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Breeding Bird Assemblages in Relation to Changing Forest Composition in North-Eastern Algeria: Zonation or Continuum?

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Key words
Forest areas, Souk Ahras, Non-parametric multivariate methods, Bird species, Dissimilarity

ABSTRACT

Forest areas of Mechroha municipality are among the most dynamic and rich ecosystems in Souk Ahras region. These complex landscapes are typically considered vulnerable by intensive land use and human activities, which related to: illegal cuttings, overgrazing, and other anthropological impacts. Protecting and helping the rehabilitation of forest areas are essential for sustaining the integrity of these forest habitats. In this study, non-parametric multivariate methods were used to understand how a particular bird species responds to a particular forest habitat. We have conducted the first bird survey in Ouled Bechih forest of Mechroha municipality using the point count method across the three oak forest types (cork oak stands, mixed oak forests and zeen oak stands). A total of 62 species were observed among which 20 protected species, only one vulnerable species, and 12 endemic species to the Maghreb and/or to North Africa. The bird assemblages of the forest of Ouled Bechih varied significantly between the different forest habitats, as well as the differences in bird species assemblages among the possible pairwise combinations in the three forest habitats were significant only between zeen oak stands and cork oak stands. The main discriminant species that contributed significantly to the dissimilarity between cork oak stands and oak mixed forests were Sardinian warbler, common cuckoo, great spotted woodpecker and European serin. The differences between zeen oak and cork oak woodlands were produced mainly by African Blue Tit, Atlas Pied Flycatcher, common wood pigeon and woodlark. The dissimilarity showed between zeen oak stands and oak mixed forests are the results from Western Bonelli's Warbler, common cuckoo and common wood pigeon presence.

INTRODUCTION

Birds occupy different habitat types and ecosystems which make them a useful tool for numerous purposes by landscape services (Whelan *et al*., 2008; Sekercioglu, 2012; Maas *et al*., 2016), such as application of biodiversity maintenance and restoration, and landscape-scale conservation (Sandström *et al*., 2006).

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During the past decades, avian research scientists have long been interested in bird habitat relationships based on ecological systems features with the main objective of studying spatial distribution variability in presence/absence of bird species (MacArthur and MacArthur, 1961; MacArthur, 1964; Cody, 1985; Wiens, 1989) because habitat requirements had a great effect on bird community structure and composition. Generally, many physical and biological constraints that manage bird species and their functioning, such as the presence or availability of foraging resources and the potential bird niche space, which in turn are affected by the spatial scale of landscape patterns (MacArthur and MacArthur, 1961; MacArthur, 1964; Cody, 1985; Wiens, 1989). Therefore, the understanding of the spatial scale of landscape patterns influence is related also to the proper temporal scale (Wiens, 1989).

Results of many studies carried out earlier have considered that plant composition was the secondary determinant factor for bird assemblages (Robinson and Holms, 1984; Rotenberry, 1985; Benyakoub, 1993; Bellatreche, 1994). Other environmental factors include foliage volume (Buchanan *et al*., 1999), tree age (Sallabanks *et al*., 2006; Menaa, 2017), forest productivity (Cody, 1981), physiognomy of shrub layer (Reid *et al*., 2004; Diaz, 2006), plant succession (Sweeney *et al*., 2010), the size and structures of the habitat patch or connectivity (Henderson *et al*., 1985), and edge effects (McGarigal and McComb, 1995; Kuehler *et al*., 2001). All of these findings were in relation to the ecological system hierarchy and scale (Virkkala, 1991).

Plant composition changes along gradients of ecological factors, where their ecological parameters varied significantly across altitudinal changes which are considered as the biggest determinant factor affecting floristic composition (Hemp, 2006). This important determinant factor is still a central issue whether altitudinal gradients are *continuous* or *discontinuous.* This issue is related to *zonation* and *continuum* concepts.

Many authors described vegetation communities as a continuum such as the forest stands of the tropical mountains (Hamilton, 1975, Hamilton *et al*., 1989; Lieberman *et al*., 1996; Lovett, 1996, 1998). However, other studies highlighted that landscape systems of vegetation surrounded by narrow boundaries in which there is altitudinal gradient discontinuous vary in plant composition or structure and forms zones or belts (Woldu *et al*., 1989; Friis and Lawesson, 1993).

The forest of Ouled Bechih is known as an important ecosystem for biodiversity and unfortunately is subject to natural and anthropogenic disturbance factors (Ganaoui *et al*., 2020; Guellati *et al*., 2022). It is located in a region characterized by an exceptional climate. This led to a clear variation in plant structure and in plant species diversity, and consequently in habitats. Despite all this significant plant diversity, this complexity of landscape has never been the subject of any serious ornithological study.

In the present study, our overarching aim was: (i) to prepare the inventory of forest avifauna of the forest of Ouled Bechih; (ii) to explore the effects of the habitat type (cork oak woodlands, mixed oak woodlands and zeen oak woodlands) on forest avifauna, by studying community parameters (abundance, species richness, and frequency of occurrence); (iii) to determine the intensity of selection of each species by their preferred habitat; and (iv) to provide management recommendations for encouraging forest avifauna in woodlands.

MATERIALS AND METHODS

Study site

This study was carried out in the forest of Ouled Bechih (Mechroha municipality) in the extreme Northeastern Algeria within the territory of the province of Souk Ahras in the north, limited to the north and the north-east by the forests of Beni Salah and Fedj Laamed, to the west and the north-west by the forests of Beni Salah and Oued Ghanem and to the south by the forests of Rezgoune and Fedj Mactaa. It covers approximately 6,582 ha (Fig. 1) and includes three major forest types classified by their dominant tree species: Zeen oak (*Quercus canariensis*) stands, cork oak (*Quercus suber*) stands and mixed cork oak and zeen oak forests. The coordinates of the central locality of the forest of Ouled Bechih are: 36° 23.415'N; 7° 52.735'E, with altitudes ranging from about 392 to 1,252 m. Principal soil types are podzol, brown forest soil and siliceous soils. Among these types, siliceous soil is predominant.

