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Seasonal bird assemblages in Dehesas (substeppic prairies with *Quercus suber*) of North-Western Sardinia (Italy): A poorly studied landscape of high eco-biogeographic interest

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SUMMARY

Dehesas (i.e., substeppic prairies with *Quercus suber*) represent a poorly studied Mediterranean habitat type of high eco-biogeographic interest. Here, we applied a point-transect method along a yearly cycle (from spring to autumn), to focus on seasonal differences in bird assemblages inhabiting a Dehesas landscape in north-western Sardinia (Italy). We confirmed the presence of Mediterranean species with restricted ranges (e.g. *Sturnus unicolor*, *Sylvia sarda*). At the community level, seasonal patterns show significant differences among mean abundance, with a maximum in autumn and a minimum in summer. The highest values in autumn may be explained by the aggregations of wintering small passerines. Considering the univariate metrics of diversity, the number of species significantly differs among seasons, with the richest community in spring. Shannon-Wiener diversity and Margalef (normalized richness) were higher in spring, and summer compared to autumn. Habitat heterogeneity of these landscape mosaics, driven by historical agro-pastoral practices (fires and pastures), together with the presence of patchy 'key structures', positively affects bird species richness and abundance, improving, respectively, the number of niches and resources. More resource effort should be devoted to study these habitat types recently interested in an increased anthropogenic pressure (urban sprawl and road infrastructures, location of wind power plants, etc.).

INTRODUCTION

The pastures with scattered evergreen oaks (class *Poetea bulbosae* Rivas Goday & Rivas-

Martínez in Rivas-Martínez 1978; Dehesas; EU habitat 6310) are Mediterranean environments of high ecological, biogeographical and conservation interest (Joffre et al., 1988). These

habitat types include a variety of xeric, thermophilic perennial and annual grasslands growing on usually eutrophic, but also oligotrophic soils, with evergreen isolated and patchy trees (mainly *Quercus suber* L.; Plieninger & Wilbrand, 2001; Terzi & Marvulli, 2006).

These pseudo-steppe environments represent a cultural landscape used for extensive livestock rearing (Caballero et al., 2011; Dutoit et al., 2011; Alvarez & Ramón, 2016), widespread throughout the Mediterranean Basin (Diaz et al., 1997). In Sardinia (central Mediterranean area) these habitats are still largely diffused (Bacchetta et al., 2009) and host bird species of high eco-biogeographic interest and conservation concern, in numerical decline and often critically endangered (e.g., Massa & La Mantia, 2010; Santangeli & Dolman, 2011; Grussu et al., 2012; Gustin & Petretti, 2013). However, although many studies have been carried out on Dehesas birds at single species level (Maranón, 1988; Pulido & Diaz, 1992; Tellería, 2001), studies about the patterns of univariate metrics of diversity (i.e., species abundance, richness and diversity) at the community level are still scarce and preliminary (Calvario et al., 1999).

This work has been focused on the analysis of seasonal patterns (spring-autumn) in uni-variate metrics of bird diversity of a Dehesas landscape located in north-western Sardinia. Our aims were: (i) to verify inter-seasonal differences in diversity metrics; (ii) to provide an arrangement of seasonal-related dominance at single species. To our knowledge, these analyses has been applied for the first time in these environmental mosaics of high eco-biogeographic interest. Moreover, since Dehesas in Sardinia are recently under significant anthropogenic pressures (building of new road infrastructures, increase of urban sprawl, location of wind power plants), we think that our data may have implications for conservation of these peculiar Mediterranean habitat types.

MATERIALS AND METHODS

Study area

The study area is located in the municipalities of Sindia (Nuoro), Monte Sant'Antonio and Montiferru (Oristano) at an altitude ranging between approximately 400 and 800 m a.s.l. (Monte Sant'Antonio, 808 m a.s.l.; North-Western Sardinia; Fig. 1). In this landscape mosaic, heterogeneous habitat types occur, largely represented by a matrix with pseudo-steppe environments of mainly annual plants with *Quercus suber* dominant ('Dehesas'). At higher altitude, mesophilous oak woods with dominance of *Quercus pubescens* Willd., and undergrowth with *Crataegus monogyna* Jacq. and *Rubus* sp. are present (see Bacchetta et al., 2009). The site is surrounding to the Special Protection Area (EU Directive) SPA ITB023050 "Piana di Semestene, Bonorva, Macomer and Bortigali".

