



Bird Diversity Across Farmland, Wetland, and Forest Environments of the Moulouya High Plain, Morocco

Diversidad de aves en entornos agrícolas, humedales y forestales del altiplano de Moulouya, Marruecos

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ABSTRACT

A survey of avian diversity in a specific environment is the first step to deeply understand the importance of this area, and to implement appropriate conservation policies. From January 2015 to December 2020, monthly surveys were conducted in Morocco's Moulouya High plain. The study documented 136 avian species belonging to 44 families and 21 orders. In addition, five species of conservation concern, namely the endangered *Neophron percnopterus* (migrant); the Near Threatened *Aythya nyroca* (wintering) and *Gypaetus barbatus* (resident summering); the Vulnerable *Streptopelia turtur* (migrant breeder), and *Chersophilus duponti* (resident breeder), were observed in the Moulouya High plain. On the other hand, the comparison of the diversity indices (Margalef, Simpson, and Shannon-Wiener indices) and compositional parameters (Taxa and abundance) revealed the maximum avian richness in forest and wetland habitats, while farmlands were the least diverse habitats. Finally, this study provides the first and only comprehensive data on the Moulouya High plain's bird species. The data collected from this study will be useful for future conservation efforts and the monitoring of the most endangered species and their habitats.

Keywords: Endangered species, biodiversity, Moulouya High plain, avian species.

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RESUMEN

Un estudio de la diversidad de aves en un entorno específico es el primer paso para comprender en profundidad la importancia de esta zona y aplicar políticas de conservación adecuadas. De enero de 2015 a diciembre de 2020, se realizaron estudios mensuales en las altas mesetas de Moulouya en Marruecos. El estudio documentó 136 especies de aves pertenecientes a 44 familias y 21 órdenes. Además, se observaron en dicha altiplanicie cinco especies de interés para la conservación, a saber: *Neophron percnopterus* (migrante), en peligro de extinción; *Aythya nyroca* (invernante), y *Gypaetus barbatus* (residente veraneante), en una situación casi amenazada; *Streptopelia turtur* (migrante reproductora), vulnerable, y *Chersophilus duponti* (residente reproductora). Por otra parte, la comparación de los índices de diversidad (índices de Margalef, Simpson y Shannon-Wiener) y los parámetros de composición (Taxa y abundancia) revelaron que la máxima riqueza de aves se registró en los hábitats de bosque y humedal, mientras que las tierras agrícolas fueron los hábitats menos diversos. Finalmente, este estudio proporciona los primeros y únicos datos completos sobre las especies de aves de la Alta Planicie de Moulouya. Los datos recopilados en este estudio serán útiles para futuros esfuerzos de conservación y para el seguimiento de las especies más amenazadas y sus hábitats.

Palabras clave: Especies en peligro, biodiversidad, Alta Planicie de Moulouya, especies de aves.

INTRODUCTION

Investigating bioecological and habitat diversity on a large scale is difficult (Dobson, 2005) political leaders at the 2002 World Summit on Sustainable Development (held in Johannesburg, South Africa. Patterns of biogeographical dispersal, species frontiers, dissimilarity, and taxonomy diversity should be examined and determined for both animal and plant species (Martínez-Ortega, Delgado, Albach, Elena-Rossello, Rico, 2004). A regional perspective of spatial deviation in endemism and diversity should integrate habitat records, which should be used to identify tiers of diversity at the local scale (Colwell and Coddington, 1994). Therefore, to have a comprehensive understanding of the mechanisms influencing diversity profiles, these configurations can be associated with other factors, including abiotic aspects of the environment (Poff and Ward, 1990). The achievement of this combination, primarily modalities of ecological diversity, is of paramount importance for scientific and public awareness as well as for management purposes toward the progression of ecological richness.

Morocco is situated in the extreme western portion of the Mediterranean basin, and it is one of the 25 diversified countries and the most threatened ecoregions of the planet. It is distinguished by its maritime

diversity, ranking second in term of vegetation and animal richness in the entire Mediterranean zone. Furthermore, Morocco hosts more than 31,000 species of both animal and vegetal, of which nearly 11 % are limited to the Moroccan territory. On the other hand, Morocco's residences have about 500,000 birds, including breeding, resident, migrating, wintering, and accident visitor species (Dakki, Qninba, El Agbani, Benhoussa, Beaubrun, 2001; Maggini and Bairlein, 2011; Cherkaoui, Magri, and Hanane, 2016).

