JOURNAL OF ANIMAL BEHAVIOUR AND BIOMETEOROLOGY

RESEARCH ARTICLE
Published Online: June 2, 2022
https://doi.org/10.31893/jabb.22025

The avifauna of two High Atlas valleys: breeding assemblages in forest stands and open lands

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Abstract In this study, we surveyed the diversity and distribution of breeding birds in dominating habitat of Central High Atlas valleys and principal governing factors. In the point-counts method with 170 sampling points from 2018 to 2019, richness parameters and multivariate analysis were used to assess the distribution of recorded birds. We recorded 92 breeding birds of migrants (34%) and residents (68%), belonging to 34 families and 13 orders. The families of Muscicapidae (13 species), Fringillidae (8 species), and Accipitridae (7 species) were the most abundant, while the Regulidae, Malaconotidae, Acrocephalidae, Cettiidae, Pycnonotidae, Cinclidae, Oriolidae, Laniidae, Phylloscopidae, Troglodytidae, Meropidae, Coraciidae, Cuculidae, Caprimulgidae, Upupidae, and Ciconiidae, were the less observed with one bird species each. One species of conservation concern, namely the globally vulnerable Turtle dove, was recorded. On the other hand, Statistical analysis showed that bird richness was similar among forest stands, while abundance differed significantly. In contrast, both richness and abundance were statistically different among open habitats. Further, 46 species were found in Juniper stand surrounded by agricultural fields, followed by 30 species in Holm Oak stands where the density of trees, shrubs, and canopy coverage were higher, while in Black poplar stands characterised by higher trees and shrubs, and high availability of water hosted only 20 species. Rare and accidental birds dominate the forest and open lands, demonstrating the vulnerability of these habitats. This study could serve as a great reference for comparative studies of interesting birds on both slopes of the Mediterranean.

Keywords: avian species, Atlas Mountains, breeders, diversity, habitat use

1. Introduction

In the Northern slope of the Mediterranean basin, forest ecosystems have shown a great diversity of avian species among breeders, winterers, and migrants (Fernández-Juricic 2004; Bartolommei et al 2013). Thanks to their richness in fruits, seeds, and abundant trees, forest ecosystems offer birds foraging resources and breeding requirements (Muiruri et al 2016; Campos-Silva and Piratelli 2021; Mansouri et al 2022a). Therefore, avian species select specific forest stands that offer the needed requirements, leading to an affinity between vegetation cover and birds (Schuster and Arcese 2013; Muiruri et al 2016). These strategies result in segregation between bird communities and species to avoid competition for breeding and foraging resources (Mansouri et al 2022a).

In Morocco, ornithology studies started in the early decades of the 20th century 1976 (Smith 1965; Thévenot 1976; Ater et al 2008; Cherkaoui et al 2009). These studies have investigated terrestrial and aquatic birds from the Mediterranean coasts to the extreme Southern Atlantic coasts (Green et al 2002; Hilgerloh et al 2006; Ouassou et al 2018; Squalli et al 2020; Touhami et al 2020; Salai et al 2021). Further, farmland and aquatic birds were the most investigated birds (Hanane and Baamal 2011; Hanane 2016; Mansouri et al 2018, 2019, 2020; El Hassani et al 2021), while forest and Mountainous species have received little interest (Cherkaoui et al 2009; Hanane et al 2012; Mansouri et al 2021a). Therefore, the investigation of forest ecosystems is suggested to fill the gap in forest birds.

In Morocco, forest ecosystems are distributed in coastal lines of the Mediterranean, Atlantic, and Mountainous areas in the Atlas and Rif chains (Muller et al 2015; Abel-Schaad et al 2018). These ecosystems are characterised by their diversity with more than 4500 plant species (Taleb and Fennane 2019). Their ecological roles are via hosting animal species counting birds, and maintaining the ecological interactions between them (Ajbilou et al 2006; Waters et al 2017). However, birds' affinity toward forest stands is not yet analysed (Hanane et al 2019). This gap is suggested to clarify the role of forest stands in offering food supplies and nesting requirements for birds counting the most threatened species. As demonstrated previously, Moroccan ecosystems play vital roles for migratory birds that cross between Europe and Africa (Ayache et al 2009; Khelifa et al 2017; Mansouri et al 2022a); therefore, the

 Received: April 23, 2022 | Accepted: May 28, 2022

understanding of avian species that use these habitats is suggested to help in protecting them.

The present study aimed to evaluate the diversity of breeding birds in the Central High Atlas valleys of Beni Mellal in terms of species richness, abundance, phenological status, and trophic guilds. Equally, we investigated the distribution of breeding birds in the most dominating habitats, counting forests and open lands, to conclude if there are a kind of affinities between birds and vegetation cover. Environmental variables were also involved in explaining any variation in avian distribution. Further, the assemblage of recorded birds was used to evaluate the quality of monitored habitats.

2. Materials and Methods

2.1. Study area and sampling points

This study covered both valleys of the northern slopes of the High Atlas Mountains (Lakhdar-Aït Bouguemez and Oued Ahansal), between 800 m and 2600 m of elevation over sea level (Figure 1). The rivers' flow is mainly defined by a series of permanent springs and tributaries, with some intermittent creeks highly dependent on seasonal rainfall and melting snow. These rivers drain large watersheds, comprising high massifs, culminating at 2000 to 4000 meters and marked by numerous rocky escarpments. The study area climate is oromediterranean, characterised by large seasonal and interannual rainfall amplitude, with an average between 500 and 800 mm/year (Romagny et al 2008; Auclair and Alifriqui 2012) and high spatiotemporal variation of temperatures.