The vegetation is represented by calciferous pastures of *Poetea bulbosae* with dominant *Poa bulbosa* L. and many ruderal species (*Cichorium intybus* L., *Dipsacus fullonum* L.). The tree layer is represented by scattered individuals of *Quercus suber* and, more rarely, of the endemic *Quercus ichnusae* Mossa, Bacch. & Brullo, a species of the cycle of *Quercus pubescens*, which has been recently described (Mossa et al., 1999). The Dehesa derives from the degradation of the *Quercus suber* forest, referable to the association *Violo dehnhardtii-Quercetum suberis* Bacchetta, Bagella, Biondi, Farris, Filigheddu & Mossa, typical of the lower mesomediterranean belt on basalts and other volcanic rocks (Bacchetta et al., 2004). This habitat has been completely altered by intense grazing, coppicing and fire in historical times. It is therefore a partially anthropogenic and cultural environment that nonetheless optimizes the human exploitation with very low energetic input (Guzman, 2016). In the last times, these habitats are under anthropogenic pressure (building of road infrastructures and wind power plants, urban sprawl and so on).



Figure 1. Map of the study area (North-Western Sardinia).

Protocol

We carried out a field sampling protocol allowing a quali-quantitative characterization of bird communities during the period May-October 2021, using the point-transect method (Bibby et al., 2000; modified), carrying out a number of sessions, standardized in space (1 km transect each one, with lateral belts of 50 m), geo-referenced on technical maps (scale 1:2,000). We could not carry out the study in the winter period: for this reason, the data refer only to the spring-autumn period.

Data were stratified for three seasons: spring (breeding birds), summer and autumn. In particular, the following sampling sessions ($n = 132$) were carried out (approximately 32 hours of total research effort): spring: 7 - 8 May; 12 June; 28 - 29 June 2021; $n = 40$ sessions; summer: 4, 27, 28 July; 2 - 13 September 2021; $n = 72$ sessions; autumn: 25 - 26 October; $n = 20$ sessions.

For each transect/point session, we obtained the number of individual records subdivided for each species. The total values of species-specific records (n) and relative frequencies ($fr = n/N$, where N is the total number of all species-specific records per season) were obtained for each seasonal session. Species with $fr > 0.05$ were considered as dominant (Turcek, 1956).

At the community level, the following community univariate metrics were obtained: number of species obtained with the standard transect method (S); normalized species richness (Margalef index): $Dm = S - 1 / \ln(N)$; Shannon-Wiener diversity index (Shannon & Weaver, 1963): $H' = - \sum fr \times \ln(fr)$; evenness index: $e = H' / \ln S$ (Magurran, 2013, for a review of diversity metrics). Averaged values have been compared using the Kruskal-Wallis test for equal medians. Alpha was set at 0.05 level.

To compare species diversity among seasonal assemblages, we performed the

approach for diversity profiles, which the main purpose is to compare diversities in several samples using graphs (Tothmeresz, 1995). The bootstrapping option (giving a 95% confidence interval) is based on 2000 replicates, using PAST software (Hammer et al., 2001).

Taxonomic nomenclature follows Baccetti et al. (2021).

RESULTS

A total of 4963 records were obtained (1,386 in spring, 2,399 in summer and 1,178 in autumn) belonging to 60 species.

The most frequent species (= dominant with $fr > 0.05$) were: (i) forest species as *Columba palumbus* (spring, $n = 74$), *Fringilla coelebs* (autumn, $n = 77$), and *Turdus merula* (spring, $n = 74$), (ii) edge, mosaic and synanthropic species as *Corvus cornix* (spring, $n = 196$; summer, $n = 214$; autumn: $n = 231$), *Passer hispaniolensis* (spring, $n = 158$, summer, $n = 285$), *Motacilla alba* (autumn, $n = 93$), *Sturnus vulgaris* (summer, $n = 148$; autumn, $n = 64$), *Sturnus unicolor* (spring, $n = 172$; summer, $n = 443$; autumn, $n = 218$), *Corvus monedula* (autumn, $n = 103$; Tab. 1). *Corvus cornix* and *Sturnus unicolor* were dominant in all seasons (Tab. 1).

