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Ornithical community of Vallombrosa Biogenetic National Nature Reserve (Italy)

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Abstract

The aim of this work was to monitor the ornithic community of the forest of Vallombrosa Biogenetic National Nature Reserve, in the Florence area. The forest covers about 1273 hectares, at an altitude of 470 to 1440 m above sea level (a.s.l.). The main forest types are coniferous woodland, mixed woodland of coniferous and deciduous trees with a prevalence of beech, and open areas. The bird monitoring was carried out using the point count method. Forty-one listening points were considered. The results of the counts allowed the calculation of abundance per station (n), richness (S), Shannon–Wiener diversity (H'), evenness (J') and non-passerine incidence (NP). The data were analysed using the Kruskal–Wallis non-parametric test and principal component analysis, considering the forest type, season and altitude as sources of variability. Forty-seven bird species were identified. Abundance was higher in open areas, in the pre-reproductive period and at 800–1000 m a.s.l. Richness was higher in open areas, in reproductive and pre-reproductive periods and at lower altitudes. Diversity index was higher in open areas, in the reproductive period and at lower altitudes. Evenness was greater in the reproductive period, lower in the broadleaved-tree woodland and lower at higher altitudes. Non-passerine incidence was lower in deciduous areas, higher in the pre-reproductive and reproductive periods and higher at lower altitudes. Seventeen species registered more than 100 contacts each. The highest average values of richness, abundance, diversity and non-passerine incidence were found in the open areas and at high altitudes. Considering the ornithical community throughout the year, the ecological indices taken together showed the highest values in the pre-reproductive and reproductive periods. Because of the area's high richness and biodiversity, and the significant presence of species that are rare and of naturalistic interest, Vallombrosa forest is confirmed to be of high ornithological value.

Keywords: Vallombrosa Nature Reserve, biodiversity, bird community, point count method

Introduction

This work aimed to determine the structure and composition of the bird community of Vallombrosa Biogenetic National Nature Reserve (Vallombrosa forest). This work complies with Annex V of Directive 2009/147/CE of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (*Official Journal of the European Union*, 26 January 2010), and with the Istituto superiore per la protezione e la ricerca ambientale (ISPRA) guidelines (ISPRA 2017). Furthermore, this work considers the bird community a relevant ecological indicator, following previous authors (Pilastro et al. 1993; O'Connell et

al. 2000; Stolen et al. 2005; Padoa-Schioppa et al. 2006; Radhouani et al. 2012).

Bird classes include many species with important and differentiated roles in terrestrial ecosystems, and that are easy to detect. Birds are homeotherms, able to remain active during the whole year. Their particular locomotion ability allows birds to adapt in different natural environments, quickly adapting to climate changes (Wiens 1992) and showing high ecological ductility (Dorst 1982). Birds are indicators of the health status of a territory, aiding territory planning, also at large scale (Bermejo 2010). Woodland birds merit continuous and careful attention because their biological cycle is strictly connected to the woodlands,

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especially in the more exigent species (“interior species”). Forests, used by humans for centuries as a source of wood (MacArthur & MacArthur 1961; Furness & Greenwood 1994; Berg 1997; Brichetti & Gariboldi 1997; Villard 1998; Martini 2011; Martini et al. 2013), are important for biodiversity.

This survey was carried out during a new phase of forestry ecosystem management and during important climate alterations, including a catastrophic windstorm in 2015. The current forestry management (2006–2015) indicates that about 90% of the forest will be re-naturalised through innovative, cautious and widespread silvicultural operations, synergic to the natural dynamics (Ciancio 2009). This method represents a turning point for the reserve: after centuries of major exploitation of woodlands for commercial purposes, for about 20 years (in the 20th and 21st centuries) there was poor forest management (i.e. poor cutting of dead, endangered, or falling trees).

The aim of this work was to evaluate the main ecological indices of the Vallombrosa forest and to determine its biodiversity level from the bird structure and composition as a function of the type of forest, season and altitude.

The terrible windstorm on 5 March 2015 resulted in fallen trees in large areas of the forest; the results of this study represent the “first phase” of a series of observations and considerations taken at a local level on the impacts and damage of climate change. The continuation of the study in 2017–2018 will allow a first evaluation of the possible changes to the bird community in the forest.

Materials and methods

Study area

Vallombrosa Biogenetic National Nature Reserve is located in the municipality of Reggello in the province of Florence, on the north-west side of Pratomagno Massif, which divides the Casentino Valley and the upper Valdarno. The size of the reserve is 1273 ha and the altitude varies between 470 and 1447 m above sea level (a.s.l.). This area is characterised by steep slopes and torrential, seasonal and short rivers (Patrone 1970).

Sedimentary rocks, mainly sandstones of varying structure and texture, characterise the area of the reserve. There are also many schistose rocks (called “galestro”) that produce poor limestone and rather acid soils.

Soils are well drained and well structured, with variable depth. The Mediterranean climate of this area is characterised by cool summers and mild winters, with frequent, sometimes heavy rains. The main

forest type is the high forest of *Abies alba* (664 ha), but the end of the cutting of trees at ground level and the suspension of anthropogenic restoration practices, along with the frequent windstorms, are leading to a mixed forest of deciduous prevalence. The high forest of *Fagus sylvatica*, the second forest type of the reserve, occupies 187 ha between 1000 and 1450 a. s.l. This is an old forest, between 70 and 170 years old. Near the high-altitude limit, the prevalent species is *Pinus nigra* (also *Pseudotsuga menziesii*, introduced for experimental purposes). At the same altitude there are also deciduous mixed forests of *Castanea sativa*, *Quercus cerris*, *Quercus pubescens*, *Ostrya carpinifolia*, *Fagus sylvatica* and *Fraxinus ornus*, in addition to a few tree species with high naturalistic relevance: old chestnut coppice and chestnut trees for fruit production that are growing in natural forest.

The most common mammals are ungulates, mainly *Dama dama* and *Sus scrofa*. These animals have a detrimental effect on forest restoration, without affecting the conservation of the forest ecosystem. This area also hosts *Capreolus capreolus* and *Cervus elaphus*, the latter a species thought to be moving towards larger and richer pastures. Among the small mammals, there are *Vulpes vulpes*, *Mustela nivalis*, *Martes faina*, *Mustela putorius*, *Glis glis*, *Hystrix cristata*, *Lepus europaeus*, *Erinaceus europaeus*, *Sciurus vulgaris*, *Meles meles*, *Muscardinus avellanarius* and various bats. The presence of *Canis lupus* and *Felis silvestris* has been documented in this area.

Among the reptiles of European interest in this area are *Lacerta viridis* and *Podarcis muralis*, while among the amphibia there are *Bombina pachypus*, *Triturus carnifex*, *Speleomantes italicus* and *Salamandra salamandra*, protected by Regional Law (L.R.) 56/2000 (Ciancio 2009).