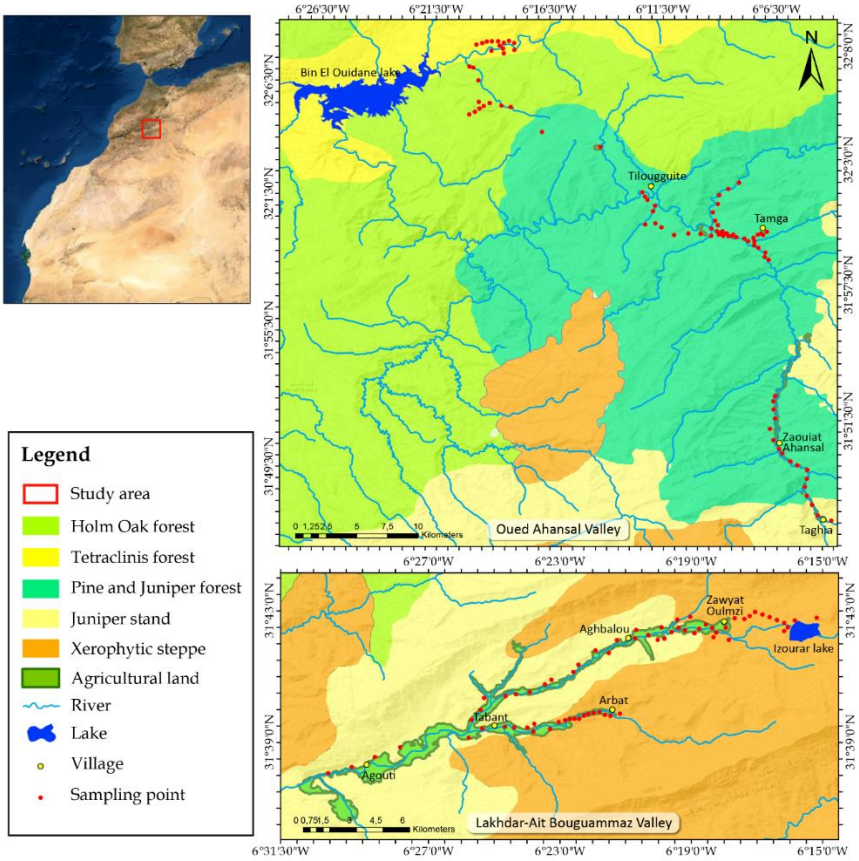

Figure 1 Location of the study area and site surveys.

The vegetation of the valley bottoms is dominated by forest formations, high mountain low formations, and cultivated lands, which vary with the elevation. In the Ahansal valley, the forest formations consist of Aleppo pine *Pinus halepensis* and Phoenician juniper *Juniperus phoenicea*, sometimes associated with the holm oak *Quercus rotundifolia*. These are accompanied by woody shrubs (Balearic boxwood *Buxus balearica*, Mastic tree *Pistacia lentiscus*, and Thymus *Thymus satureioides*). The natural riparian vegetation, well developed in the Tamga sector, is composed of Black poplar stands *Populus nigra*, accompanied by *Nerium oleander* (Ibn Tattou and Fennane 2006). Resin spurge formations *Euphorbia resinifera* cover the rocky slopes upstream to Bin El Widane reservoir and the Assif Melloul gorges. In Aït Bouguemez valley, forests consist of Phoenician juniper and Thurifer juniper *Juniperus thurifera*, sometimes associated with Cade juniper *Juniperus oxycedrus* and Holm oak. The Balearic boxwood colonises the rocky screes and the mobile substrates (Auclair 1996), while the Thurifer juniper represents the highest forest formations (Rhanem 1985), generally located far from streambeds.

In the two watersheds, the high mountain low formations correspond to lawns, appearing in some open valleys of small permanent creeks, and to steppes of spiny xerophytes (*Bupleurum spinosum*, *Hormathophylla spinosa*, *Genista lobelia*, *Ormenis scariosa*), which occupy the slopes of the highest valleys (Aude Nuscia et al 2015). The cultivated lands (orchards and irrigated cereal fields) occupy small alluvial banks and terraces, sometimes extended as alluvial plains (Auclair 1996). Still, they are progressively expanding in altitude and replacing the forest cover.

Bird sampling concerns the valley bottoms, mainly the river banks and the adjacent slopes, where habitats are more or less dependent on the river hydrology, sedimentation, and physiography. In Ahansal valley, the sampling concerns a large altitudinal range (800 to 1900 meters), more precisely the sections located between Bin El Widane reservoir (32°6'55.36''N, 6°21'33.14''W) and the Ahansal springs in Taghia (31°47'5.20''N, 6°4'15.44''W), passing through the Tamga forest (1200 m) and Zawiyat Ahansal village (1630 m). In Lakhdar-Aït Bouguemez valley, the sampling is carried out in a higher sector (1800-2560 m of altitudes), explicitly between Agouti village (31°38'15.02''N, 6°29'19.98''W") and Izourar lake (31°42'36.00''N, 6°15'23.58''W), passing through the rural communities of Tabant-Zawiyat Oulmzi.