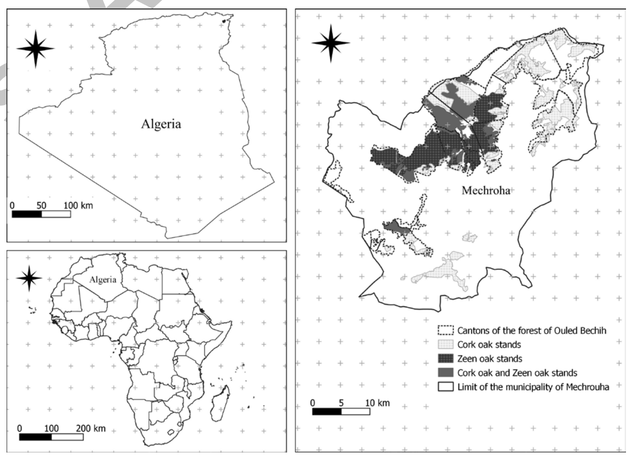

Fig. 1. Geographic location of the study area.

The forest Ouled Bechih is located between the humid and subhumid bioclimatic stage with a dry season from mid-May to late October, and a rainy season from November to mid-May. It receives an annual average of 690 mm of precipitation and the average temperature is 16°C.

Bird surveys

Forest birds were sampled with the point-counting method or IPA method (Indices Ponctuels d'Abondance) (Blondel *et al*., 1970; Bibby *et al*., 2000) in providing two bird survey rounds (Drapeau *et al*., 1999) among the breeding periods of 2018 and 2019, from mid-March to mid-April for early breeders and from mid-May to

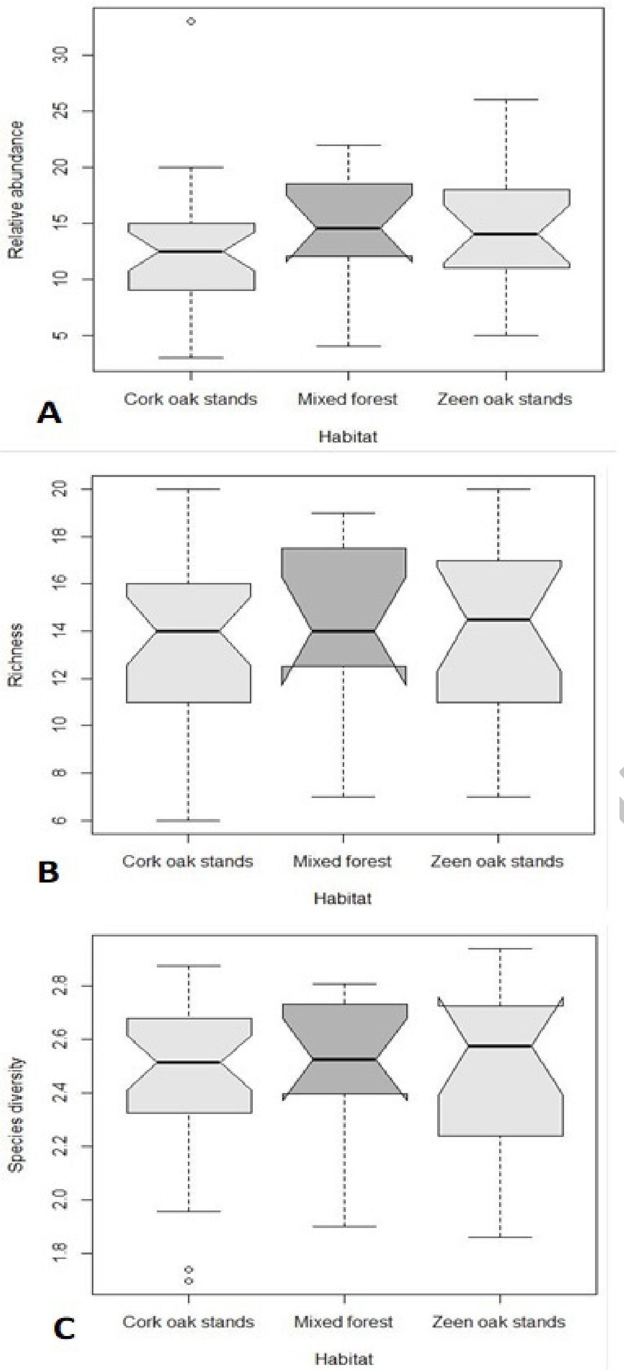

Fig. 2. The relative abundance (A), species richness (B), and species diversity (C) of forest birds in vork oak woodlands (Cork); oak mixed forests (Mixed); zeen oak woodlands (Zeen).

mid-June for late breeding species. This technique involved a count of all birds seen or heard inside or outside a 100 m radius circular plot during a 15 min period; overflying birds that did not land in trees or on the ground were recorded but their data were not used in statistical analysis because point-counting method is not a suitable sampling method for these taxa (Bibby *et al*., 2000). Bird surveys occurred within four hours of sunrise when song activities of diurnal birds begin (Frochot and Roché, 1990), and restricted to good weather conditions. The different point count stations were distributed systematically and covered the study area; each point count was separated by at least 350 m from the other points to minimize the probability of contacting the same individual bird more than once because it can be heard at distances of 250 m (Foucès, 1995).