The class of birds includes numerous species related to old forest that play an important ecological role in these ecosystems. These birds belong to the orders Passeriformes, Piciformes, Columbiformes, Accipitriformes and Strigiformes. The Species of Conservation Interest (SCI) under Directive 147/2019 92/43/EEC reported in the reserve are the Eurasian tree-creeper *Certhia familiaris*, the lesser spotted woodpecker *Dendrocopos minor* and the European honey buzzard *Pernis apivorus*. Vallombrosa forest is a Biogenetic National Nature Reserve, registered in the official List of Protected Areas (R.L. 394/91). The reserve includes the Special Conservation Zone (SCZ) IT51400012 “Vallombrosa and Sant’Antonio Forest” (Natura 2000 network), which is defined as a “Site of Regional Interest” (SIR46) according to the Tuscan Regional Law no. 56/2000: “Rules for the conservation of the natural and semi-

natural environment and of flora and wildlife”. In this site, characterised by many habitats and species of European interest, and for scientific purposes, innovative “forestry ecosystem management” was introduced and developed. This management is innovative because is a complex biological system based on autopoiesis, which describes the capacity of an entity to reproduce itself and permits autonomous organisation and evolution of the forest. Systemic silviculture using the “modular cutting system” was carried out; this system applies targeted methods that allow the conservation, preservation and re-naturalisation of the forest. The conservation permits the maintenance of the historical, cultural and landscaping (about 100 ha) characters; the preservation permits the monitoring of non-anthropised forest areas and those undergoing re-naturalisation (about 50 ha). This re-naturalisation improves the intrinsic self-organisation of the natural and evolutive processes of the forest stands (about 1100 ha). The systemic silviculture, respecting and promoting forest functionality, considers anthropic activity essential in the ecosystem (Ciancio 2009).

Bird community

To study the bird populations of Vallombrosa Reserve, the “point count” method was used (Blondel et al. 1981; Volpato et al. 2009). This method is commonly used in ornithology because it allows the collection of information about the number of species and individuals in a particular area, and it is the most suitable for use in a forest environment

(Massa 1998; Klingbeil & Willig 2015). Individuals seen and/or heard were annotated while standing still in one place (station) for 10 minutes (Thompson et al. 2002). Forty-one stations were distributed at intervals of no more than 200 m along the pathways, public roads and forest roads of the reserve (Dawson 1981; Bibby et al. 1992). The position of the stations was recorded via paper cartography (forestry vegetation map, scale 1:10,000, attached to the Forestry Management Plan 2006–2025) and via Global Positioning System (GPS), then imported into a Geographic Information System (GIS; Figure 1).

The bird population was studied considering the vegetation cover (individuated through the Forestry Management Plan), the season and the altitude. The “listening points” were chosen via stratified sampling, considering the level of the vegetation cover. The vegetation classes used were the following:

- Marginal areas (MA): Represented by the few open areas of the reserve, near the Vallombrosa Abbey, around the buildings and nurseries. Five marginal areas were chosen; these are relevant ecological zones.
- Coniferous (Co): Coniferous forests, mainly *Abies alba*. Eighteen coniferous areas were chosen.
- Coniferous and broadleaved (Co/Bl): Mixed broadleaved and coniferous woodland forest, in variable percentages. Thirteen mixed areas were chosen.
- Broadleaved (Bl): Broadleaved forests, mainly represented by *Fagus sylvatica*. Five deciduous areas were chosen.

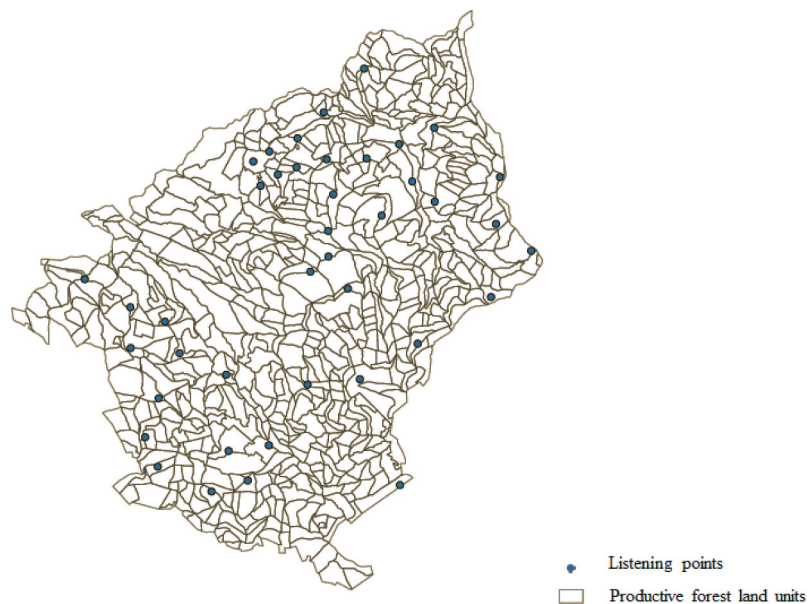


Figure 1. Point counts map – listening points.

Throughout the year, each station was visited once a month; the listening time was 10 minutes for each station. For all species and in all cases, playback was never used to stimulate the bird response. Monitoring began at sunrise and continued for 5 hours, except when there was rainfall or snowfall, or unfavourable wind.

For the seasonal parameter, the reproductive physiological status of the bird populations was considered. Four groups were individuated: February, March (FM) – the pre-reproductive period; April, May, June, July (AMJJ) – the reproductive period; August, September, October, November (ASON) – the post-reproductive period; December, January (DJ) – the wintry period.

The altitude of the stations was considered to evaluate the altitude parameter. Four classes were individuated: 600–800, 800–1000, 1000–1200 and 1200–1400 m a.s.l.

Using the count data, the main ecological parameters were calculated:

Abundance (N): The total number of individuals.

Richness (S): The number of species. This gives the population richness and its complexity.

Relative frequency (p_i): The ratio of the number of individuals of a particular species to the number of total individuals in the ornithical community. The equation for the relative frequency is $p_i = n_i/N$, where n_i = number of individuals of the i th species and $N = \sum n_i$. When p_i is equal to or greater than 0.05, the species is considered dominant (Turček 1956; Oelke 1980; Fulco & Tellini Florenzo 2008; Angelici et al. 2012; Domokos & Domokos 2016); when p_i is between 0.02 and 0.05, the species is subdominant. This index indicates the relative relevance of every species in a community.

Shannon–Wiener Diversity (H') (Wiener 1948; Shannon & Weaver 1949): This is the most commonly used index for species diversity (Hubalek 2000). This index gives the population biodiversity, and it depends on the number of species and their abundance. The equation for calculating this index is $H' = -\sum_{i=1}^S (p_i \cdot \ln p_i)$. It ranges between 0 (monospecific community) and $\ln S$ (maximum richness, where the species are equally represented). It measures the probability that individuals of different species will be found during the monitoring. Diversity is positively correlated with the H' value: an increase in H' corresponds to a higher diversity. The value of H' can range between 0 and, theoretically, $+\infty$.

Evenness (J'): The homogeneity of distribution of the different species abundances in a community. The equation for calculating this index is $J' = H'/$

H'_{\max} , where $H'_{\max} = \ln S$. Its value varies between 0, when only one species is present, and 1, when the species of the community are equally distributed (equal abundance index). It depends only on the distribution of the abundances of individuals within the species (Lloyd & Ghelardi 1964; Pielou 1966).

Non-passerine percentage (NP%): In a bird community, this parameter gives the percentage of the species not belonging to the order Passeriformes. It can indicate the presence of stenoic species; previous studies have shown that the non-Passeriformes may be absent in the initial phases of an ecological succession, and may increase in the subsequent stages (Bellomo 2006).

The ecological parameters and the overall species abundances higher than 100 were analysed, using JMP® (2012), with the Kruskal–Wallis non-parametric test, considering the following as fixed factors:

Vegetation type: marginal areas (MA); coniferous forests (Co); coniferous and broadleaved forests (Co/Bl); broadleaved forests (Bl).