In both valleys, bird listening points were selected along the central river course, making them at least one kilometer distant from each other to avoid double counts. Nevertheless, as their choice is based on habitat variations along the rivers, this distance decreases when necessary to 300 meters. We estimate the bird detection radius to be 100-150 meters around each sampling point. To cover the habitats exhaustively along the two rivers, we selected 170 sampling points in both valleys.

Bird investigations, mainly based on listening sessions of 10 to 20 minutes, concern eight types of ecosystems, including forest and riparian formations, steppes, and agricultural lands.

2.2. Bird surveys

Bird data mainly were collected using the PAI (punctual abundance index) method, which is a relative method of point counts implemented during the breeding period (when songbirds show spatiotemporal stability); this method is mainly based on the listening technic suggested by(Blondel et al 1970). This classic method, suited for forest birds in dense habitats (Morris 2001), allows significant comparisons of different songbird communities.

Some groups (Apodidae, Hirundinidae, Corvidae, and Raptors) were counted by direct observation, which allowed to locate the nesting sites. For nocturnal birds (nightjars, owls), we organised night listening sessions in short field itineraries.

The PAI surveys of the breeding birds, carried out by the same observer, were made in 2018 and 2019 during the spring season. The sampling operation happened within the first 3-5 hours after sunrise when the vocal activity of songbirds was at its maximum, during which we recorded all the birds seen or heard. The sampling is interrupted when the weather conditions are unfavourable to bird activity.

Each listening point benefited from two spring visits between the mid-March and mid-April (early breeders) and between the first decade of May and the last decade of June (late breeders). In total, we carried out 340 partial PAI in 170 sampling points.

Table 1 Environmental parameters useful for interpreting the bird communities of the Central High Atlas valleys.

Parameter	Definition	Method
Trees height	Average of the tree heights in each forest sampling point	Average calculates for a representative sample of trees
Shrub height	Average of the shrub plant heights in each forest sampling point	Average calculates for a representative sample of plants
Shrub coverage	Coverage of shrub plants in each forest sampling point	Estimated with help of photos
Canopy coverage	Surface occupied by trees species in each forest sampling point	Estimated using Google Earth Pro imagery
Trees density	Number of trees in each forest sampling point	Calculated using Google Earth Pro imagery
Agricultural field coverage	Area occupied by agricultural lands in each forest sampling point	Estimated using Google Earth Pro imagery
Number of trees and shrubs species	Species richness of tree and shrub formations in each forest sampling point	Calculated average of the number of trees and shrub species, sampled in the field and identified
Water availability	Presence of water resources in each forest stand	Calculated in each forest stand based on the percentage of sampling points where water resources (springs, watercourses...) are available

2.3. Environmental variables

In each listening point, we estimated eight environmental variables characterising forest ecosystems (Table 1): tree height, shrub height, shrub coverage, canopy coverage, tree density, agricultural field coverage, number of plant species (only trees and shrubs) and water availability.

2.4. Data analysis

Recorded pairs were grouped for each habitat in both forests and open lands. Further, we calculated species richness (total number of bird species recorded for each habitat), abundance (number of breeding pairs), and frequency of occurrence (number of observations/total observation points) for each habitat. For abundance, we considered different indexes suggested by (Blondel et al 1981): a singing male, courtship display, occupied nest, pair of birds, the family group are assigned to one pair for each breeding species, while a single bird, flying or foraging or calling, is assigned to 0.5 pair. We also calculated for each type of habitat the average bird richness and abundance in each sampling point to normalise the richness and abundance values in different types of habitats and avoid the effects of surfaces and the number of observation points among studied habitats. The frequency of occurrence of a species in each type of habitat is an additional criterion that informs on the birds' preferences and the organisation of their communities (Müller 1985). It is calculated using the formula K/N x 100 (N is the total number of sampling points in a habitat type, and K is the number of points hosting the species). We compared studied parameters counting richness and abundance among studied habitats in both forests and open lands with ANOVA one way test.

We used Multivariate analysis to investigate the distribution of recorded species among studied habitats and controlling factors. For the selection of breeding habitats, breeding pairs of avian species (in our case, only 60 species were tested, while gregarious birds where pairs were unclear and birds unrelated to vegetation cover were excluded) were considered as dependent variables. In contrast, breeding habitats (n=8: four in forest ecosystems and four in open lands) were considered as factors (independent variables) and analysed with Factorial Correspondence Analysis (FCA) (Benzécri 1973). In our case, only two axes were generated and selected (with eigenvalues >1 and % variance>50%). To investigate the principal environmental variables characterising each habitat in forests, we used Canonical Correspondence Analysis CCA (ter Braak 1986). We considered breeding habitats selected by breeding pairs as dependent variables while environmental variables (n=8) were considered as factors. Statistical tests were conducted using SPSS 18 (SPSS IBM, 2009), and graphs were built using GraphPad Prism 9.0.0 software.

3. Results

3.1. Community of breeding species

From 2018 to 2019, 92 breeding birds were recorded in studied valleys and counted breeders belonging to 34 families and 13 orders. The order of Passeriformes counted 61 species and 21 families (Figure 2), followed by Accipitriformes with seven species and one family, and Columbiformes with five species and one family. In contrast, five orders counting Coraciiformes, Cuculiformes Caprimulgiformes, Bucerotiformes, and Ciconiiformes recorded only one species and one family each and marked the less diverse orders. The most abundant families were Muscicapidae with 13 species, Fringillidae with eight species, and Accipitridae with seven species. In contrast, sixteen families counting Regulidae, Malaconotidae, Acrocephalidae, Cettiidae, Pycnonotidae, Cinclidae, Oriolidae, Laniidae, Phylloscopidae, Troglodytidae, Meropidae, Coraciidae, Cuculidae, Caprimulgidae, Upupidae, and Ciconiidae recorded only one species each and considered as less observed.