Forest bird species structure and composition

To compare the structure and the composition of the bird species among the three forest types, we used a variety of ecology parameters, the Shannon-Wiener index (H') and the parameters that affect this index such as species richness (S) and relative abundance (A) (Anjos et al., 2010). The significance of differences in species richness, relative abundance and diversity among these forest habitats was checked with one-way ANOVA analysis test. The normality of the observation of the different ecology parameters were tested by the Shapiro-Wilk test (Shapiro and Wilk, 1965). The homogeneity of their variances among the main habitats was also tested using the Fligner Killeen test (Fligner and Killeen, 1976).

Forest bird assemblage structure and composition

Permutational multivariate analysis of variance (PERMANOVA) method was used to compare differences in bird assemblage composition across habitat types (Anderson, 2001), which is undertaken on a matrix-based nonparametric analysis of variance. By using permutation methods, the PERMANOVA analyses and divides the sums of squares based on semi-metric and metric distance matrices (Anderson, 2005).

One-way analysis of similarity ANOSIM (analysis of similarity) was also performed to further determine if bird community structure (a single data frame composed of the relative abundances of all bird species detected at each point count) differed significantly among the possible pairwise combinations of the three sampled forest areas (Minchin, 1987) when the PERMANOVA results gave significant differences. Furthermore, the dissimilarities in the assembly composition were checked if they were larger between combinations than inside the combinations and produces an estimated *p*-value based on 10,000 Monte Carlo simulations (Clarke, 1993).

A complementary non-parametric technique was used to project the variation of avian assemblages among forest habitats, using nonmetric multidimensional scaling

(NMDS) method; the NMDS was conducted with a data frame of ecological dissimilarity among the different habitat types (Legendre and Legendre, 1998), and a probability value was calculated based on 10,000 Monte Carlo simulations. The NMDS builds upon a general principle of ranked distances and linearized relationship between environmental distance and ecological distance (Legendre and Legendre, 1998). The importance of stress value could be used in order to judge the goodness of fit of this nonparametric method (Kruskal, 1964). A low importance of the stress value (< 0.2) indicates a good fit, whereas a high importance (> 0.2) indicates a weak fit (Oksanen, 2013).

Complementarily, a similarity percentage (SIMPER) test was performed to estimate overall dissimilarity between habitats and also to determine the relative contribution of each bird species to the community composition, both in respect of contributions to the average similarity within a community assemblage (i.e. identity and relative abundances of species which unite a group) and average dissimilarity between community assemblages (i.e. identity and relative abundances of species which to separate groups) (Clarke, 1993). Bray-Curtis pairwise distance coefficients were used in all analyses to express similarities and/or dissimilarities, which it is less sensitive to differences among rare species, where they were also based on 10.000 Monte Carlo permutations to generate a random test statistic (Bray and Curtis, 1957).

These analyses were all undertaken in R (R Development Core Team, 2020) with the Community Ecology Package 'vegan' (Oksanen *et al*., 2010) and the create elegant data visualisations using the grammar of graphics pakage 'ggplot2' (Wickham *et al*., 2016).

RESULTS

Forest bird species structure and composition

We conducted 120 visits (120 partials IPA) in the breeding period of 2018 and 2019. A total of 1119.5 pairs of birds in 50 genera and 62 species were recorded. Forty-five species were Passeriformes and the remainder (17) was non-Passeriformes; 50 bird species were found in cork oak woodlands, 46 in zeen oak woodlands, and 44 in mixed oak forests (Table I).

Table I. Bird species/ families/ orders and avian distribution recorded in the forest of Ouled Bechih during the breeding period of 2018 and 2019. Cork, Cork oak woodlands; Mixed, oak mixed forests; Zeen, zeen oak woodlands.

No. Common English name (Scientific name)	Habitat	F (%)	Abon-dance (pairs)	IUCN red list status 2022.2	National protection status 2012
Order: PASSERIFORMES					
Family: Alaudidae					
1. Greater short-toed lark (*Calandrella brachydactyla rubiginosa*)	Zeen	1.67	1	LC	UP
2. Eurasian skylark (*Alauda arvensis*)	Zeen	1.67	0.5	LC	UP
3. Woodlark (*Lullula arborea*)	Cork/Zeen	11.67	9.5	LC	UP
Family: Certhidae					
4. Short-toed treecreeper (*Certhia brachydactyla*)	Cork/Mixed	55	32	LC	UP
Family: Cettiidae					
5. Cetti's warbler (*Cettia cetti*)	Zeen	6.67	4	LC	UP
Family: Emberizidae					
6. Cirl bunting (*Emberiza cirlus*)	Cork/Mixed/Zeen	1.67	1	LC	UP
Family: Pycnonotidae					
7. Common bulbul (*Pycnonotus barbatus*)	Cork/Mixed	10	7.5	LC	UP
Family: Fringillidae					
8. European goldfinch (*Carduelis carduelis*)	Cork/Zeen	1.67	1.5	LC	P
9. Common chaffinch (*Fringilla coelebs*)	Cork/Mixed/Zeen	90	77.5	LC	UP
10. European serin (*Serinus serinus*)	Cork/Mixed/Zeen	18.33	15	LC	P
11. European greenfinch (*Chloris chloris voousi*)	Cork/Mixed	8.33	14	LC	UP
12. Spotless starling (*Sturnus unicolor*)		21.67	22	LC	P