The biodiversity of plants and animals in Morocco is preserved by various factors, such as the variety of environments (forests, coastlines, mountains, etc.) (Dakki, El FELLah, and Qninba, 2020; Fouzi, Youness, Guy, Ali, Andrés, 2020), variable climatic conditions (Mediterranean in the North, Mountainous in central, and Saharan in the South) (Tramblay et al., 2012) past trends in extreme precipitation and future projections using an ensemble of regional climate models (RCM, and geographical localization (crossroad between Europe and Africa). In reality, Morocco records ten natural/national parks, including three with marine boundaries within their borders, 38 wetlands classified as RAMSAR sites and 160 sites classified as Spots of Biological and Ecological Interest (SIBE) (Dakki, Menioui, Amhaouch, 2016). In addition, Morocco is considered the gateway between the African continent in the south and the European continent in the North for millions of migrant birds (Sander, Eccard, Heim, 2017). However, Moroccan systems are less studied despite their productivity and diversity because many are affected by both natural and man-made factors, such as habitat change and agriculture expansion. In Morocco's rich biodiversity context, Arabi et al. (2024) reported that various challenges affected Moroccan biodiversity, including forest reduction, declining mammalian diversity, and agricultural water stress (Arabi et al., 2024). In the same vein, numerous studies have proclaimed that climate change affects the potential distribution of different species (Moukrim et al., 2019; Kassout et al., 2022) we successfully modeled the habitat suitability of this species for the current and future climate change scenarios (2050 and 2070).

Within this framework, this investigation has two principal purposes: (i) to present a list of recorded avian species in the High plain of Moulouya, and (ii) to present habitat uses, mainly the importance of forests, wetlands, and farmlands for breeding, and foraging avian populations.

METHODS AND MATERIALS

Study area

Moulouya High plain is located in the center of Morocco, in the connection between the South of Fez-Boulmane and North of the Daraa-Tafilalet regions (Figure 1). Geographically, the Moulouya High plain is situated in the Eastern limit of the High Atlas Mountains and the South-eastern limit of the Middle Atlas, on a raised plain between 1300 and 1500 m (Chiapuris,