The recorded species were dominated by resident birds with 62 species (68%), followed by migrant avifauna with 32 species (34%). On the other hand, among documented species, 91 birds were classified as least-concern species according to UICN conservation status. Only the globally threatened Turtle dove *Streptopelia turtur arenicola* registered in both valleys was classified as vulnerable species.

Trophic guilds of recorded species were diverse. Insectivorous dominated with 49 species (51.64%), principally Muscicapidae with 13 species, Sylviidae with five species, and Motacillidae with four species, followed by carnivorous, omnivorous, and granivorous with 15, 14, and 12 species each, respectively. On the contrary, Species with a mixed diet (granivorous-insectivorous) counted only five species (5.49%) (Supplementary Material).

3.2. Selection of nesting habitats

3.2.1. Bird species richness and abundance

The valley of Aït Bouguemez hosted 84 breeding species compared to 79 species recorded in the valley of Oued Ahansal. Recorded species belong to 13 orders and 32 families in Aït Bouguemez, while in Oued Ahansal 33 families and 13 orders were documented.

Bird richness and abundance were different among studied habitats (Table 2). In forest habitats counting Holm oak, Juniper, Aleppo pine, and black poplar, bird richness was similar, while abundance differed. The higher abundance was recorded in Juniper and Aleppo pine, while holm oak and black poplar recorded the lowest abundance. Equally, both richness and abundance in open lands were different in studied habitats. Agricultural lands and Grasslands recorded the highest richness and abundance, while Resin spurge and Spiny xerophytes steppes recorded the lowest rates.

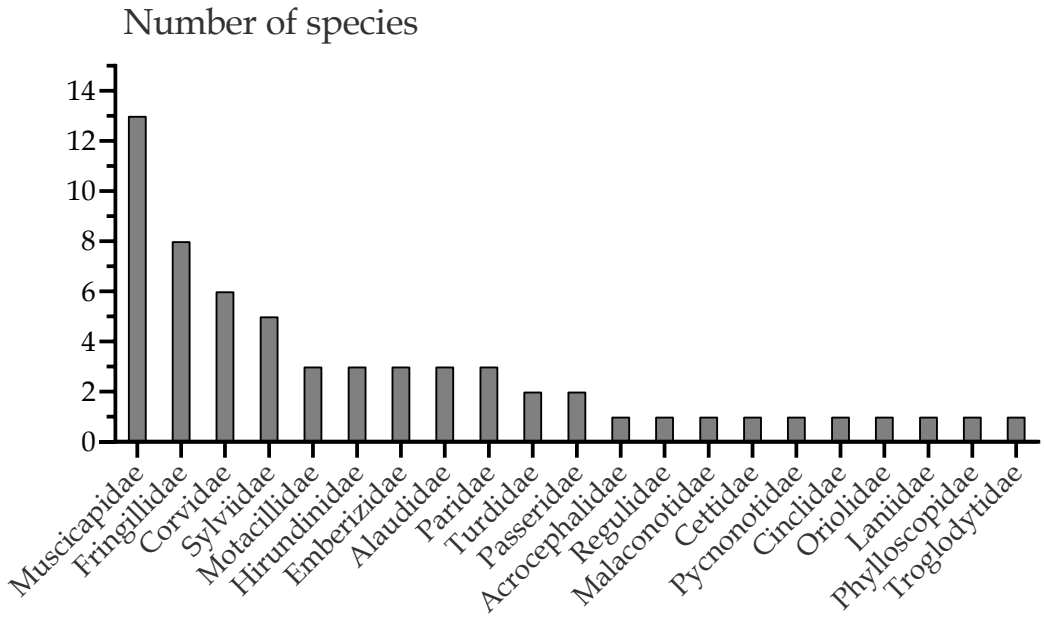

Figure 1 Number of breeding Passerines by families present in the valleys of Ahansal and Aït Bouguemez.

3.2.2. Bird species frequency

The frequency of occurrence of avian species in forest and open lands are summarised in Figure 3. Accidental birds (5%< F < 25%) were the most recorded species in forests, mainly in Juniper, Holm oak, Aleppo pine, and Black poplar stands, followed by incidental birds (25%< F < 50%) principally in Juniper, Aleppo pine, and Holm oak. Rare (F<5%), regular (50%< F <75%), and constant birds (F>75%) marked the less observed species in forest habitats. Accidental species recorded the highest rates in all studied habitats in open lands. Incidental birds recorded the highest rates in Grasslands and Resin spurge. Rare birds recorded the highest rate in agricultural lands. In contrast, regular and constant birds recorded the lowest richness in all studied habitats.

Table 2 Comparison of Breeding bird richness and abundance with ANOVA test (we compared the mean of observed pairs per observation point in each habitat).