Table 1. Species recorded, seasonal abundance (n) and relative frequency (fr). (*): species recorded outside the standardized point/transect method. In bold: dominant species ($fr > 0.05$). Species in alphabetic order. Taxonomic nomenclature follows Baccetti et al. (2021).

Species	spring		summer		autumn	
	N	fr	n	fr	N	Fr
<i>Alauda arvensis</i> Linnaeus, 1758	9	0.006	5	0.002	0	0
<i>Alectoris barbara</i> (Bonnaterre, 1792)	0	0	0	0	1	0.001
<i>Anas platyrhynchos</i> Linnaeus, 1758	4	0.003	0	0	0	0
<i>Anthus pratensis</i> (Linnaeus, 1758)	0	0	0	0	46	0.039
<i>Apus apus</i> (Linnaeus, 1758)	56	0.04	68	0.028	0	0
<i>Athene noctua</i> (Scopoli, 1769)	1	0.001	5	0.002	0	0
<i>Bubulcus ibis</i> (Linnaeus, 1758)	7	0.005	0	0	0	0
<i>Buteo buteo</i> (Linnaeus, 1758)	11	0.008	27	0.011	7	0.006
<i>Carduelis carduelis</i> (Linnaeus, 1758)	18	0.013	44	0.018	2	0.002
<i>Cettia cetti</i> (Temminck, 1820)	13	0.009	6	0.003	7	0.006
<i>Chloris chloris</i> (Linnaeus, 1758)	13	0.009	35	0.015	1	0.001
<i>Columba livia</i> J. F. Gmelin, 1789 dom. form	23	0.017	52	0.022	0	0
<i>Columba palumbus</i> Linnaeus, 1758	74	0.053	113	0.047	53	0.045
<i>Corvus corax</i> Linnaeus, 1758	26	0.019	33	0.014	11	0.009
<i>Corvus cornix</i> Linnaeus, 1758	196	0.141	214	0.089	231	0.196
<i>Corvus monedula</i> Linnaeus, 1758	8	0.006	99	0.041	103	0.087
<i>Coturnix coturnix</i> (Linnaeus, 1758)	7	0.005	1	0.001	0	0
<i>Cuculus canorus</i> Linnaeus, 1758	1	0.001	0	0	0	0
<i>Cyanistes caeruleus</i> (Linnaeus, 1758)	1	0.001	3	0.001	0	0
<i>Delichon urbicum</i> (Linnaeus, 1758)	40	0.029	17	0.007	0	0
<i>Dendrocopos major</i> (Linnaeus, 1758)	3	0.002	1	0.001	14	0.012
<i>Emberiza calandra</i> Linnaeus, 1758	39	0.028	11	0.005	8	0.007
<i>Emberiza cirrus</i> Linnaeus, 1766	23	0.017	12	0.005	2	0.002
<i>Erithacus rubecula</i> (Linnaeus, 1758)	35	0.025	115	0.048	20	0.017
<i>Falco tinnunculus</i> Linnaeus, 1758	14	0.01	2	0.001	10	0.008
<i>Fringilla coelebs</i> Linnaeus, 1758	4	0.003	14	0.006	77	0.065
<i>Garrulus glandarius</i> (Linnaeus, 1758)	5	0.004	15	0.006	7	0.006
<i>Hirundo rustica</i> Linnaeus, 1758	59	0.043	115	0.048	0	0
<i>Larus michahellis</i> J.F. Naumann, 1840	6	0.004	41	0.017	5	0.004
<i>Linaria cannabina</i> (Linnaeus, 1758)	0	0	21	0.009	23	0.02
<i>Lullula arborea</i> (Linnaeus, 1758)	1	0.001	8	0.003	6	0.005
<i>Luscinia megarhynchos</i> C.L. Brehm, 1831	5	0.004	5	0.002	0	0
<i>Merops apiaster</i> Linnaeus, 1758	4	0.003	0	0	0	0