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No. Common English name (Scientific name)	Habitat	F (%)	Abon-dance (pairs)	IUCN red list status 2022.2	National protection status 2012
Family: Sylviidae					
13. Eurasian blackcap (*Sylvia atricapilla*)	Cork/Mixed/Zeen	60	47.5	LC	UP
14. Common whitethroat (*Curruca communis communis*)	Cork/Zeen	6.67	3.5	LC	UP
15. Sardinian warbler (*Curruca melanocephala*)	Cork/Mixed/Zeen	61.67	36.5	LC	UP
16. Western orphean warbler (*Curruca hortensis*)	Cork	3.33	2	LC	UP
17. Western subalpine warbler (*Curruca iberiae*)	Cork	5	3	LC	UP
18. Dartford warbler (*Curruca undata*)	Cork	1.67	1	LC	UP
Family: Corvidae					
19. Eurasian jay (*Garrulus glandarius cervicalis*)	Cork/Mixed/Zeen	36.67	32	LC	P
20. Northern raven (*Corvus corax*)	Cork/Mixed/Zeen	15	6	LC	UP
Family: Muscicapidae					
21. Semi-collared flycatcher (*Ficedula semitorquata*)	Zeen	3.33	5	LC	UP
22. Atlas pied flycatcher (*Ficedula hypoleuca*)	Cork/Mixed/Zeen	33.33	27	LC	UP
23. Spotted flycatcher (*Muscicapa striata*)	Cork/Mixed/Zeen	20	15.5	LC	P
24. Common nightingale (*Luscinia megarhynchos*)	Cork/Mixed	8.33	6	LC	UP
25. European robin (*Erithacus rubecula witherbyi*)	Cork/Mixed/Zeen	83.33	61	LC	UP
26. Moussier's redstart (*Phoenicurus moussieri*)	Cork	5	3	LC	P
27. Whinchat (*Saxicola rubetra*)	Mixed	1.67	1	LC	UP
28 European Stonechat (*Saxicola rubicola*)	Mixed/Zeen	3.33	2	NE	UP
Family: Malaconotidae					
29. Black-crowned tchagra (*Tchagra senegalus*)	Zeen	1.67	1	LC	UP
Family: Turdidae					
30. Mistle thrush (*Turdus viscivorus*)	Mixed/Zeen	6.67	3.5	LC	UP
31. Common blackbird (*Turdus murela*)	Mixed/Zeen	81.67	73.5	LC	UP
Family: Hirundinidae					
32. Barn swallow (*Hirundo rustica rustica*)	Cork/Mixed/Zeen	6.67	3	LC	UP
Family: Acrocephalidae					
33. Melodious warbler (*Hippolais polyglotta*)	Cork/Zeen	3.33	2	LC	UP
Family: Oriolidae					
34. Eurasian golden oriole (*Oriolus oriolus*)	Cork/Mixed/Zeen	10	8	LC	P
Family: Paridae					
35. Coal tit (*Periparus ater ledouci*)	Cork/Mixed/Zeen	25	15.5	LC	UP
36. African blue tit (*Cyanistes teneriffae*)	Cork/Mixed/Zeen	98.33	101	LC	UP
37. Great tit (*Parus major*)	Cork/Mixed/Zeen	78.33	69	LC	UP
Family: Passeridae					
38. Spanish sparrow (*Passer hispaniolensis*)	Cork/Mixed/Zeen	8.33	17.5	LC	UP
Family: Phylloscopidae					
39. Western bonelli's warbler (*Phylloscopus bonelli*)	Cork/Mixed/Zeen	58.33	46	LC	UP
40. Willow warbler (*Phylloscopus trochilus*)	Cork/Mixed/Zeen	16.67	10.5	LC	UP
41. Iberian chiffchaff (*Phylloscopus ibericus*)	Zeen	1.67	1	LC	UP
42. Wood warbler (*Phylloscopus sibilatrix*)	Cork/Mixed/Zeen	8.33	8	LC	UP
43. Common chiffchaff (*Phylloscopus collybita*)	Cork/Mixed/Zeen	20	15	LC	UP

Table continued on next page...........

No. Common English name (Scientific name)	**Habitat**	**F (%)**	**Abon-dance (pairs)**	**IUCN red list status 2022.2**	**National protection status 2012**
Family: Regulidae					
44. Common firecrest (*Regulus ignicapilla*)	Cork/Mixed/Zeen	50	41	LC	P
Family: Troglodytidae					
45. Eurasian wren (*Regulus ignicapilla*)	Cork/Mixed/Zeen	70	49.5	LC	UP
Order: ACCIPITRIFORMES					
Family: Accipitridae					
46. Long-legged buzzard (*Buteo rufinus*)	Cork/Mixed	5	2	LC	P
47. Black kite (*Milvus migrans migrans*)	Mixed	1.67	1	LC	P
Order: GALLIFORMES					
Family: Phasianidae					
48. Common quail (*Coturnix coturnix africana*)	Mixed	3.33	2	LC	UP
49. Barbary partridge (*Alectoris barbara barbara*)	Zeen	5	2.5	LC	UP
Order: STRIGIFORMES					
Family: Strigidae					
50. Tawny owl (*Strix aluco*)	Cork/Zeen	3.33	2	LC	P
Order: CICONIIFORMES					
Family: Ciconiidae					
51. White stork (*Ciconia ciconia ciconia*)	Cork/Mixed	3.33	1	LC	P
Order: CUCULIFORMES					
Family: Cuculidae					
52. Common cuckoo (*Cuculus canorus*)	Cork/Mixed/Zeen	35	25	LC	P
Order: CORACIIFORMES					
Family: Méropidae					
53. European bee-eater (*Merops apiaster*)	Cork/Mixed	5	1.5	LC	P
Order: BUCÉROTIFORMES					
Family: Upupidae					
54. Eurasian hoopoe (*Upupa epops*)	Cork/Mixed/Zeen	13.33	7	LC	P
Order: APODIFORMES					
Family: Apodidae					
55. Common swift (*Apus apus apus*)	Cork/Mixed/Zeen	28.33	42	LC	UP
Order: PICIFORMES					
Family: Picidae					
56. Levaillant's woodpecker (*Picus vaillantii*)	Cork/Mixed/Zeen	65	36	LC	P
57. Great spotted woodpecker (*Dendrocopo major numidus*)	Cork/Mixed/Zeen	53.33	24.5	LC	P
58. Lesser spotted woodpecker (*Dendrocopos minor*)	Cork/Mixed/Zeen	30	14	LC	P
59. Eurasian wryneck (*Jynx torquilla*)	Cork	5	4	LC	P
Order: COLUMBIFORMES					
Family: Columbidae					
60. Common wood pigeon (*Columba palumbus*)	Cork/Mixed/Zeen	38.33	23	LC	UP
61. European turtle dove (*Streptopelia turtur*)	Cork/Mixed/Zeen	38.33	28.5	VU	UP
Family: Turnicidae					
62. Common buttonquail (*Turnix sylvaticus*)	Mixed	1.67	1	LC	P

P, Protected; UP, Unprotected (according to the National protection status 2012); NE, Not Evaluated; LC, Least Concern; EN, Endangered (according to the IUCN Red List status 2022.2).