Forests stands			Open lands		
Formations	Bird richness	Bird abundance	Formations	Bird richness	Bird abundance
Holm oak	8.35±2.64	10.18±4.98	Grasslands	7.07±2.73	10.43±4.5
Juniper	9.86±4.73	16.44±8.92	Resin Spurge	5.91±2.98	7.32±6.49
Aleppo Pine	8.25±4.55	16.67±10.88	Spiny xerophytes	3.2±1.61	3.65±2.57
Black poplar	8.33±3.08	11.11±6.35	Agricultural lands	7.36±2.79	11.75±6.65
F-value (f)	0.95	2,935	F-value (f)	6.729	5,775
P-value (p)	0.406	0,038	P-value (p)	0.000	0,001

Selected breeding habitats are summarised in Figure 4. The xerophyte steppes were excluded from the analysis as they host some very characteristic species counting the *Rhodopechys alienus*, *Eremophila alpestris*, *Oenanthe seebohmi*, and *Monticola saxatilis*. These species appear to be off-centered in the FCA diagram, which dilutes the information provided by the first factorial axes. Thus, this analysis was restricted to 55 bird species. Eleven species counting *Oriolus oriolus*, *Dendrocopos major*, *Picus vaillantii*, *Muscicapa striata*, *Coracias garrulus*, *Ficedula speculigera*, *Upupa epops*, *Carduelis carduelis*, *Coccothraustes coccothraustes*, *Pycnonotus barbatus*, and *Caprimulgus europaeus* nested in habitats dominated by Black poplar. Thirteen species counting *Galerida theklae*, *Oenanthe leucura*, *Phoenicurus moussieri*, *Linaria cannabina*, *Emberiza calandra*, *Motacilla flava*, *Motacilla alba*, *Petronia petronia*, *Lanius senator*, *Tchagra senegalus*, *Cuculus canorus*, *Pica Mauritanica*, and *Alectoris barbara* selected commonly Grasslands and Resin spurge. Nine species counting *Periparus ater*, *Cyanistes teneriffae*, *Parus major*, *Sylvia communis*, *Lullula arborea*, *Loxia curvirostra*, *Garrulus glandarius*, *Chloris chloris*, And *Columba palumbus*, were most abundant in

Aleppo pine forest. Finally, 21 species counting *Turdus viscivorus*, *Fringilla coelebs*, *Turdus merula*; *Troglodytes troglodytes*, *Coturnix coturnix*, *Cettia cetti*, *Emberiza cia*, *Emberiza cirlus*, *Erithacus rubecula*, *Hippolais polyglotta*, *Luscinia megarhynchos*, *Monticola solitarius*, *Motacilla cinerea*, *Phylloscopus collybita*, *Phoenicurus ochruros*, *Regulus ignicapilla*, *Serinus serinus*, *Sylvia atricapilla*, *Sylvia cantillans*, *Sylvia conspicillata*, and *Sylvia melanocephala*, used partially forests dominated by Holm oak, Phoenician juniper, as well as agricultural lands dominated by orchards and cereals.

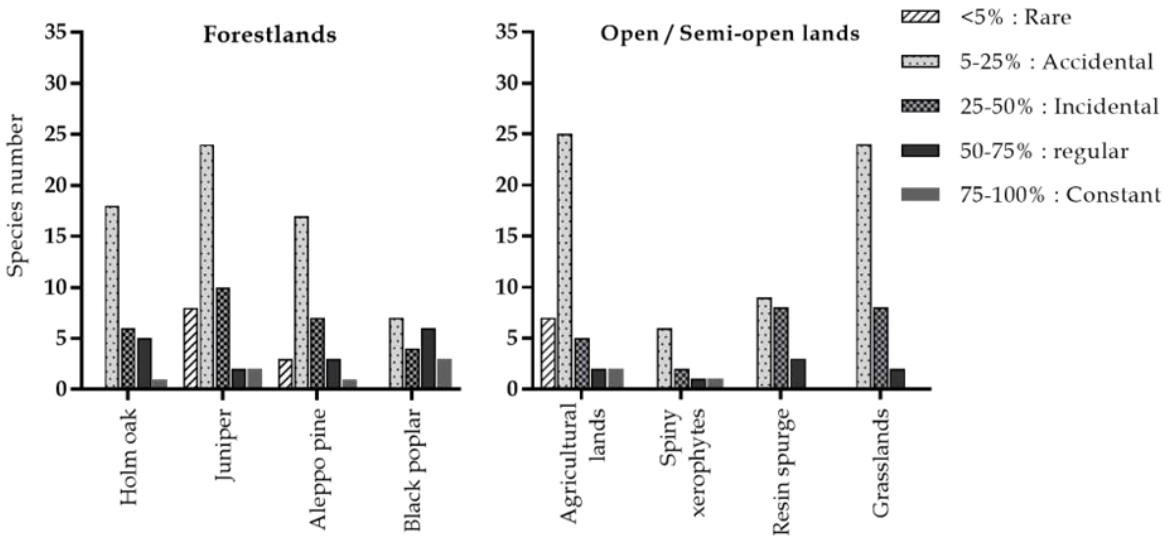

Figure 2 Number of breeding species by frequency classes in the eight habitat types.