Species	spring		summer		autumn	
	N	fr	n	fr	N	Fr
<i>Milvus milvus</i> (Linnaeus, 1758)	2	0.001	2	0.001	0	0
<i>Motacilla alba</i> Linnaeus, 1758	46	0.033	25	0.01	93	0.079
<i>Motacilla cinerea</i> Tunstall, 1771	1	0.001	1	0.001	0	0
<i>Muscicapa striata</i> (Pallas, 1764)	36	0.026	11	0.005	0	0
<i>Nycticorax nycticorax</i> (Linnaeus, 1758)	0	0	3	0.001	0	0
<i>Otus scops</i> (Linnaeus, 1758)	0	0	(*)	0	0	0
<i>Parus major</i> Linnaeus, 1758	21	0.015	28	0.012	25	0.021
<i>Passer hispaniolensis</i> (Temminck, 1820)	158	0.114	285	0.119	50	0.042
<i>Passer montanus</i> (Linnaeus, 1758)	0	0	12	0.005	0	0
<i>Phoenicurus ochruros</i> (S.G.Gmelin, 1774)	0	0	0	0	4	0.003
<i>Phylloscopus collybita</i> (Vieillot, 1817)	2	0.001	0	0	3	0.003
<i>Regulus ignicapilla</i> (Temminck, 1820)	1	0.001	0	0	0	0
<i>Saxicola torquatus</i> (Linnaeus, 1766)	28	0.02	92	0.038	41	0.035
<i>Serinus serinus</i> (Linnaeus, 1766)	10	0.007	0	0	0	0
<i>Streptopelia decaocto</i> (Frivaldszky, 1838)	0	0	40	0.017	0	0
<i>Streptopelia turtur</i> (Linnaeus, 1758)	46	0.033	4	0.002	0	0
<i>Sturnus unicolor</i> Temminck, 1820	172	0.124	443	0.185	218	0.185
<i>Sturnus vulgaris</i> Linnaeus, 1758	29	0.021	148	0.062	64	0.054
<i>Sylvia atricapilla</i> (Linnaeus, 1758)	15	0.011	11	0.005	0	0
<i>Sylvia communis</i> Latham, 1787	(*)	0	(*)	0	0	0
<i>Sylvia melanocephala</i> (J.F. Gmelin, 1789)	32	0.023	78	0.033	1	0.001
<i>Sylvia sarda</i> Temminck, 1820	5	0.004	10	0.004	13	0.011
<i>Troglodytes troglodytes</i> (Linnaeus, 1758)	0	0	0	0	7	0.006
<i>Turdus merula</i> Linnaeus, 1758	74	0.053	114	0.048	21	0.018
<i>Turdus philomelos</i> C.L.Brehm, 1831	0	0	0	0	3	0.003
<i>Tyto alba</i> (Scopoli, 1769)	0	0	2	0.001	0	0
<i>Upupa epops</i> Linnaeus, 1758	2	0.001	8	0.003	1	0.001
TOTAL	1386	1	2399	1	1178	1

The number of individuals in any session ranged from 15 (spring) to 142 (autumn). The average number of records was statistically different between seasons ($H = 18.12$, $p < 0.001$; Kruskal-Wallis test for equal medians) with a maximum in autumn (58.9 ind./session \pm 28.98) and a minimum in summer (33.43 ind./session \pm 14.18; Tab. 2, Fig. 2). The highest values in autumn are explained by the autumn aggregations of small passerines, occurring in this season.

Table 2. Average number of individual records in the seasonal sessions. N: number of replicated sessions; minimum (Min), maximum (Max) and average (Mean, with standard deviation) values.

	spring	summer	Autumn
N	40	72	20
Min	15	12	22
Max	76	81	142
Mean	35	33.43	58.9
st. dev	15.16	14.18	28.98