Seasonal period (Season): pre-reproductive period, in February and March (FM); reproductive period, in April, May, June and July (AMJJ); post-reproductive period, in August, September, October and November (ASON); wintry period, in December and January (DJ).

Altitude: 600–800 (A), 800–1000 (B), 1000–1200 (C) and 1200–1400 (D) m a.s.l.

To compare the groups, the non-parametric Dunn test was used.

For the above parameters, principal component analysis (PCA) was also applied. PCA belongs to the group of multivariate analysis methods. Its basic concept is to describe a given phenomenon using a small number of so-called hidden factors (i.e. components) in relation to an extensive set of primary variables. This method was selected to determine the degree of similarity between vegetation type, season, altitude and bird populations. The Kaiser test was applied, and biplot graphics were created to visualise the bird population distribution in different vegetation types, seasons and altitudes (Sargentini et al. 2018).

The abbreviations used for the listed species are as follows: common swift – *Apus apus* (AA); long-tailed bushtit – *Aegithalos caudatus* (AC); Eurasian sparrow hawk – *Accipiter nisus* (AN); tree pipit – *Anthus trivialis* (AT); common buzzard – *Buteo buteo* (BB); short-toed treecreeper – *Certhia brachydactyla* (CB); goldfinch – *Carduelis carduelis* (CC); Eurasian blue tit – *Cyanistes caeruleus* (Cc); common cuckoo – *Cuculus canorus* (Cca); greenfinches – *Carduelis chloris* (Cch); Hooded Crow – *Corvus cornix* (Cco); hawfinch –

Coccothraustes coccothraustes (Coco); common wood-pigeon – *Columba palumbus* (CP); Eurasian siskin – *Carduelis spinus* (CS); great spotted woodpecker – *Dendrocopus major* (DM); black woodpecker – *Dryocopus martius* (Dm); lesser spotted woodpecker – *Dendrocopus minor* (DMi); ciril bunting – *Emberiza cirilus* (EC); European robin – *Erithacus rubecula* (ER); common chaffinch – *Fringilla coelebs* (FC); brambling – *Fringilla montifringilla* (FM); Eurasian jay – *Garrulus glandarius* (GG); crested tit – *Lophophanes cristatus* (Lc); white wagtail – *Motacilla alba* (MA); grey wagtail – *Motacilla cinerea* (MC); spotted flycatcher – *Muscicapa striata* (MS); coal tit – *Periparus ater* (PA); European honey buzzard – *Pernis apivorus* (Pa); chiffchaff – *Phylloscopus collybita* (PC); great tit – *Parus major* (PM); black redstart – *Phoenicurus ochruros* (PO); marsh tit – *Poecile palustris* (PP); Eurasian bullfinch – *Pyrrhula pyrrhula* (Pp); common redstart – *Phoenicurus phoenicurus* (Pph); Eurasian crag martin – *Ptyonoprogne rupestris* (PR); European green woodpecker – *Picus viridis* (PV); common firecrest – *Regulus*

ignicapilla (RI); goldcrest – *Regulus regulus* (RR); blackcap – *Sylvia atricapilla* (SA); tawny owl – *Strix aluco* (Sa); European nuthatch – *Sitta europaea* (SE); European serin – *Serinus serinus* (SS); Eurasian blackbird – *Turdus merula* (TM); song thrush – *Turdus philomelos* (TP); Eurasian northern wren – *Troglodytes troglodytes* (TT); mistle thrush – *Turdus viscivorus* (TV); Eurasian hoopoe – *Upupa epops* (UE).

Results

Bird community and ecological indices

From September 2013 to August 2014, 47 bird species were recorded in Vallombrosa Reserve (Table I): 11 species belonged to non-passerine orders (Accipitriformes, Apodiformes, Bucerotiformes, Cuculiformes, Columbiformes, Piciformes, Strigiformes) and 36 were Passeriformes. Among the non-passerine species, there were diurnal and nocturnal birds of prey. In this study, 6569 contacts were recorded. During the

Table I. Total number of birds contacted (n_i) and dominance (relative frequency) (p_i).

	Species	Order	n_i	p_i		Species	Order	n_i	p_i
1	AA	Apodiformes	16	0.002436	25	MC	Passeriformes	10	0.001522
2	AC	Passeriformes	54	0.00822	26	MS	Passeriformes	2	0.000304
3	AN	Accipitriformes	1	0.000152	27	PA	Passeriformes	1130	0.17202
4	AT	Passeriformes	1	0.000152	28	Pa	Accipitriformes	2	0.000304
5	BB	Accipitriformes	15	0.002283	29	PC	Passeriformes	21	0.003197
6	CB	Passeriformes	385	0.058609	30	PM	Passeriformes	82	0.012483
7	CC	Passeriformes	1	0.000152	31	PO	Passeriformes	19	0.002892
8	Cc	Passeriformes	234	0.035622	32	PP	Passeriformes	116	0.017659
9	Cca	Cuculiformes	18	0.00274	33	Pp	Passeriformes	3	0.000457
10	Cch	Passeriformes	21	0.003197	34	Pph	Passeriformes	13	0.001979
11	Cco	Passeriformes	14	0.002131	35	PR	Passeriformes	1	0.000152
12	Coco	Passeriformes	16	0.002436	36	PV	Piciformes	23	0.003501
13	CP	Columbiformes	110	0.016745	37	RI	Passeriformes	370	0.056325
14	CS	Passeriformes	90	0.013701	38	RR	Passeriformes	111	0.016898
15	Dm	Piciformes	19	0.002892	39	SA	Passeriformes	104	0.015832
16	DM	Piciformes	160	0.024357	40	Sa	Strigiformes	1	0.000152
17	DMi	Piciformes	6	0.000913	41	SE	Passeriformes	512	0.077942
18	EC	Passeriformes	2	0.000304	42	SS	Passeriformes	1	0.000152
19	ER	Passeriformes	209	0.031816	43	TM	Passeriformes	262	0.039884
20	FC	Passeriformes	1645	0.250419	44	TP	Passeriformes	187	0.028467
21	FM	Passeriformes	12	0.001827	45	TT	Passeriformes	202	0.03075
22	GG	Passeriformes	235	0.035774	46	TV	Passeriformes	122	0.018572
23	Lc	Passeriformes	5	0.000761	47	UE	Bucerotiformes	1	0.000152
24	MA	Passeriformes	5	0.000761					

Notes. Apus apus (AA); Aegithalos caudatus (AC); Accipiter nisus (AN); Anthus trivialis (AT); Buteo buteo (BB); Certhia brachydactyla (CB); Carduelis carduelis (CC); Cyanistes caeruleus (Cc); Cuculuscanorus (Cca); Carduelis chloris (Cch); Hooded Crow – Corvus cornix (Cco); Coccothraustes coccothraustes (Coco); Columba palumbus (CP); Carduelis spinus (CS); Dendrocopus major (DM); Dryocopus martius (Dm); Dendrocopus minor (DMi); Emberiza cirilus (EC); Erithacus rubecula (ER); Fringilla coelebs (FC); Fringilla montifringilla (FM); Garrulus glandarius (GG); Lophophanes cristatus (Lc); Motacilla alba (MA); Motacilla cinerea (MC); Muscicapa striata (MS); Periparus ater (PA); Pernis apivorus (Pa); Phylloscopus collybita (PC); Parus major (PM); Phoenicurus ochruros (PO); Poecile palustris (PP); Pyrrhula pyrrhula (Pp); Phoenicurus phoenicurus (Pph); Ptyonoprogne rupestris (PR); Picus viridis (PV); Regulus ignicapilla (RI); Regulus regulus (RR); Sylvia atricapilla (SA); Strix aluco (Sa); Sitta europaea (SE); Serinus serinus (SS); Turdus merula (TM); Turdus philomelos (TP); Troglodytes troglodytes (TT); Turdus viscivorus (TV); Upupa epops (UE).

considered period, five species were found to be dominant, meaning each showed an abundance value higher than 5% of the total abundance (Turček 1956): common chaffinch, coal tit, European nuthatch, short-toed treecreeper and common firecrest. The following sub-dominant species had abundance values between 2% and 5% of the total abundance (Purroy 1975): Eurasian blackbird, Eurasian jay, Eurasian blue tit, European robin, northern wren, song thrush, European green woodpecker.