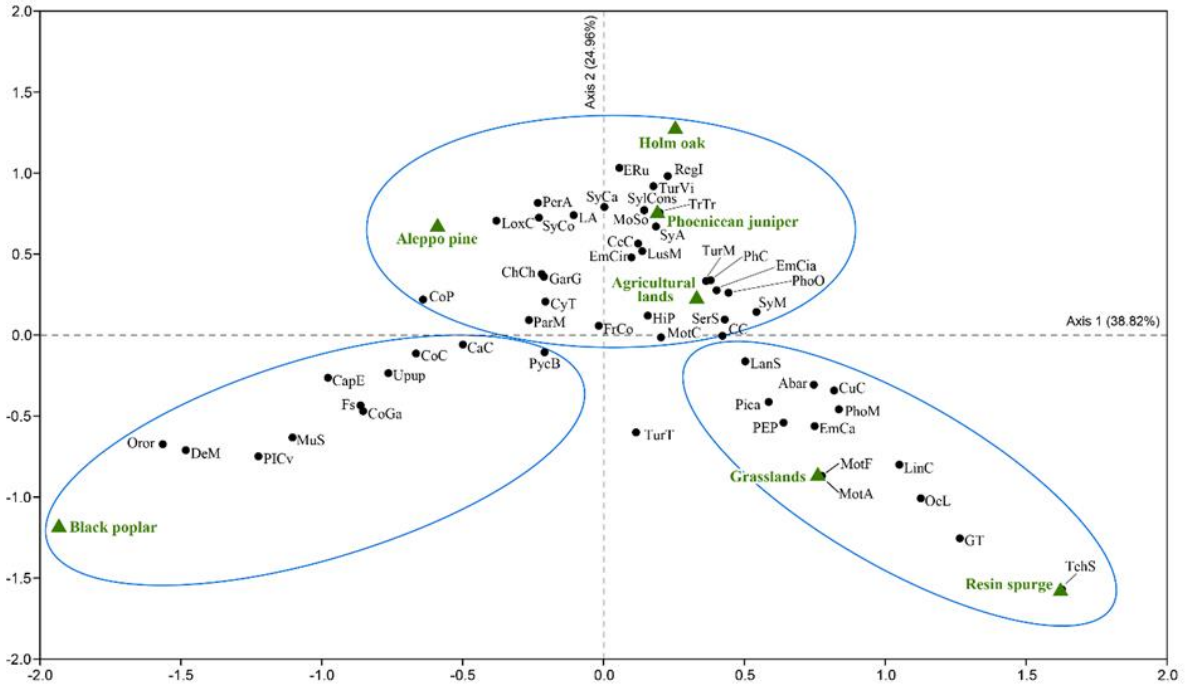

Figure 3 Projection on the first two axis of the Factorial Correspondence Analysis of habitat types and characteristic bird species. Species code: Abar: *Alectoris barbara*; EmCir: *Emberiza cirlus*; MotC: *Motacilla cinérea*; RegI: *Regulus ignicapilla*; CaC: *Carduelis carduelis*; Eru: *Erithacus rubecula*; MotF: *Motacilla flava*; SerS: *Serinus serinus*; CapE: *Caprimulgus europaeus*; FrCo: *Fringilla coelebs*; MuS: *Muscicapa striata*; SyA: *Sylvia atricapilla*; CC: *Coturnix coturnix*; Fs: *Ficedula speculigera*; OeL: *Oenanthe leucura*; SyCa: *Sylvia cantillans*; CeC: *Cettia cetti*; GarG: *Garrulus glandarius*; Oror: *Oriolus oriolus*; SyCo: *Sylvia communis*; ChCh: *Chloris chloris*; GT: *Galerida theklae*; ParM: *Parus major*; SylCons: *Sylvia conspicillata*; CoC: *Coccothraustes coccothraustes*; HiP: *Hippolais polyglotta*; PEP: *Petronia petronia*; SyM: *Sylvia melanocephala*; CoGa: *Coracias garrulus*; LA: *Lullula arbórea*; PerA: *Periparus ater*; TchS: *Tchagra senegalus*; CoP: *Columba palumbus*; LanS: *Lanius senator*; PhC: *Phylloscopus collybita*; TurM: *Turdus merula*; CuC: *Cuculus canorus*; LinC: *Linaria cannabina*; PhoM: *Phoenicurus moussieri*; TurT: *Streptopelia turtur*; CyT: *Cyanistes teneriffae*; LoxC: *Loxia curvirostra*; PhoO: *Phoenicurus ochruros*; TurVi: *Turdus viscivorus*; DeM: *Dendrocopos major*; LusM: *Luscinia megarhynchos*; Pica: *Pica Mauritanica*; Upup: *Upupa epops*; EmCa: *Emberiza calandra*; MoSo: *Monticola solitarius*; PICv: *Picus vaillantii*; TrTr: *Troglodytes troglodytes*.

Multivariate CCA (Figure 5) showed that in Black poplar, the recorded breeders counting *Dendrocopos major*, *Picus vaillantii*, *Coracias garrulus*, *Upupa epops*, *Ficedula speculigera*, *Muscicapa striata*, *Carduelis carduelis*, *Coccothraustes coccothraustes*, *Oriolus oriolus*, and *Streptopelia turtur arenicola* were attracted principally to water and the height of both trees and shrub. *Curruca melanocephala*, *Sylvia atricapilla*, *Regulus ignicapilla*, *Erithacus rubecula*, *Periparus ater*, *Troglodytes troglodytes*, *Garrulus glandarius*, *Luscinia megarhynchos*, *Turdus merula*, *Emberiza cia*, and *Alectoris barbara*, were found in Holm oak Forest characterised by a high density of trees, high shrubs, and canopy coverage. Phoenicean juniper attracted birds counting *Emberiza calandra*, *Emberiza cirlus*, *Lullula arborea*, *Hippolais polyglotta*, *Serinus serinus*, *Linaria cannabina*, *Chloris chloris*, *Lanius senator*, *Phoenicurus moussieri*, *Phylloscopus collybita*, *Curruca communis*, *Sylvia cantillans*, *Oenanthe leucura*, *Turdus viscivorus*, and *Monticola solitarius*, due to the nearby areas occupied by agricultural fields rich in cultivated seeds and irrigation channels. In contrast, six species mainly *Fringilla coelebs*, *Columba palumbus*, *Pycnonotus barbatus*, *Motacilla cinerea*, *Parus major*, and *Cyanistes teneriffae* were common in all studied habitats and not influenced by their relevant characteristics.