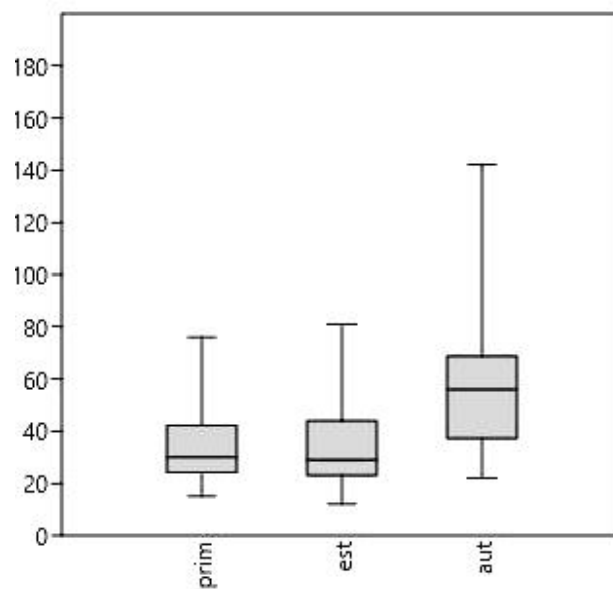


Figure 2. Box plots of total records in seasonal sessions (y-axis): prim: spring, est: summer; aut: autumn. The minimal and maximal values are shown with short horizontal lines ("whiskers"); 25-75 percentiles are drawn using a box; horizontal line shows the median values.

The number of species recorded ranged from 7 (spring/summer) to 24 (spring). The mean number of species was statistically different between seasons ($H = 7.582$, $p = 0.02$; Kruskal-Wallis test for equal medians), with a maximum in spring (14 ± 4.72) and a minimum in summer (11.79 ± 2.34 ; Tab. 3; Fig. 3).

Table 3. Averaged number of species per seasonal session. N: number of replicas; minimum (Min), maximum (Max) and average (Mean, with standard deviation) values.

	spring	summer	Autumn
N	40	72	20
Min	7	7	9
Max	24	18	21
Mean	14.00	11.79	13.50
st. dev	4.72	2.34	3.12

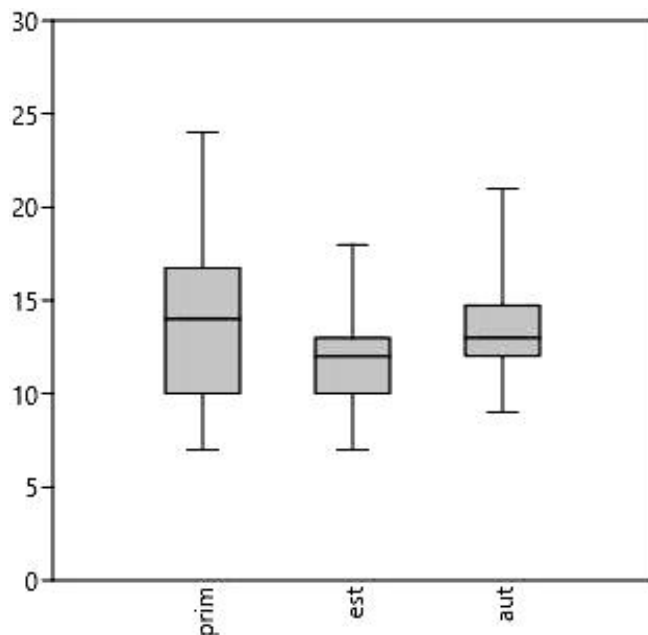


Figure 3. Box plots of bird species richness in seasonal sessions (y-axis): prim: spring, est: summer; aut: autumn. The minimal and maximal values are shown with short horizontal lines ("whiskers"); 25-75 percentiles are drawn using a box; horizontal line shows the median values.

Considering the community parameters, we recorded the richest community in spring ($n = 48$) (Tab. 4), also considering the normalized richness (Margalef). Evenness index was higher in spring and autumn than in summer (Tab. 4). Diversity profiles evidenced the highest alpha-diversity in spring and summer (Fig. 4).