In this study individuals of *Dryocopus martius* were found in six live beech trees with damaged trunks, which contained 22 holes (nest cavities), including one that was an outline and two that were not completed. Many holes for feeding were found on trunks of *Abies alba*, *Pinus nigra* and *Fagus sylvatica* at altitudes ranging from 800 to 1400 m. a.s.l.

The most important ecological indices, considered throughout the whole year, showed an S' value of 47 and a non-passerine percentage of 23.40%.

The annual trend of the species richness and the percentage of non-passerine species is shown in Figure 2. The richness estimated throughout the year (Figure 2) produced the following results: the lowest values were found in DJ, with 21 recorded species; and the highest number of species was recorded, with a

peak of 33 in April, during the reproductive and post-reproductive period (from April to August), when nesting species are present in the reserve.

The non-passerine species were present throughout year (Figure 2) with percentages higher than 14.3% (DJ). The highest percentages occurred in May and June, when they reached 22.2% (five NP species among 27 counted species) and 21.9% (seven NP species among 33 counted species), respectively. A peak of 21.7% was registered in October. The overall Shannon–Wiener index reached a value of 2.50, while the evenness index (J') was 0.91 (Figure 3). The Shannon–Wiener diversity index reached its highest values in the spring and summer months, with a peak in June, when many nesting species are present in the forest. The lowest values were registered in October and November. The evenness index was constant during the year (Figure 3).

Vegetation type ecological indices

In Table II the most important ecological indices considered for listening points and vegetation type are shown. The abundance index, the species richness and the Shannon–Wiener index were highest in MA. The evenness index did not show significant

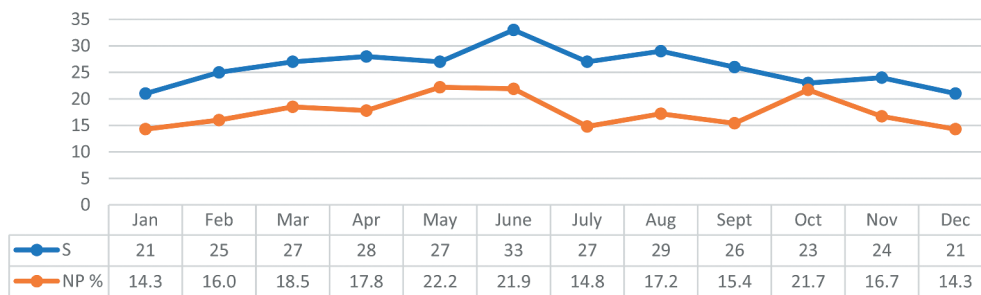


Figure 2. Trend throughout the year of species richness (S) and of non-passeriform species percentage (NP%).

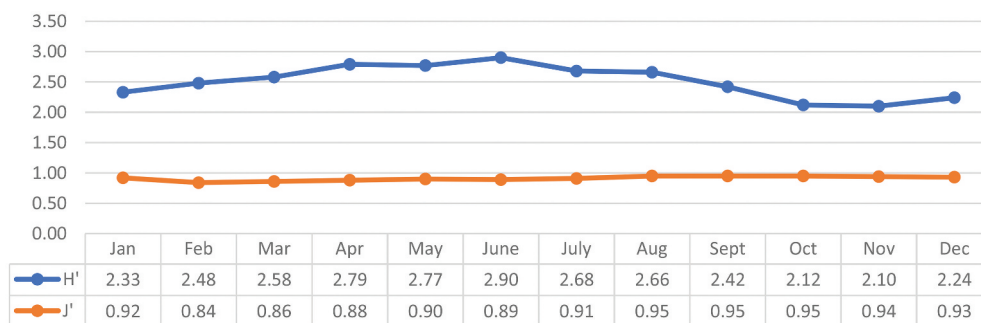


Figure 3. Trend throughout the year for the Shannon–Wiener (H') and evenness (J') indices.

Table II. Ecological Indices by vegetation type (mean \pm standard deviation; χ^2 and $P > \chi^2$ from Kruskal-Wallis test) using Dunn's multiple comparison test.

	MA	Co	Co/Bl	Bl	χ^2	$P > \chi^2$	Dunn's test differences
N	18.48 \pm 9.39	12.78 \pm 5.94	12.55 \pm 6.38	13.83 \pm 9.85	29.27	<0.0001*	Co vs MA; Co/Bl vs AM; Bl vs MA
S	9.05 \pm 3.08	7.05 \pm 2.36	6.81 \pm 3.39	5.23 \pm 2.12	60.02	<0.0001*	Bl vs Co; Co vs MA; Bl vs Co; Co/Bl vs MA; Bl vs MA
H'	1.92 \pm 0.44	1.75 \pm 0.38	1.71 \pm 0.40	1.33 \pm 0.51	54.09	<0.0001*	Co vs MA; Co/Bl vs MA; Bl vs Co/Bl; Bl vs Co; Bl vs MA
J'	0.91 \pm 0.07	0.92 \pm 0.07	0.92 \pm 0.08	0.84 \pm 0.17	9.58	0.0225*	
NP%	9.71 \pm 8.83	8.03 \pm 9.25	7.92 \pm 9.95	4.90 \pm 9.23	11.43	0.0096*	Bl vs Co; Bl vs MA

Notes. Marginal areas (MA); Coniferous (Co); Coniferous and broadleaved (Co/Bl); Broadleaved (Bl); Abundance (N); Richness (S); Shannon–Wiener Diversity (H'); Evenness (J'); Non Passerine percentage (NP%).

variation among groups, and the non-passerine index was significantly lower in the Bl forests.

Seasonal ecological indices

The ecological indices of the bird community evaluated according to season and phenological stadium are shown in Table III. The abundance was higher in FM, while the specific richness was higher in the pre-reproductive period (FM) and reproductive period (AMJJ). The Shannon–Wiener index was higher in the reproductive season (AMJJ). The evenness index was higher in the reproductive period, indicating that this forest is a nesting area with equal species richness. Even the non-passerine index was higher in the pre-reproductive and reproductive seasons.

Altitude ecological indices

Table IV shows the distribution of the ornithical community according to altitude: abundance and richness were higher at low altitudes. The richness was higher between 600 and 1000 m a.s.l.; it decreased

significantly at 1000–1200 m and again at 1200–1400 m. The Shannon–Wiener index showed the same trend as the richness (Table IV). The percentage of non-passerine species was higher at low altitude; it decreased at 800–1200 m a.s.l., and the lowest value was found at 1200–1400 m. The evenness index was high and did not differ with altitude, while the non-passerine index was lower at high altitudes.