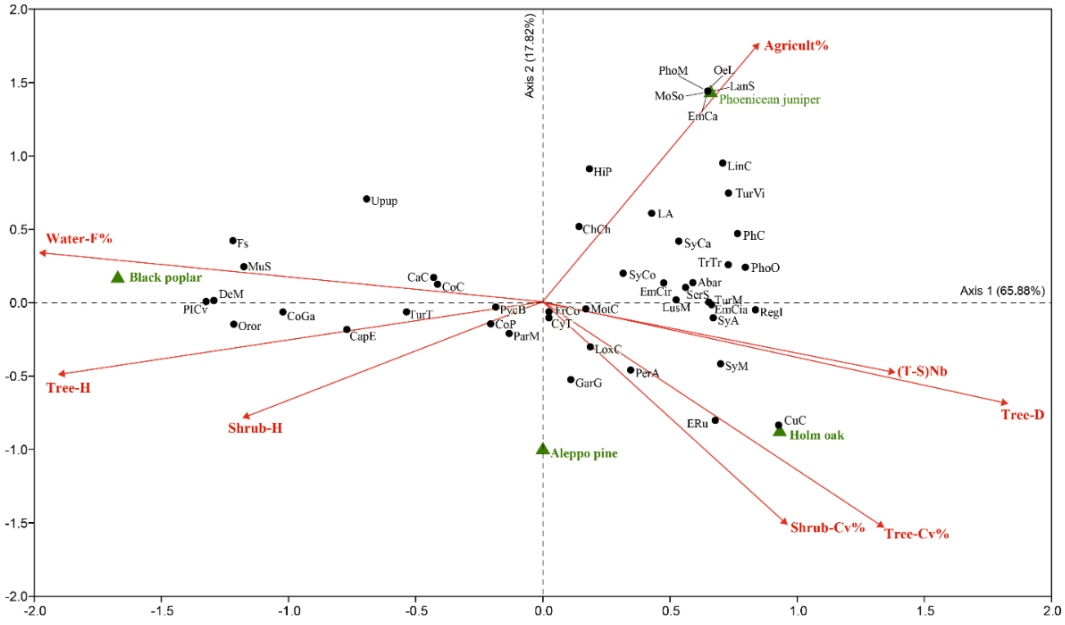

Figure 4 Projection on the first two axis of the Canonical Correspondence Analysis showing the relationships between environmental variables and bird species. Tree-H: Trees height; Shrub-H: Shrub height; Shrub-Cv%: Shrub coverage; Tree-CV%: canopy coverage; Tree-D: Trees Density; (T-S)Nb: (Trees-Shrub) species number; Agricult%: surface occupied by Agricultural fields; Water-F%: water availability.

4. Discussion

This study investigated the diversity of breeding birds and their affinity toward dominating forest and open lands in the Oued Ahansal and Aït Bouguemez valleys located in the Central High Atlas of Morocco. The obtained data are the first in this neglected zone of Moroccan and Northwest African ecosystems. Moreover, these data are of valuable importance in filling the gap of avifauna in Morocco.

Our investigations revealed 92 breeding species among residents and migrants, dominated by Passeriformes, principally the families of Muscicapidae and Fringillidae (principally the *Fringilla coelebs*, *Serinus serinus*, and *Cyanistes teneriffae* that recorded the highest abundance respectively in all habitat types studied) which is similar to results revealed in Midelt (which only 180 km from our study area) in which 98 breeding species were recorded currently (Mansouri et al 2021a). Moreover, this study updated the breeding case of six species in the Central High Atlas valleys: *Curruca conspicillata* (with adult feeding nestlings in the xerophytic steppes of Aït Bouguemez) previously mentioned as a breeder in Zaouiat Ahansal (Thevenot et al 2005). *Hippolais polyglotta* (with more than 20 breeding pairs in agricultural lands in both studied valleys) previously mentioned nesting in Taghia springs (El Ghazi and Franchimont 1997); *Tchagra senegala* (with one pair in the resin spurge formations upstream of Bin El Ouidane lake) previously mentioned breeding in the foothills of the Central High Atlas (Smith 1965); The *Monticola saxatilis* (with one singing male and one sub-adult found at the xerophytic steppes near Izourar Lake) cited before as a breeder in Dadès Gorges and at Oukaïmden (Brosset 1957; El Ghazi and Franchimont 1997); *Monticola solitarius* (with one pair feeding nestlings above 2200m in Aït Bouguemez) previously mentioned as a breeder in the High Atlas (Barreau et al 1987). *Aquila fasciata* (with one pair nesting on a cliff at Aït Bouguemez valley) was mentioned once as a nester on Jbel Ayachi (Bergier and Naurois 1985).