In contrast, four species was recorded only in mixed forests (*Coturnix coturnix africana, Turnix sylvaticus, Milvus migrans migrans, Saxicola rubetra*), five species were found only in cork oak woodlands (*Jynx torquilla, Curruca hortensis, Curruca iberiae, Curruca undata, Phoenicurus moussieri*), and six were found only in zeen oak woodlands (*Alectoris barbara Barbara, Alauda arvensis, Calandrella brachydactyla rubiginosa, Phylloscopus ibericus, Ficedula semitorquata, Emberiza cirlus*) (Table I).

Table II. The composition of avian families according to their species number and their relative abundance (pairs).

No.	Family	Species	P (%)	Abundance (pairs)	P (%)
01.	Ciconiidae	1	1.61	1	0.09
02.	Accipitridae	2	3.23	3	0.27
03.	Phasianidae	2	3.23	4.5	0.4
04.	Turnicidae	1	1.61	1	0.09
05.	Columbidae	2	3.23	51.5	4.6
06.	Cuculidae	1	1.61	25	2.23
07.	Strigidae	1	1.61	2	0.18
08.	Apodidae	1	1.61	42	3.75
09.	Méropidae	1	1.61	1.5	0.13
10.	Upupidae	1	1.61	7	0.63
11.	Picidae	4	6.45	78.5	7.01
12.	Alaudidae	3	4.84	11	0.98
13.	Hirundinidae	1	1.61	3	0.27
14.	Pycnonotidae	1	1.61	7.5	0.67
15.	Troglodytidae	1	1.61	49.5	4.42
16.	Muscicapidae	8	12.9	120.5	10.76
17.	Turdidae	2	3.23	77	6.88
18.	Cettiidae	1	1.61	4	0.36
19.	Acrocephalidae	1	1.61	2	0.18
20.	Sylviidae	6	9.68	93.5	8.35
21.	Phylloscopidés	5	8.065	80.5	7.191
22.	Régulidés	1	1.61	41	3.66
23.	Paridae	3	4.84	185.5	16.57
24.	Certhidae	1	1.61	32	2.86
25.	Oriolidae	1	1.61	8	0.71
26.	Malaconotidés	1	1.61	1	0.09
27.	Corvidae	2	3.23	38	3.39
28.	Sturnidae	1	1.61	22	1.97
29.	Passéridae	1	1.61	17.5	1.56
30.	Fringillidae	4	6.45	108	9.65
31.	Emberizidae	1	1.61	1	0.09

The family with the highest species richness was Muscicapidae (eight species), followed by Sylviidae (six species), Phylloscopidae (five species), Fringillidae (four species), and Picidae (four species) (Table II). These five families alone represented more than 40% of the total species richness of the community. Paridae (dominated the population in number of pairs with 185.5 pairs, followed by Muscicapidae (120.5 pairs), Fringillidae (108 pairs), Sylviidae (93.5 pairs), and Phylloscupidae (80.5 pairs). They represented more than 52% of the total abundance of the entire population (Table II).

The five most commonly detected species in the forest of Ouled Bechih were *Cyanistes teneriffae* (101 pairs), *Fringilla coelebs* (77.5 pairs), *Turdus murela* (73.5 pairs), *Parus major* (69 pairs) and *Erithacus rubecula witherbyi* (61 pairs). These five species accounted about (39%) of all recorded species (Table I).

Results from the one-way ANOVA analysis for the effect of forest type on bird indices richness (S), abundance (A), and diversity (H') indicated that forest bird abundance, richness and species diversity did not vary significantly among the three forest types (abundance: $F_{2,57} = 2$, $p > 0.05$; richness: $F_{2,57} = 0.156$, $p > 0.05$; species diversity: $F_{2,57} = 0.213$, $p > 0.05$) (Fig. 2a, b, c).

Forest bird assemblage structure and composition

The bird assemblages of the forest of Ouled Bechih varied significantly between the different habitats (PERMANOVA: $F_{2,57} = 0.0824$, $p < 0.001$), as well as the differences in bird species assemblages among the possible pairwise combinations in the three forest habitats were confirmed by the ANOSIM test, where the significant differences have been shown only between *Q. canariensis* woodlands and *Q. suber* woodlands (Table III).

Table III. Analysis of similarities (ANOSM), R value for bird assemblages among the possible pair wise combinations in the three sampled forests: Cork oak woodlands (Cork); oak mixed forests (Mixed); zeen oak woodlands (Zeen).

Comparaison	R	P
Cork-Mixed	0.006193	0.427
Cork-zeen	0.1761	0.003**
Zeen-Mixed	0.09357	0.071

p = significance based on 1,000 randomizations.

These results are supported by the NMDS analysis, indicating a good fit (0.1747 stress, $p < 0.05$) with a clear positive linear relationship between the observed dissimilarity and the ordination distances (for linear fit: $r^2 = 0.849$, Fig. 3).