Table 4. Structural parameters of the bird communities detected in the three seasonal sessions (spring, summer, autumn) with the transects/points in the project area. S: number of species contacted with the listening station method; H' : Shannon-Wiener diversity index; e: evenness index (equal distribution of frequencies); Dm: Margalef index (normalized species richness); N: number of individual records. For further details, see Methods.

	spring	summer	autumn
S	48	46	34
H'	3.14	3.01	2.69
E	0.811	0.786	0.846
Dm	6.50	5.78	4.67
N	1386	2399	1178

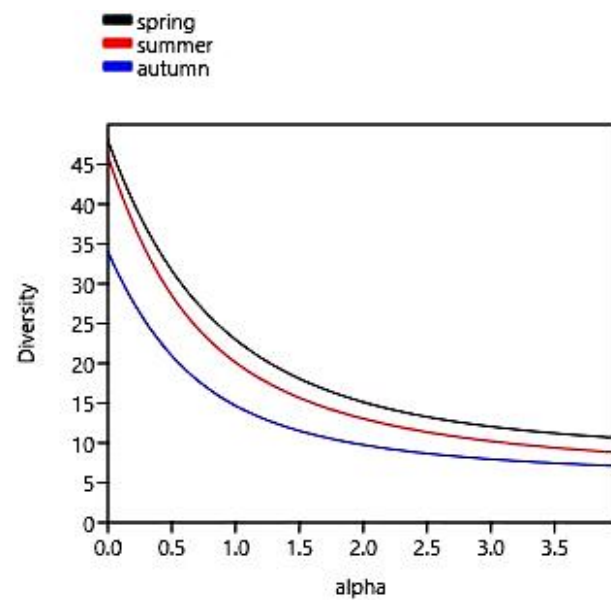


Figure 4. Alpha-diversity profile for the three seasonal bird communities. See Methods for details.

DISCUSSION

Dehesas of North-Western Sardinia host peculiar bird communities including both synanthropic/generalist species, widely distributed at Mediterranean level (e.g., Godinho & Rabaça, 2011) and species of high biogeographic interest (e.g., genus *Sylvia*: Cody & Walter, 1976; Martin & Thibault, 1996; Covas & Blondel, 1998; Massa, 2006) and conservation concern, also at continental level (included in the EU Dir. 147/2009/CEE; e.g. Gustin & Petretti, 2013). Among them, different species of specific ecological guilds have been represented as diurnal raptors and

ground-nesting birds, strongly declining, or threatened at different scales (e.g., Massa & La Mantia, 2010; Grussu et al., 2012).

We observed a significant increase in total abundance especially in the autumn period, due to the high availability of resources (mainly for ground foraging species; Leal et al., 2019). The role of Mediterranean agro-environments for the wintering of many species is widely known (e.g., Telleria, 2001; Gillings et al., 2005; Telleria et al., 2005). However, even forest environments locally host interesting aggregations of some species in winter (for example, *Columba palumbus*). Regarding species richness and diversity, we observed highest values in spring and summer seasons, as evidenced by univariate metrics and diversity profiles.

Environmental heterogeneity, together with the presence of 'key structures' can greatly increase the species richness and the individual abundance (Tews et al., 2000; Zamora et al., 2007), also in birds (Farina, 1997; Malavasi et al., 2009; Pickett and Siriwardena, 2011; Santana et al., 2017). In this regard, a large number of available niches allows the coexistence of many species with different ecology (i.e. high richness), and the abundance of resources can explain the large number of individuals (i.e. high abundance; Wiens, 1992), as largely observed in Mediterranean landscapes (e.g. Atauri and de Lucio, 2001).

However, most of the studies are concentrated in continental areas and data for macro-insular environments are still scanty. Our data evidenced a role of Sardinian Dehesas as habitats with a high seasonal dynamism (i.e. high bird richness and diversity in spring and summer and high abundance in autumn-winter).

The area has been poorly studied in respect its eco-biogeographic value, excluding a scanty local literature (e.g., Schenk et al., 1995). The mosaic of Dehesas is characterized by a high habitat heterogeneity with including oak wood patches, embedded in landscape matrix with pseudo-steppes, pastures and

isolated *Quercus suber* trees. Although this landscape shows a very low anthropization (limited mainly to extensive traditional agro-pastoral practices) and patchy disturbances (e.g., fires), recently many new infrastructures have been planned (road infrastructures, wind farm plants). Therefore, this lack of knowledge may have conservation implications in the light of these landscape use changes, moving from agro-forest and pastoral ecosystems to urbanization and infrastructuration.

Our study represents only a preliminary arrangement and further research is necessary (winter period has been not considered). In this regard, we stimulated an increase of research effort, around a whole yearly cycle, about structure and dynamics of bird communities inhabiting these still little known Dehesas of high ecological and biogeographical interest.

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