However, 34% of breeders were migrants, indicating the area's role in offering nesting requirements for migratory

breeding birds, including the globally threatened Turtle dove (Mansouri et al 2021a). This is of great importance since Turtle doves have lost the majority of thier breeding habitats in Europe (Moreno-Zarate et al 2020; Mansouri et al 2022b), which may help in the recovery of its population in the Southern Slope of the Mediterranean. Similarly, the recorded species demonstrated a diversified trophic diet counting granivorous, insectivorous, omnivorous, carnivorous, and mixed, and these indicate the richness of foraging resources in the study zone, which is of great importance for breeders during the incubation of chicks (Sommerfeld and Hennicke 2010; Barger et al 2016), as demonstrated for Turtle dove in Midelt currently (Mansouri et al 2021b).

Our study investigated the affinity of birds toward the forest and open habitats. In forests, the higher numbers of species were recorded in Aleppo pine (31 species), and Holm oak (30 species) which is in agreement with results revealed in Moroccan forests, counting Thuya and Cork oak forests, in which 44 breeding species were recorded (Cherkaoui et al 2009; Hanane et al 2019), as well as with native oak forests of North-western Tunisia in which 31 nesting species were documented (Touihri et al 2014) and 39 bird species recorded in the Zeen oak stands in Algeria (Menaa et al 2016). Generally, forest ecosystems are known for their avian diversity on both slopes of the Mediterranean basin because of the abundance of nesting elements (forest trees) and foraging resources (wild seeds, fruits, insects, and water) (Prodon and Lebreton 1981; Mosimann et al 1987; Cherkaoui et al 2007; Dronneau 2007; Bergner et al 2015; Hanzelka and Reif 2016). On the contrary, the riparian trees of Black poplar did not host a high species richness like the other stand types (20 species) despite their closest location to rivers rich in water. Similar results were currently revealed in three riparian zones in Midelt (Squalli et al 2022), in which only nine breeding birds were documented. However, the low species richness in poplar stands has been reported in Europe (Le Floch and Terrasson 1995; Mourgaud 1996; Rotach 2004), which is richer in water compared with North African ecosystems threatened by aridity (Escoriza and Pascual 2021).

On the other hand, the breeding avifauna in the high mountain steppes of the Central High Atlas is relatively poor compared to the other habitats in open fields, as they recorded the lowest species richness in the study region (10 species). This very low richness at such high altitudes has been reported in a previous study carried out in the Western High Atlas in mount Toubkal (Cuzin 2010). It is probably due to the extreme conditions in this mountainous region, related to the high altitude, very low temperatures, late snowfall, and low productivity of the environment, limiting other bird species' presence.

Canonical analysis showed the principal factors influencing birds' affinity toward studied habitats. In Holm oak forests, the breeding community was attracted by a higher density of trees, high shrubs, and canopy coverage, in Phoenicean juniper, breeding birds were attracted to areas occupied by agricultural fields rich in cultivated seeds and irrigation channels, and in Black poplar, the recorded breeders were attracted principally to water, the height of both trees and shrub. Similar results were revealed in natural and artificial forests in other Moroccan provinces (Hanane et al 2019) in which shrub layer complexity and tree size were the most factors influencing birds' diversity. Equally, the diversity, and abundance of trees and bushes have favoured avian diversity in Cork oak forests of Maamora located in Northwest Morocco (Cherkaoui et al 2009). Moreover, currently, segregation of foraging resources (fruits and wild seeds in forests, water and cultivated seeds in riparian vegetation and farmlands) and nesting supports (forest trees in Holm oak and Juniper, riparian trees in Black poplar, orchards in farmlands) have revealed important effects on the distribution of birds among forest stands, riparian habitats, and farmlands and these are suggested to lead to segregation of selected habitat between breeding birds (Duron et al 2018; Mansouri et al 2022a; Squalli et al 2022) since recorded birds were different in their nesting requirements (cavity-nesting, farmland birds, and riparian species) and trophic guilds.

Accidental and incidental birds were the most observed species in both forest and open habitats compared with constant and regular species. These findings indicate that these habitats are not balanced since the richness of regular birds was lower. This is the case in most North African natural ecosystems impacted by natural and human factors (le Polain de Waroux and Lambin 2012; Chebli et al 2021). Currently, degradation of natural habitats, counting forests (Barakat et al 2018, 2019) and intensification of farming activities (Hilali et al 2021) have shown adverse effects on avian species in the study area, counting the vulnerable doves impacted by human farming practices (Hanane 2016; Mansouri et al 2020; Squalli et al 2022).

5. Conclusions

In summary, throughout this study, we documented the diversity of breeding birds in the Central High Atlas valleys of Beni Mellal, Morocco. Gained results revealed remarkable breeding communities of migrant and resident species in both forest and open lands, as well as diversity in trophic guilds of recorded birds. Equally, we demonstrated the impacts of higher density of trees, high shrubs, canopy coverage, agricultural fields, and water resources in controlling the attractiveness of selected habitats toward breeding pairs. The abundance of rare and accidental birds demonstrated the vulnerability of forests and open lands in the study area. Therefore, more deep investigations are urgently required to clarify the ecological roles of this important ecosystem in the way to classify them as sites of biological and ecological interest, which is suggested to increase the protection of potentially vulnerable elements.

Conflict of Interest

The authors declare no conflict of interest.

Funding

This research did not receive any financial support.

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