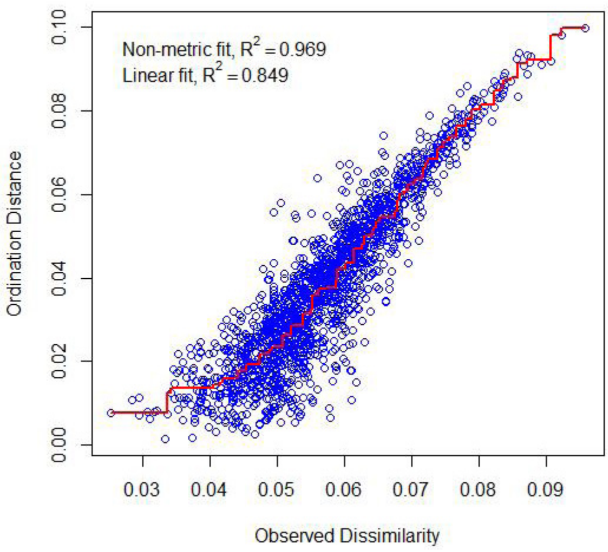

Fig. 3. Shepard plot for nonmetric multidimensional scaling (NMDS) results. Dashed line signifies a perfect linear relationship between calculated and ordination distances.

According to the NMDS diagram, some species were entirely restricted to a given forest, which shared different complements of its bird community with other forests (Table IV and Fig. 4). The most marked contrast in species composition was therefore between the bird assemblages of *Q. canariensis* stands and oak mixed forests with only 14 species in common (Table IV and Fig. 4) on the one hand, and between *Q. suber* stands and oak mixed forests with only 14 species in common (Table IV and Fig. 4) on the other. They separated considerably in their bird assemblage composition, being distinctly divided at opposite ends of the ordination graph. The *Q. canariensis* sites were similarly distinct, with 14 species in common with *Q. suber* woodlands (Table IV), appearing to cluster between these woodlands (Fig. 4). As well as the most dissimilar across the communities is *Q. canariensis* woodlands, considering the intersecting of *Q. suber* stands and oak mixed forests (Table IV).

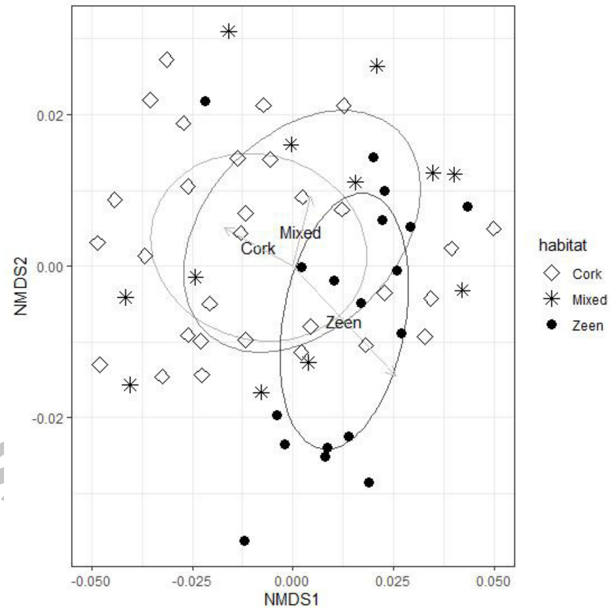

Fig. 4. Nonmetric multidimensional scaling (NMDS) analysis ordination biplot based on Bray-Curtis coefficient of similarities between avian assemblages and forest types (stress=0.1747).

Table IV. Cumulative contributions of most influential species in the mean dissimilarity and similarity among the possible pair wise combinations in the three sampled habitats: Cork oak woodlands (Cork); oak mixed forests (Mixed); zeen oak woodlands (Zeen). ava, avb: Average abundances per group (forest types).

Species	Contrubition	av.a	av.b	Contribution %	Cumulative contribution %	p
Cork mixed						
Parus major	0.0329113	0.98333	1.33333	5.86733	5.86733	0.082
Turdus murela	0.0311331	1.30000	1.12500	5.55033	11.41766	0.544
Fringilla coelebs	0.0294294	1.38333	1.41667	5.24658	16.66424	0.174
Curruca melanocephala	0.0273392	0.78333	0.79167	4.87395	21.53819	0.003**
Sylvia atricapilla	0.0254664	0.73333	0.79167	4.54008	26.07827	0.681
Cuculus canorus	0.0231068	0.16667	0.83333	4.11942	30.19769	0.012*
Phylloscopus bonelli	0.0227068	0.56667	0.75000	4.0481	34.24579	0.785
Regulus ignicapilla	0.0204808	0.56667	0.58333	3.65127	37.89706	0.952
Troglodytes troglodytes	0.0204006	0.85000	1.08333	3.63696	41.53402	0.553

Table continued on next page...............