Species by vegetation type (numbers greater than 100)

Among the species having numbers greater than 100, Eurasian blue tit, great spotted woodpecker and Eurasian blackcap prefer the marginal areas (Table V). These results were confirmed by the PCA (Figure 4).

Marsh tit lives in the broadleaved forests and in the marginal areas (Table V). In the beech woodlands an average abundance of 0.571 was found. The Northern wren prefers the pure and mixed coniferous forests. Among the members of the family Turdidae, the Eurasian blackbird prefers mainly the marginal areas, then the pure and mixed coniferous forests and finally the broadleaf forests.

Table III. Ecological Indices by season (mean \pm standard deviation; χ^2 and $P > \chi^2$ from Kruskal-Wallis test) using Dunn's multiple comparison test.

	AMJJ	ASON	DJ	FM	χ^2	$P > \chi^2$	Dunn's test differences
N	12.85 \pm 4.46	13.62 \pm 9.13	12.21 \pm 7.20	16.10 \pm 7.91	18.091	0.0003*	FM vs DJ; FM vs ASON; FM vs AMJJ
S	8.09 \pm 2.32	6.11 \pm 2.47	5.60 \pm 2.28	7.90 \pm 2.52	84.03	<0.0001*	FM vs DJ; FM vs ASON; ASON vs AMJJ; DJ vs AMJJ
H'	1.94 \pm 0.32	1.53 \pm 0.42	1.46 \pm 0.46	1.82 \pm 0.38	104.13	<0.0001*	FM vs DJ; FM vs ASON; ASON vs AMJJ; DJ vs AMJJ
J'	0.95 \pm 0.03	0.89 \pm 0.11	0.89 \pm 0.12	0.90 \pm 0.10	46.52	<0.0001*	DJ vs AMJJ; FM vs AMJJ; ASON vs AMJJ
NP%	0.09 \pm 0.09	0.05 \pm 0.08	0.04 \pm 0.07	0.08 \pm 0.09	29.55	<0.0001*	FM vs DJ; FM vs ASON; ASON vs AMJJ; DJ vs AMJJ

Notes. Abundance (N); Richness (S); Shannon–Wiener Diversity (H'); Evenness (J'); Non Passerine percentage (NP%); April, May, June, July (AMJJ); August, September, October, November (ASON); December, January (DJ); February, March (FM).

Table IV. Ecological Indices by elevation (mean \pm standard deviation; χ^2 and $P > \chi^2$ from Kruskal-Wallis test) using Dunn's multiple comparison test.

	A	B	C	D	χ^2	$P > \chi^2$	Dunn's test differences
N	13.83 \pm 3.71	14.60 \pm 7.80	12.51 \pm 6.60	12.50 \pm 9.03	23.42	<0.0001*	C vs B; C vs A; D vs B; D vs A
S	8.23 \pm 2.06	7.73 \pm 2.74	6.47 \pm 2.15	5.2 \pm 2.19	76.86	<0.0001*	C vs B; D vs C; C vs A; D vs B; D vs A
H'	1.95 \pm 0.31	1.81 \pm 0.40	1.65 \pm 0.35	1.35 \pm 0.51	81.34	<0.0001*	C vs B; D vs C; C vs A; D vs B; D vs A
J'	0.94 \pm 0.03	0.92 \pm 0.08	0.91 \pm 0.08	0.87 \pm 0.16	4.75	<0.1910	
NP%	0.10 \pm 0.09	0.07 \pm 0.08	0.07 \pm 0.09	0.03 \pm 0.07	26.35	<0.0001*	D vs C; C vs A; D vs B; D vs A

Notes. Richness (S); Shannon–Wiener Diversity (H'); Evenness (J'); Non Passerine percentage (NP%); 600–800 meters above sea level (A); 800–1000 meters above sea level (B); 1000–1200 meters above sea level (C); Abundance (N).

Table V. Distribution of species with total number > 100 by vegetation type (Average number of individuals per station) using Dunn's pairwise multiple-comparison test.

Species	MA	Co	Co/Bl	Bl	χ^2	Dunn's test differences
PP	0.52	0.11	0.14	0.67	46.95	MA vs Co; MixCo/Bl vs MA; MixCo/Bl vs Bl; Co vs Bl
Cc	1.10	0.34	0.41	0.55	24.38	MA vs Co; MA vs Bl; MixCo/Bl vs MA
PA	2.33	2.49	2.20	2.07	10.71	n.s.
CP	0.33	0.21	0.25	0.12	4.26	n.s.
GG	0.65	0.44	0.51	0.40	4.28	n.s.
TT	0.35	0.51	0.42	0.13	17.08	Co vs Bl; MixCo/Bl vs Bl;
ER	0.43	0.43	0.50	0.25	3.26	n.s.
TM	1.10	0.52	0.51	0.12	38.34	MA vs Bl; MA vs Co; MixCo/Bl vs Bl; Co vs Bl; MixCo/Bl vs MA
TP	0.30	0.47	0.40	0.15	17.72	Co vs Bl; MA vs Co
TV	0.32	0.28	0.24	0.10	4.03	n.s.
RI	0.60	0.98	0.79	0.10	36.85	Co vs Bl; MixCo/Bl vs Bl; MA vs Bl
RR	0.08	0.30	0.28	0.00	21.84	Co vs Bl; MixCo/Bl vs Bl; MAVs Co
CB	0.70	0.99	0.79	0.22	52.29	Co vs Bl; MixCo/Bl; MA vs Bl
SE	1.25	1.02	1.03	1.07	2.07	n.s.
DM	0.50	0.43	0.22	0.10	26.09	MAvs Bl; Cova Bl; MixCo/Bl vs Co; MixCo/Bl vs MA
FC	3.53	2.63	3.09	6.60	10.72	Co vs Bl
SA	0.83	0.13	0.15	0.07	59.83	MA vs Bl; MA vs Co; MixCo/Bl vs MA

Notes. Poecile palustris (PP); Cyanistes caeruleus (Cc); Periparus ater (PA); Columba palumbus (CP); Garrulus glandarius (GG); Troglodytes troglodytes (TT); Erithacus rubecula (ER); Turdus merula (TM); Turdus philomelos (TP); Turdus viscivorus (TV); Regulus ignicapilla (RI); Regulus regulus (RR); Certhia brachydactyla (CB); Sitta europaea (SE); Dendrocopos major (Dm); Fringilla coelebs (FC); Sylvia atricapilla (SA); Marginal areas (MA); Coniferous (Co); Coniferous and broadleaved (Co/Bl); Broadleaved (Bl).

Goldcrest and common firecrest showed higher average abundance values in the pure and mixed coniferous forest. The short-toed treecreeper showed lower average abundance values in the broadleaf (beech) forest. The coal tit showed higher average abundance values in the coniferous forest.

Species by season (numbers greater than 100)

Table VI shows the average number of individuals per station in different periods of the year. Marsh tit, Eurasian blue tit and coal tit showed the highest abundance values in late summer/autumn (ASON) and in FM. The findings in the table agree with the PCA results (Figure 5). The highest average number of common

woodpigeon individuals was found in FM and AMJJ. The highest average numbers of northern wren and European robin individuals were found in AMJJ, while Eurasian blackbird and common firecrest individuals showed their highest numbers in FM and AMJJ. During the trial the song thrush was mainly individuated in FM, when its singing activity was highest; short-toed treecreeper and European nuthatch individuals showed their highest numbers in ASON. The great spotted woodpecker reached its highest numbers in FM, when the individuals of this species – early singing birds – start to sing; even the common chaffinch showed the highest abundance in this period, probably because of the presence of migratory birds. The average number of Eurasian blackcap individuals was highest by far in AMJJ.