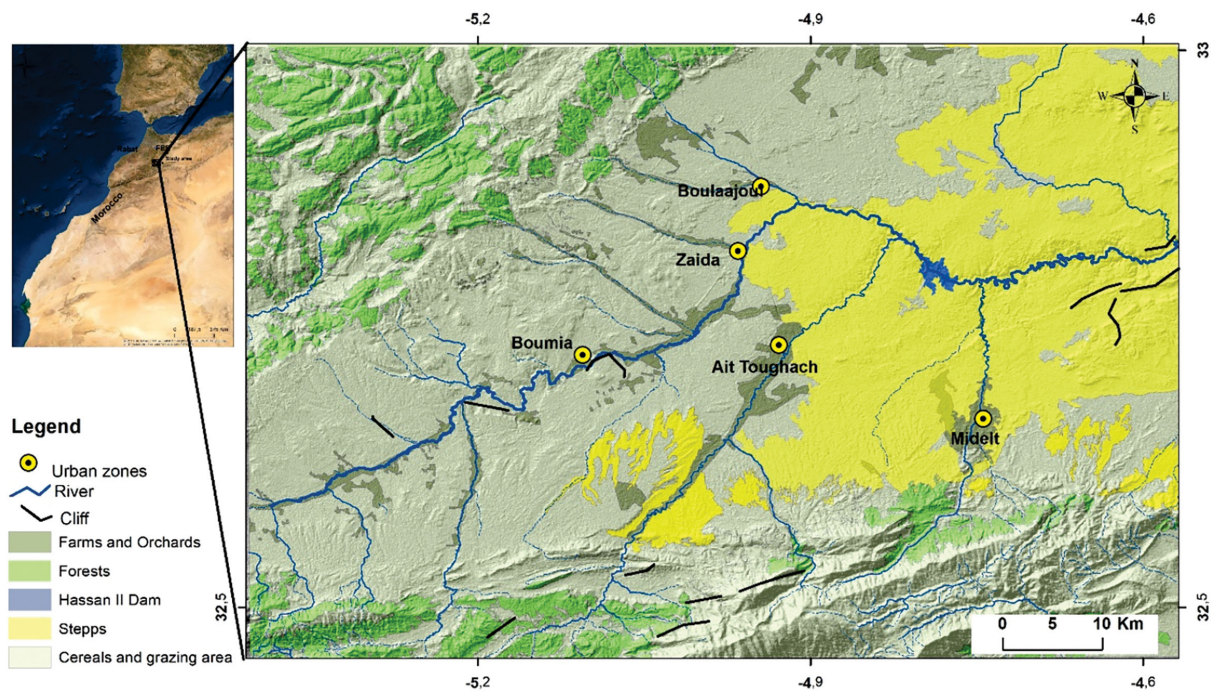


Figure 1. The main dominating habitats in the upper Moulouya plain (central Morocco).

Figura 1. Principales hábitats dominantes en la llanura superior de Moulouya (Marruecos central).

1979; Depreux et al., 2021). This zone surrounds the last humid ecosystems, including forests, rivers, and ponds in the Northwest of the Tafilalet palm oasis. In addition, the upper Moulouya is predominated by irrigated and rained agroecosystems. The main watered harvests are fruit agrosystems, mostly apple cultures, vegetables, and forage yields, while the key crops in rained lands are cereals, including wheat and barley.

Data collection

We selected the Moulouya High Plain based on its location between the Atlas mountainous chains, which are categorized as the water tower of central Morocco, and the first North African Saharan lands in the eastern Tafilalet. Additionally, this zone hosts two RAMSAR wetlands, the Isli and Tislit lakes, which are classified as the least mountainous wetlands that can be used by Palearctic migrant species as stopover sites before crossing the long Saharan flyway. Consequently, understanding the biological diversity of avian species and habitat use in this distinctive zone will be of great interest for future comparative studies and the implementation of conservation strategies.

Three principal ecosystems were distinguished in the upper Moulouya: farmlands, wetlands, and forests (Table 1). In each habitat, we recorded the avian species and other data that are susceptible to interference with the abundance and richness of the species. Avian species and abundance were

Table 1. Type and geographical location of explored habitats in the upper Moulouya.

Tabla 1. Tipo y localización geográfica de los hábitats explorados en los altos de Moulouya.