Species	Contrubition	av.a	av.b	Contribution %	Cumulative contribution %	p
Cyanistes teneriffae	0.0197498	1.55000	1.66667	3.52094	45.05496	0.968
Picus vaillantii	0.0196619	0.53333	0.79167	3.50526	48.56022	0.191
Erithacus rubecula	0.0195160	1.06667	1.20833	3.47926	52.03948	0.851
Streptopelia turtur	0.0188103	0.61667	0.33333	3.35344	55.39292	0.611
Dendrocopo major	0.0175052	0.31667	0.58333	3.12077	58.51369	0.049*
Serinus serinus	0.0171263	0.26667	0.50000	3.05323	61.56692	0.031*
Certhia brachydactyla	0.0169273	0.41667	0.58333	3.01775	64.58467	0.809
Garrulus glandarius cervicalis	0.0166385	0.50000	0.25000	296626	67.55093	0.899
Ficedula hypoleuca	0.0157374	0.25000	0.45833	2.80562	70.35655	0.919
Cork zeen						
Turdus murela	0.0309073	1.30000	1.16667	5.166268	5.166268	0.578
Cyanistes teneriffae	0.0286848	1.55000	1.91667	4.794756	9.961024	0.014 *
Parus major	0.0279100	0.98333	1.30556	4.665248	14.626272	0.851
Sylvia atricapilla	0.0275040	0.73333	0.88889	4.597391	19.223663	0.312
Garrulus glandarius cervicalis	0.0270097	0.50000	0.77778	4.514761	23.738424	0.088
Phylloscopus bonelli	0.0268643	0.56667	1.11111	4.490451	28.228875	0.054
Regulus ignicapilla	0.0267804	0.56667	0.94444	4.476432	32.705307	0.075
Fringilla coelebs	0.0252623	1.38333	1.05556	4.222685	36.927992	0.822
Ficedula hypoleuca	0.0253027	0.45833	0.77778	1.663521	38.591513	0.008**
Erithacus rubecula	0.0241070	1.06667	0.80556	6.424571	45.016084	0.065
Curruca melanocephala	0.0222548	0.78333	0.19444	3.719965	48.736049	0.171
Troglodytes troglodytes	0.0206281	0.85000	0.61111	3.448053	52.184102	0.481
Streptopelia turtur	0.0205778	0.61667	0.33333	3.439645	55.623747	0.333
Columba palumbus	0.0199726	0.20000	0.77778	3.338495	58.962242	0.001***
Certhia brachydactyla	0.0191808	0.41667	0.69444	3.20614	62.168382	0.141
Cuculus canorus	0.0170766	0.16667	0.55556	2.854418	65.022800	0.609
Picus vaillantii	0.0170399	0.53333	0.58333	2.848273	67.871073	0.852
Lullula arborea	0.0152172	0.03333	0.47222	2.543603	70.414676	0.001***
Mixed zeen						
Parus major	0.0296241	1.33333	1.30556	5.110953	5.110953	0.513
Phylloscopus bonelli	0.0295114	0.75000	1.11111	5.091504	10.202457	0.041 *
Fringilla coelebs	0.0293905	1.41667	1.05556	5.070643	15.2731	0.204
Cyanistes teneriffae	0.0293690	1.66667	1.91667	5.066936	20.340036	0.103
Sylvia atricapilla	0.0274394	0.79167	0.88889	4.734026	25.074062	0.425
Erithacus rubecula	0.0267158	1.20833	0.80556	4.609193	29.83255	0.055
Turdus murela	0.0263313	1.12500	1.16667	4.542858	34.226113	0.959
Ficedula hypoleuca	0.0253027	0.45833	0.77778	4.365400	38.591513	0.063
Regulus ignicapilla	0.0250168	0.58333	0.94444	4.316064	42.907577	0.419
Troglodytes troglodytes	0.0233771	1.08333	0.61111	4.033178	46.940755	0.134
Curruca melanocephala	0.0229666	0.79167	0.19444	3.962348	50.903103	0.219
Cuculus canorus	0.0225905	0.83333	0.55556	3.89746	54.800563	0.040*
Garrulus glandarius cervicalis	0.0204176	0.25000	0.77778	3.522585	58.323148	0.630
Certhia brachydactyla	0.0200465	0.58333	0.69444	3.458554	61.781702	0.137
Picus vaillantii	0.0195874	0.79167	0.58333	3.379359	65.161061	0.240
Columba palumbus	0.0188926	0.25000	0.77778	3.259477	68.420538	0.006**
Dendrocopo major	0.0165457	0.58333	0.44444	2.854585	71.275123	0.188

p = significance dissimilarity based on 1,000 randomizations.

Nine species are responsible for the mean of over 30% of dissimilarity between sampled areas (Table IV). The dissimilarity produced between *Q. suber* stands and oak mixed forests was in general, by the abundance difference of *Curruca melanocephala, Cuculus canorus, Dendrocopo major numidus* and *Serinus serinus.* The differences between *Q. canariensis* and *Q. suber* woodlands are produced mainly by *C. teneriffae, Ficedula hypoleuca, Columba palumbus* and *Lullula arborea* which were present with preference for a given woodlands.

The dissimilarity showed between *Q. canariensis* stands and oak mixed forests are due to *Phylloscopus bonelli, C. canorus* and *C. palumbus* presence.

DISCUSSION

Forest bird species structure and composition

406 species were found in Algeria (Isenmann and Moali, 2000), and the species recorded in the forest of Ouled Bechih correspond to 15% of the Algerian avifauna species.

More than 32% of birds species occurring in the study area are threatened (Jordap, 2012): *European goldfinch, S. serinus, Sturnus unicolor, Garrulus glandarius cervicalis, Muscicapa striata, P. moussieri, Oriolus oriolus, Regulus ignicapilla, Buteo rufinus, M. migrans migrans, Strix aluco, Ciconia ciconia ciconia, C. canorus, Merops apiaster, Upupa epops, Picus vaillantii, D. major numidus, Dendrocopos minor, J. torquilla, Turnix sylvaticus*, and from the 62 species recorded during this study, only one is vulnerable (IUCN Red List, 2022): *Streptopelia turtur,* and another is not evaluated: *Saxicola rubicola.* In this respect, 12 species are endemic to the Maghreb and/or to North Africa: *C. brachydactyla rubiginosa, Chloris chloris voousi, Curruca communis communis, G. glandarius cervicalis, Atlas pied flycatcher, E. rubecula witherbyi, H. rustica rustica, Periparus ater ledouci, A. barbara barbara, C. ciconia ciconia, Apus apus apus, P. vaillantii* and *D. major numidus.* The presence of these threatened, vulnerable and endemic species, confirms the importance of forest ecosystems of Ouled Bechih as a key habitat for the conservation of rare and endemic bird species.

The most abundant species in the studied forest areas are *C. teneriffae*, *F. coelebs*, *E. rubecula witherbyi*, *T. murela* and *P. major*, these forest birds are specialists of mediterranean oak woodlands that need more mature forest (Diaz *et al*., 1998; Santos *et al*., 2006), thus highlighting the suitability of this ecosystem for forest birds of the region. This confirms also to the importance of the biogeographic region when planning forest management measures (Suárez-Seoane *et al*., 2002).