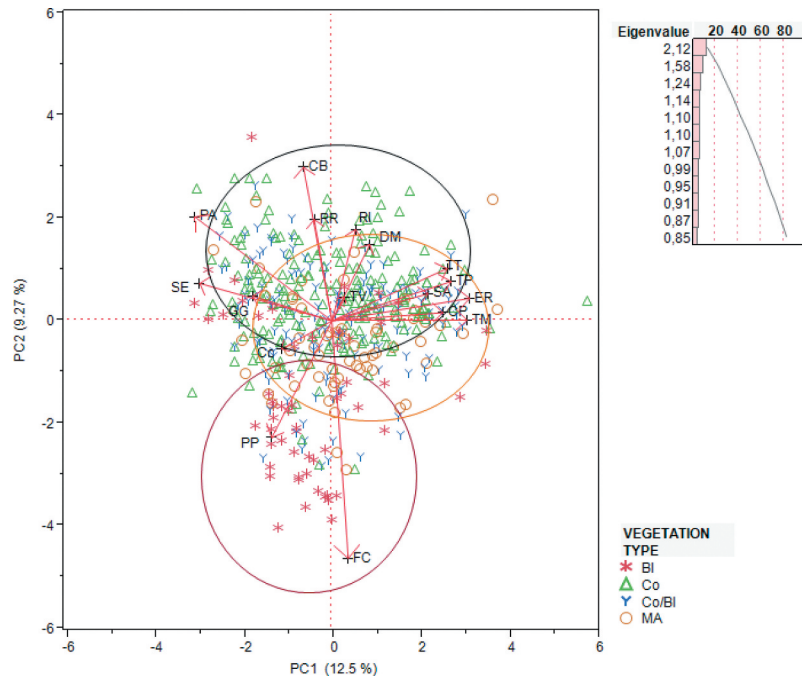


Figure 4. PCA: Biplot of the distribution of species with total number > 100 by vegetation type. *Notes.* Poecile palustris (PP); Cyanistes caeruleus (Cc); Periparus ater (PA); Columba palumbus (CP); Garrulus glandarius (GG); Troglodytes troglodytes (TT); Erithacus rubecula (ER); Turdus merula (TM); Turdus philomelos (TP); Turdus viscivorus (TV); Regulus ignicapilla (RI); Regulus regulus (RR); Certhia brachydactyla (CB); Sitta europaea (SE); Dendrocopus major (Dm); Fringilla coelebs (FC); Sylvia atricapilla (SA); Marginal areas (MA); Coniferous (Co); Coniferous and broadleaved (Co/BI); Broadleaved (BI).

Table VI. Distribution of species with total number > 100 by season (Average number of individuals per station) using Dunn’s pairwise multiple-comparison test.

Species	AMJJ	ASON	DJ	FM	χ^2	Dunn’s test differences
PP	0.11	0.40	0.18	0.23	13.71	ASON vs AMJJ
Cc	0.31	0.51	0.64	0.62	26.12	DJ vs AMJJ; FM vs AMJJ; ASON vs AMJJ
PA	1.83	2.64	2.47	2.58	18.99	FM vs AMJJ; ASON vs AMJJ
CP	0.41	0.05	0.00	0.42	79.98	FM vs DJ; FM vs ASON; ASON vs AMJJ; DJ vs AMJJ
GG	0.28	0.78	0.36	0.43	46.05	ASON vs AMJJ; FM vs ASON; DJ vs ASON
TT	0.62	0.28	0.22	0.46	35.81	ASON vs AMJJ; DJ vs AMJJ
ER	0.84	0.26	0.09	0.28	112.41	FM vs AMJJ; ASON vs AMJJ; DJ vs AMJJ
TM	0.76	0.35	0.22	0.77	43.38	FM vs DJ; FM vs ASON; ASON vs AMJJ; DJ vs AMJJ
TP	0.56	0.18	0.06	0.77	111.76	FM vs DJ; FM vs ASON; FM vs AMJJ; ASON vs AMJJ; DJ vs AMJJ
TV	0.25	0.23	0.27	0.28	3.97	n.s.
RI	0.99	0.45	0.60	1.08	44.40	FM vs ASON; FM vs DJ; DJ vs AMJJ; ASON vs AMJJ
RR	0.19	0.17	0.34	0.29	6.32	n.s.
CB	0.83	0.90	0.62	0.70	9.54	DJ vs ASON
SE	0.79	1.40	1.09	0.89	30.48	ASON vs AMJJ; FM vs ASON
DM	0.36	0.23	0.27	0.51	8.63	FM vs ASON
FC	2.14	3.86	3.77	4.54	17.43	FM vs ASON; FM vs AMJJ;
SA	0.51	0.04	0.00	0.16	101.60	FM vs AMJJ; ASON vs AMJJ; DJ vs AMJJ

Notes. Poecile palustris (PP); Cyanistes caeruleus (Cc); Periparus ater (PA); Columba palumbus (CP); Garrulus glandarius (GG); Troglodytes troglodytes (TT); Erithacus rubecula (ER); Turdus merula (TM); Turdus philomelos (TP); Turdus viscivorus (TV); Regulus ignicapilla (RI); Regulus regulus (RR); Certhia brachydactyla (CB); Sitta europea (SE); Dendrocopus major (Dm); Fringilla coelebs (FC); Sylvia atricapilla (SA); April, May, June, July (AMJJ); August, September, October, November (ASON); December, January (DJ); February, March (FM).

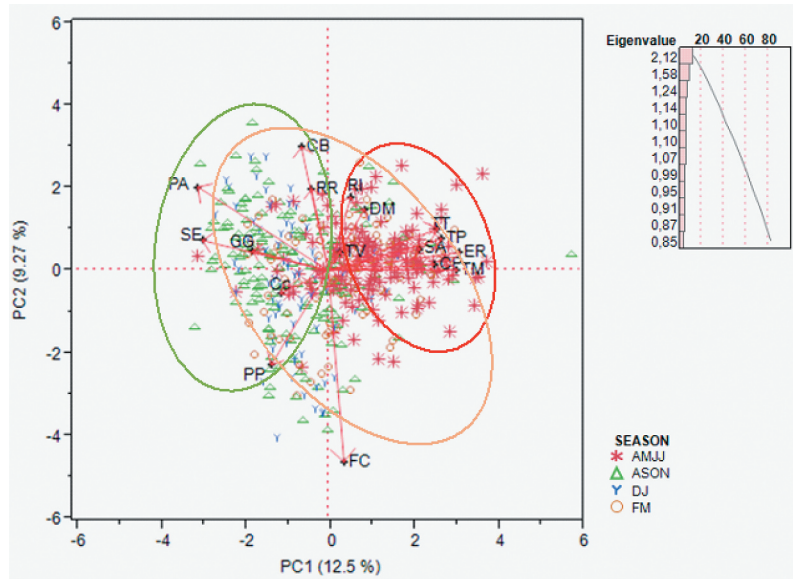


Figure 5. PCA: Biplot of the distribution of species with total number > 100 by altitude (m above sea level). *Notes.* Poecile palustris (PP); Cyanistes caeruleus (Cc); Periparus ater (PA); Columba palumbus (CP); Garrulus glandarius (GG); Troglodytes troglodytes (TT); Erithacus rubecula (ER); Turdus merula (TM); Turdus philomelos (TP); Turdus viscivorus (TV); Regulus ignicapilla (RI); Regulus regulus (RR); Certhia brachydactyla (CB); Sitta europea (SE); Dendrocopos major (Dm); Fringilla coelebs (FC); Sylvia atricapilla (SA); April, May, June, July (AMJJ); August, September, October, November (ASON); December, January (DJ); February, March (FM).