Habitats	Sites	Local name	Geographical location	
Wetlands	River	Ansguemir	32°41'11.88"N	4°57'56.21"W
		Tissouite	32°36'52.48"N	4°43'27.38"W
		Moulouya	32°43'41.15"N	5° 5'16.50"W
		Tabelkhirte	32°40'41.89"N	5° 9'30.29"W
		Ighesdis	32°44'50.63"N	5°10'15.81"W
		Tatteouine	32°36'0.51"N	4°45'56.20"W
		Aguersif	32°51'31.14"N	5° 5'17.53"W
		Tanourdi	32°50'19.11"N	5° 9'17.73"W
		Tamaloute	32°31'47.73"N	5° 4'33.95"W
	Dum	Hassan II	32°47'30.42"N	4°46'8.34"W
Forests	Forests	Imtchimne	32°31'22.98"N	5° 3'17.51"W
		Tounfite	32°28'42.18"N	5°14'12.38"W
		Ait Ouchen	32°29'43.04"N	5° 6'24.79"W
		Abouazam	32°32'38.87"N	5° 4'8.29"W
		Mi Tqan	32°31'44.01"N	4°59'24.88"W
		Sidi Yahya Ouyoussef 1	32°27'29.24"N	5°21'55.82"W
		Sidi Yahya Ouyoussef 2	32°27'1.92"N	5°25'22.71"W
		Itzer	32°50'27.58"N	5° 8'39.90"W
		Tanourdi	32°50'50.93"N	5° 9'54.88"W
		Jaafar	32°34'1.61"N	4°55'3.47"W
		Ait Brahim	32°50'45.40"N	5°10'34.38"W
	Steppe Halpha (<i>Stipa tenacissima</i>)	Mibladen	32°45'34.92"N	4°37'38.93"W
		Toughach	32°44'21.06"N	4°54'11.46"W
		Aouli	32°49'29.99"N	4°32'49.19"W
		Izegaghen	32°43'1.04"N	4°37'15.92"W
		Ghalban	32°42'51.05"N	4°52'13.34"W
	Mugwort white grass (<i>Artemisia herba-alba</i>)	Aaride	32°37'21.99"N	5° 2'37.04"W
		Ait Ayach	32°36'36.04"N	4°58'23.88"W
		Ait Oumghar	32°40'15.87"N	4°54'46.69"W
		Zaida	32°51'30.30"N	4°55'30.78"W
Farmlands	Orchards	Ait Ayach valley	32°34'12.29"N	5° 3'14.04"W
		Zebzate	32°39'31.96"N	4°35'3.03"W
		Ait Mouli	32°46'47.06"N	4°58'33.35"W
		Lksabi	32°49'57.46"N	4°29'43.34"W
		Taddamoute	32°42'11.61"N	4°46'41.76"W
		Midelt	32°41'0.08"N	4°45'1.99"W
		Ait Izdeg	32°39'43.73"N	4°45'55.10"W
		Boulaajoul	32°52'49.33"N	4°57'1.39"W
		Taouraoute	32°34'20.96"N	4°57'52.94"W
		Boumia	32°43'0.55"N	5° 6'19.46"W
		Tamouajjat	32°43'15.57"N	5° 3'52.44"W
	Cereals	Boulbzouz-Tabelkhirte	32°39'52.37"N	5° 8'21.41"W
		Ait Bouali	32°37'47.04"N	5° 9'36.17"W
		Boumia plain	32°44'16.63"N	5° 5'21.32"W
		Tadaout nsouk	32°44'32.90"N	5° 8'57.05"W
		Aghbalou	32°42'11.84"N	5°11'47.87"W
		Tanourdi	32°48'1.69"N	5°11'50.75"W
		Boutkhoubay	32°45'4.15"N	5°11'48.44"W

monitored and documented during the breeding, migration, and wintering periods (January 2015 to December 2020). In forest and farmland habitats, birds were surveyed via point-counting, with 7-10 km walking distances based on the surface of the explored habitat (Bibby, Burgess, Hill, Mustoe, 2000). “Point-count” is an operational approach for studying highly mobile and varying avian species (Bani, Massimo, Bottoni, Massa, 2006) because it allows wide range of monitoring of both the sample landscape and its adjacent environment (Gervasi et al., 2024) especially at the scale of an entire country. To produce wolf distribution and abundance estimates for the whole south-central portion of the Italian wolf population, we developed an integrated spatial model, based on the data collected during a 7-month sampling campaign in 2020–2021. Data collection comprised an extensive survey of wolf presence signs, and an intensive survey in 13 sampling areas, aimed at collecting non-invasive genetic samples (NGS). Furthermore, this technique can gather a wide range of ecological and environmental data related to species in a cost-effective manner (Selmi and Boulinier, 2003). Equally, we recorded breeding species for each habitat based on nests (during construction or occupation during incubation) or chicks (mainly for species characterized by discreet nesting).

Finally, we calculated percentages of documented and breeding species for each ecosystem (number of observed or breeding birds in the habitat/total observed or breeding birds in the entire Moulouya High plain) and data were plotted on a map of the entire study area using QGIS (open sources). Additionally, make the map more accurate, it was constructed for 2020, to clarify the habitat use by avian species.

Data analysis

First, we calculated species diversity indices based on data collected from 2015 to 2020 (12 Months), to compare the diversity among different studied ecosystems. We used the Margalef (D), Simpson (D) and Shannon-Wiener (H) indices, which are crucial indices for evaluating of any habitat diversity.

- I) Index of Shannon-Wiener: $H' = -\sum p_i \log p_i$ (Magurran, 2013),
- II) Index of Margalef: $D = \frac{S-1}{\ln N}$ (Farris, 1976),
- III) Index of Simpson: $\lambda = \frac{1}{\sum p_i^2}$.