We noted also the breeding in the studied landscape of some bird species mainly belonging to open areas, (e.g., *L. arborea*, *Emberiza cia)* and urbain land (e.g., *C. ciconia ciconia*, *S. turtur*, *H. rustica rustica*) because this study area contains forest edges and habitats influenced by human activities.

Our study also indicated that the presence of species of grassland and open areas beside purely forest species is due to the clear and the mosaic structure of the forest areas (presence of clearings and scrubland); the clearing of the open forests to create agro-forestry habitat that also supports grassland species, as the grasslands are located adjacent to the forest of Ouled Bechih, which confirms the conclusions of Rebbah *et al*. (2019).

Forest bird assemblage structure and composition

In order to apprehend the patterns of biological diversity and their fundamental causes, various diversity parameters were used. They are one of the most significant challenges used in ecological studies (Colwell and Coddington, 1994). Diversity indices are suitable ecological tools where comparisons across different habitats were needed (Begon *et al*., 1996).

Bird community enrichment is related to intensification in vegetation physiognomy, complexity and composition (Wiens, 1989; Hobson and Bayne, 2000a, b; Shochat *et al*., 2001; Laiolo, 2002; Machtans and Latour, 2003). However, no significant variation of the relative abundance, the species richness, and the species diversity of forest birds in Ouled Bechih were detected among the sampled forest areas, contrary to our expectation.

Moreover, several authors found less species richness in pure forests compared to mixed forests (James and Wamer, 1982; Barbaro *et al*., 2005) or a greater association of bird communities with the habitat complexity (Berg, 1997), although results from other studies are contradictory and related on the scales perception of the study area.

Furthermore, according to Hobson and Bayne (2000) more species richness was not related to heterogeneous forests, and other studies carried out in the Iberian Peninsula concerning the environmental factors associated with the distribution of forest bird communities also have emphasized this hesitation (Tellería and Santos, 1994; Carrascal and Díaz, 2003).

Our study revealed a significant resemblance of bird assemblages across forest types. These three forests are geographically closest to each other, while the entire of the forest of Ouled Bichih allows a sparse evolution of the vegetation, for each stage its own type of vegetation, the lower altitude stage consisting of cork oak stands, then in the middle, oak mixed forests, and finally to the highest altitude stage, zeen oak woodlands, these autochthonous species characterize the Mediterranean perimeter (Djema and Messoudène, 2009).

However, important dissimilarity bird assemblages were observed between the two pure stands, the lower forest of *Q. suber* and the upper forest of the *Q. canariensis*. This is probably due to its geographical (altitude gradient) and their ecological characteristics where most of the differences come from the lowest forest altitude part and the highest forest altitude part; in the lowest altitude stage, the cork oak stands is in direct contact with open landscapes (grasslands) and urban lands, permitting a significant species movement, and in the highest altitude of the forest, bird assembly of the cork oak woodlands presents its specific forest characteristic for altitudes above 1000m. In addition, these results determined the altitudinal zonation of the two forest stands cited above where significant discontinuities in the bird assemblages were revealed. The findings of the present study agree with previous studies (Romdal and Rahbek, 2009; Patterson *et al*., 1998; Goodman and Rasolonandrasana, 2001; Hamilton, 1975).

Nevertheless, the insignificant dissimilarity in bird assemblages within the three forests between *Q. canariensis* stands and oak mixed forests on the one hand, and between *Q. suber* stands and oak mixed forests on the other, should be the result of the continuities in the plant composition communities, which occurred in parallel between the three stands of the forest are indicative of the transition from one forest to the other by means of the middle oak mixed forests. These results led to consider the contrasting community unit theory vs (individualistic) continuum concepts (Moravec, 1989).

Despite the clear limits between the three forest landscapes, this theory illustrates that the forest of Ouled Bechih correspond as continuum landscape which can by their different forest stands perceived the same bird species assemblages. The intermediate habitat of the oak mixed forests at Ouled Bechih corresponds on the whole to a continuum of the other forest stands (*Q. suber* and *Q. canariensis*). This indicated the largest response of the oak mixed forests to the assembly of intermediate bird species that preferred zeen oak forests or cork oak forests. For these species, oak mixed forests provided habitat substitution for zeen oak forests or cork oak forests, such as habitat for movement, or habitat for foraging (Lindenmayer et al., 2002). For example, *Certhia brachydactyla* and *Pycnonotus barbatus* used oak mixed forests for foraging, permitting habitat movements to be extended outside cork oak forests into oak mixed forests because they might otherwise be considered sensitive to plant composition, indicating a preference for this habitat in some aspects of their ecology (White *et al*., 2005; Stralberg *et al*., 2015).

CONCLUSION

In conclusion, in our study, the results obtained contribute significantly to understanding the breeding bird distribution across the oak woodlands of Ouled Bechih; help further assessing the effects of plant composition on the integrity of bird communities. These findings will help also in planning future conservation measures to supporting the biodiversity in this forest landscapes by providing some management recommendations such as; (1) Forest landscape management should focus on maintaining forest heterogeneity in order to provide a diversity of habitats that are useful to a range of different bird species; (2) Especially for bird species which depend on homogenous vegetation, it is very important to restore large and structurally complex patches of homogenous forests in order to provide essential habitat for these bird species.

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IRB approval

This study was conducted in accordance with ethical standards and guidelines. As the research did not involve human participants, institutional review board (IRB) approval was not required.

Ethics statement

Our research was conducted with integrity and in accordance with the highest ethical standards and applicable regulations.

Data availability statement

Data available on request from the authors.

Statement of conflict of interest

The authors have declared no conflict of interest.

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