukmar E., Lorenzetti E., Battisti C., 2007. *Un contributo alla conoscenza della comunità ornitica nidificante del Monte Soratte (Lazio, Italia centrale)*. Alula, 14, 115-119.
- Wagner H., Wildi O., 2002. *Realistic simulation of the effects of abundance distribution and spatial heterogeneity on non-parametric estimators of species richness*. Ecoscience, 9 (2), 241-250.

(ms. pres. 30 novembre 2025; ult. bozze 19 maggio 2026)