Species by altitude (numbers greater than 100)

In terms of altitude (Table VII), marsh tit (PP) preferred the high mountains. The results shown

in Table VII were confirmed by the PCA (Figure 6). In this study, northern wren avoided high altitudes, and Eurasian blackbird lived between 600 and 1000 m a.s.l. The highest average

Table VII. Distribution of species with total number > 100 by altitude (Average number of individuals per station) using Dunn’s pairwise multiple-comparison test.

Species	A	B	C	D	χ^2	Dunn’s test differences
PP	0.10	0.25	0.06	0.61	39.27	D vs C; B vs C; B vs D; A vs D
Cc	0.67	0.57	0.26	0.50	21.54	A vs C; B vs C
PA	2.03	2.27	2.67	2.06	11.49	C vs D
CP	0.33	0.28	0.17	0.11	12.11	A vs D; A vs C
GG	0.47	0.56	0.43	0.39	4.05	n.s.
TT	0.50	0.54	0.34	0.15	21.54	B vs D; A vs D; B vs C
ER	0.88	0.39	0.37	0.30	24.10	A vs D; A vs C; B vs A
TM	0.85	0.77	0.29	0.14	50.28	A vs B; B vs D; A vs C; B vs C
TP	0.58	0.39	0.42	0.14	15.08	A vs D; B vs D
TV	0.32	0.29	0.24	0.10	5.91	n.s.
RI	0.90	0.95	0.81	0.15	32.36	A vs D; B vs D; D vs C
RR	0.17	0.25	0.32	0.01	17.90	B vs D; D vs C; A vs C
CB	1.28	0.83	0.83	0.29	55.64	A vs D; B vs D; A vs C; B vs A; D vs C
SE	0.85	1.06	1.07	1.17	2.85	n.s.
DM	0.53	0.39	0.29	0.08	23.08	A vs D; B vs D; A vs C
FC	2.67	3.04	2.99	3.33	4.91	C vs D;
SA	0.12	0.36	0.12	0.10	22.00	B vs D; B vs C; B vs A

Notes. Poecile palustris (PP); Cyanistes caeruleus (Cc); Periparus ater (PA); Columba palumbus (CP); Garrulus glandarius (GG); Troglodytes troglodytes (TT); Erithacus rubecula (ER); Turdus merula (TM); Turdus philomelos (TP); Turdus viscivorus (TV); Regulus ignicapilla (RI); Regulus regulus (RR); Certhia brachydactyla (CB); Sitta europea (SE); Dendrocopos major (Dm); Fringilla coelebs (FC); Sylvia atricapilla (SA); 600–800 meters above sea level (A); 800–1000 meters above sea level (B); 1000–1200 meters above sea level (C); 1200–1400 meters above sea level (D).

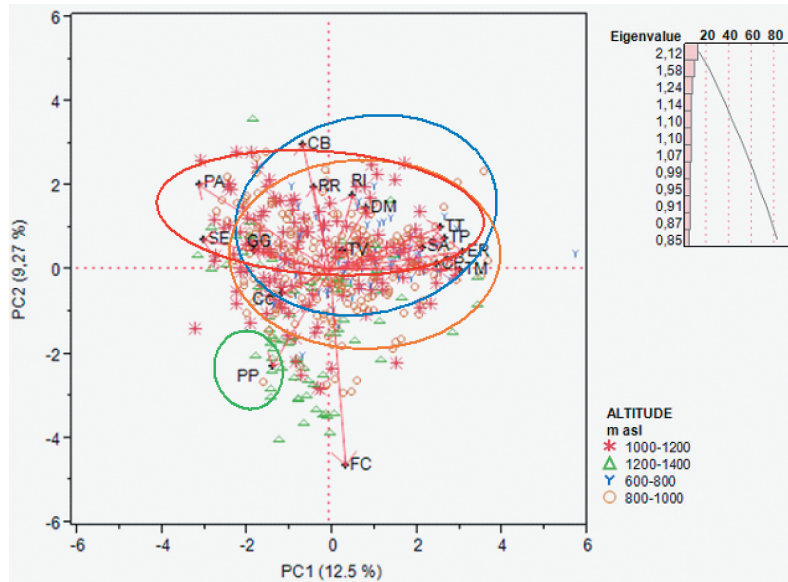


Figure 6. PCA: Biplot of the distribution of species with total number > 100 by season. *Notes.* Poecile palustris (PP); Cyanistes caeruleus (Cc); Periparus ater (PA); Columba palumbus (CP); Garrulus glandarius (GG); Troglodytes troglodytes (TT); Erithacus rubecula (ER); Turdus merula (TM); Turdus philomelos (TP); Turdus viscivorus (TV); Regulus ignicapilla (RI); Regulus regulus (RR); Certhia brachydactyla (CB); Sitta europea (SE); Dendrocopus major (Dm); Fringilla coelebs (FC); Sylvia atricapilla (SA).

abundance values of European robin (ER) were found at lower altitudes. Even the song thrush followed this trend. The highest abundance values of the short-toed treecreeper (CB) occurred between 600 and 800 m a.s.l., whereas the common firecrest and Great Spotted Woodpecker lived below 1200 m a.s.l.

Discussion

Bird community and ecological indices

The non-passerine birds represent a part of the ornithic community that is rather selective from an ecological point of view, so their abundance is an index of the higher or lower complexity of the bird community (Bernoni et al. 2012). Two examples are: the diurnal and nocturnal birds of prey, which are at the top of the food chain; and the woodpeckers, which require a complex and very peculiar environment. The presence of *Dryocopus martius*, listed in Annex I of Directive 147/2009/CE and in Annex III of the Berne Convention, was very important; it is a strictly protected species under National Law 157/92, and is a species of conservation interest in SCZ IT51400012 “Vallombrosa and Sant’Antonio Forest”. The presence of *Dryocopus martius* was identified in this area in 2010 (Martini 2011; Martini et al. 2013). The abundance index and the species richness were

highest in the ecotonal areas (Martini et al. 2017). The species richness value, an indicator of the complexity of the ornithic community (Gustin et al. 2015), agrees with the species richness value found in the wet zone of Sentina Natural Reserve (Gustin et al. 2015). The richness registered in April was higher than that registered in the nearby “Foreste Casentinesi”, where only high forest of white fir was considered (Lapini & Tellini 1990), and slightly higher than that registered in a beechwood in Basilicata (Fulco & Tellini Florenzo 2008). The number of species registered in April, May and June was higher than the average value recorded in three Aveto forests (Zatta, Lama and Penna) characterised by a different proportion of mixed *Abies alba* and *Fagus sylvatica* (Baghino 2013). The trend of this parameter during the year, characterised by small variations, agrees with the results of other studies examining complex forestry ecosystems (Malavasi 1998; Nardo 2001). The evenness index (J') as measured in this study agrees with the values for the “dello Zatta Forest” (Baghino 2013), whereas it is higher than the values found by the same author in the three regional forests of the Aveto Natural Park (Baghino 2013).

Ecological indices by vegetation type

The quite high Shannon–Wiener diversity index throughout the year confirmed, as observed by

other authors (Malavasi 1998; Nardo 2001), that evolved forestry ecosystems, having a high level of structural complexity and low anthropisation, are suitable habitats for a bird community that is qualitatively and quantitatively more or less constant during the year. The evenness is a measure of the relative abundance of the different species making up the richness of an area (Brichetti & Gariboldi 1997). This study showed index values close to the maximum value of 1; the diversified environment allows similar species abundance. The abundance index and the species richness agrees with previous studies carried out in similar and different territories: Giogo and Casaglia areas (Sposimo 1995), Foreste Casentinesi (Tellini Florenzano 1999), Brescia Prealps (Cambi & Micheli 1985), and the Niraj Valley in Romania (Domokos & Domokos 2016). The high ecological value of the ecotonal areas, which are strongly heterogeneous, is due to the so-called marginal effect (Silbernagel 2003). In these areas, various vegetation and environment typologies are present; here the typical bird species and the birds of the transitional areas, that are characterised by high density and biodiversity, live together (STERNA 2018).

Ecotonal effects on the biodiversity richness are shown in an anthropogenic naturalised environment, such as in the margins of cut woods and the nearby woods of Val di Non (Marchesi 2007). In the coniferous forest, the Shannon–Wiener index was higher than that found in an alpine environment in mixed forests with a prevalence of coniferous trees (Laiolo & Rolando 2005). In the mixed coniferous/broadleaved (beech) forest, the Shannon–Wiener value was lower than in a mixed forest of beech and white fir in Sambuca Pistoiese, where only the reproductive season (MAMJJ) was considered (Bettini & Gargani 2009–2010). The lowest evenness values were observed in broadleaved forests; this value was lower than the evenness index in similar forests in the north of Tuscany (Farina 1987).

The marginal areas, the coniferous forest, and the mixed coniferous and broadleaved forest seemed to show higher biodiversity than did the other vegetation types.

Ecological indices by season

The abundance was higher in FM, when there is an overlap of individuals in migration (mainly finches) and the early singing birds for attracting a mate. The richness results indicate that this area was chosen for nesting by various species. The Shannon–Wiener

value found in this study is comparable to that found in a study carried out in the forests of “Monte la Croce” (Sambuca pistoiese) during the period MAMJJ (Bettini & Gargani 2009–2010). In another study, in the Aveto Mounts, a very high Shannon–Wiener index was found, but only April and June were considered for the calculation (Baghino 2013).

The evenness index found in this study was higher than that obtained by Baghino (2013) in Aveto Mounts. Because the non-passerine index measures the structural complexity of the environment (Gustin et al. 2015), the values obtained in the present study indicate a good forest environmental heterogeneity. The indices found in FM and AMJJ agree with the values obtained in the Tarvisio forests in the Sciliar Natural Park (Sorace & Visentin 2007).

Ecological indices by altitude

In terms of altitude, the findings of this study agree with the results of Forconi (2018) and Massa et al. (1989) from studies carried out in Marche and in the Etna area, respectively: at high altitudes the species richness and structural complexity were lower, but more specialised birds live at these altitudes. Beskardes et al. (2018) also found, on pure oak stands in north-western Turkey, higher richness indices at lower altitude. In addition to high altitudes, a smaller difference in bird populations was found at lower latitudes and in areas with equatorial climate: in Usumbara Mountains in north-eastern Tanzania above 450 m a.s.l., the variety in composition of the bird community progressively decreased due to the lower temperature and the higher altitude.

The findings of this study do not agree with the Shannon–Wiener index found in the Italian Alps in 2010 (Popy et al. 2010); moreover, in 2019 some authors found an upwards shift in the altitudinal ranges of bird populations, caused by the warming climate and reduced snow (Bani et al. 2019). Also, in the Ailao Mountains of south-west China, in a study carried out between 1270 and 2470 m a.s.l., higher taxonomic diversity was found at high altitudes; this may be caused by the interspecific competition for food, and by the anthropic activities at lower altitudes (He et al. 2018). The evenness index, highly similar at different altitudes, indicated an adequate number of individuals distributed among the species; these results agree with the findings of Gustin and Di Federico (2016) in the Abruzzo forests and with those of Sorace and Visentin (2007) in other Italian areas. The low

non-passerine index at high altitudes agrees with the results of Brunelli et al. (2015) in the Duchessa Mountains of Latium (Central Italy).

Species by vegetation type (numbers greater than 100)

The value of Marsh tit abundance in broadleaved (0.67) was higher than the same parameter found on the Lepini Mounts (Sorace et al. 2004). The northern wren (TT) prefers the pure and the mixed coniferous forests, and does not prefer the broadleaf forests, as highlighted by Tellini Florenzano (1999) in the Casentino Forests Park, where the preferred environment of this species was the fir forest. In the same study, the Eurasian blackbird (SA) was found to avoid beech and fir forests, whereas the song thrush (TM) mainly preferred the coniferous forests. Tellini Florenzano (1999) also found goldcrest (RR) and common firecrest (RI) in the fir forest; both species showed higher average abundance values in the pure and mixed coniferous forest. A similar trend was observed in the Penna and Lama Forests (Aveto Park), where common firecrest (RI), coal tit (PA) and common chaffinch (FC) preferred pure or dominant fir forests (Baghino 2013). In the Casentino Forests (Tellini Florenzano 1999), the short-toed treecreeper (CB) avoided the broadleaved forests, whereas in the Lepini Mounts, in winter, its abundance was higher in beech forests than in marginal and reforested areas (Sorace et al. 2004). The coal tit (PA) results are in line with the results of Tellini Florenzano (1999), who showed that this species prefers the fir woodlands. In another study carried out in winter in the Lepini Mounts (Sorace et al. 2004), the abundance in the reforested coniferous areas was greater than that in the beech forests.

Species by season (numbers greater than 100)

The Eurasian blackcap findings agree with a study carried out in three state forests (Farina & Brogi 1995) in Tondo Mount area, in Monterufoli area and in Amiata Mount area (Madonna delle Querce). That study found that the species was absent in the DJ period in the forests of Tondo Mount, which has a mountain climate, and in the Monterufoli area. Results for the goldfinch (CC), northern wren (TT), goldcrest (RR), Great Spotted Woodpecker (DM) and Eurasian blackcap (SA) agree with those obtained in a study carried out in forests of England (Alder et al. 2018). The PCA partially agrees with Laiolo (2005), who found common woodpigeon (CP) associated with the spring season. Other species were associated with other seasons.

Species by altitude (numbers greater than 100)

The marsh tit (PP) findings did not agree with those of another study carried out in the Casentino forests (Tellini Florenzano 1999), where this species avoided high altitude. The results for the northern wren (TT) and Eurasian blackbird (SA) matched those of another study performed in Casentino Forests (Tellini Florenzano 1999). In contrast, in the present study, European robin (ER) showed the highest average abundance at lower altitudes. The results for short-toed treecreeper (CB) were in accord with those of a study carried out in the forests of the north Apennines (Baghino 2013).

To conclude, because of the area's high richness and biodiversity and the significant presence of species that are rare and of naturalistic interest, Vallombrosa forest is confirmed to be of high ornithological value.

Disclosure statement

No potential conflict of interest was reported by the authors.

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