For the Margalef index, the S parameter denotes the total number of avian species, and the N parameter represents the total number of individuals documented for all species. While for Shannon-Wiener and Simpson indices, the p_i parameter denotes the sum of the recorded birds for each species, and the i /aggregate number of documented avian species. Furthermore, we calculated the abundance as the relative size of an avian population, estimated from calculations of the total number of individuals

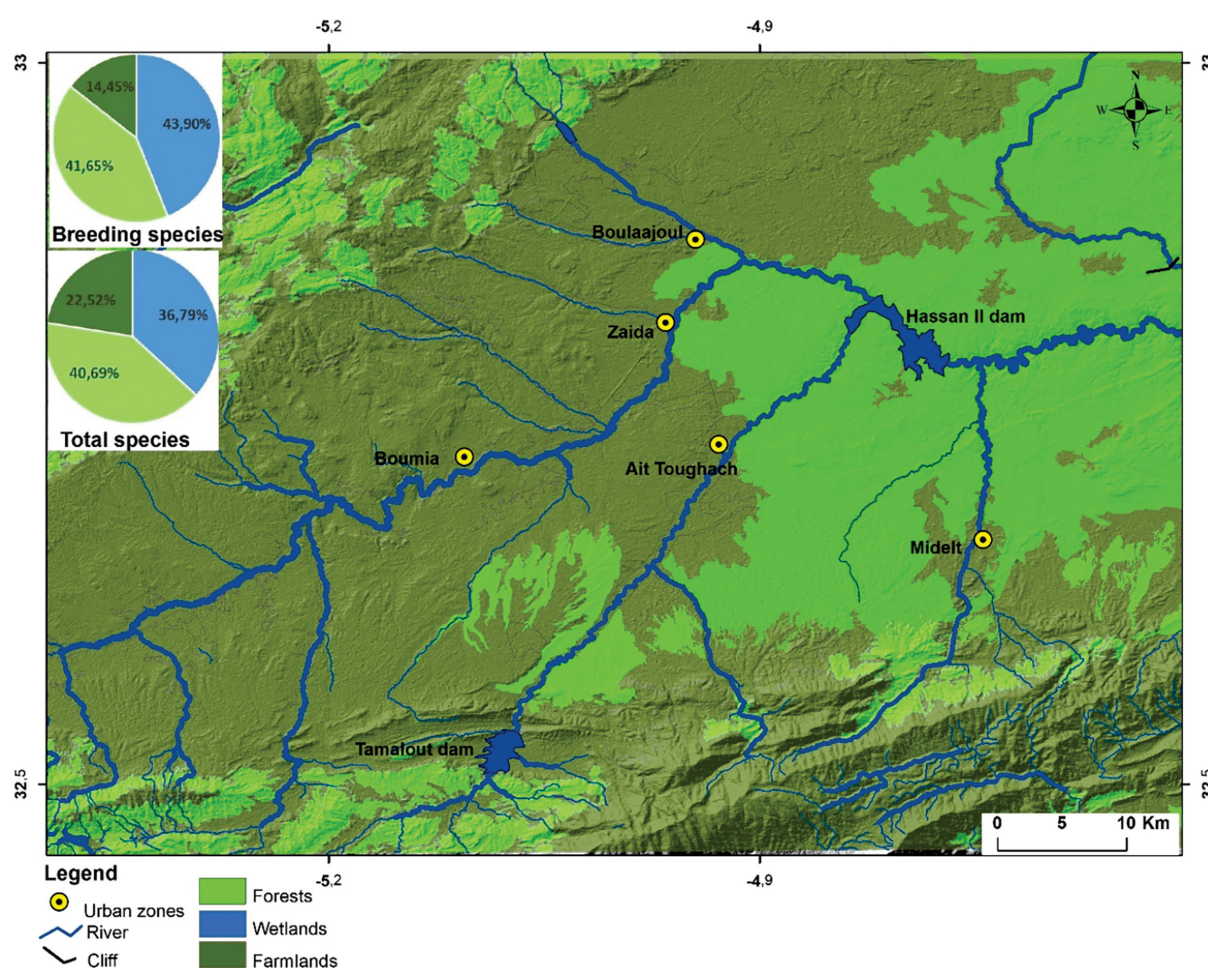


Figure 2. Summary of avian distribution and richness of studied ecosystems in Moulouya High plain.

Figura 2. Resumen de la distribución y riqueza de aves de los ecosistemas estudiados en la Alta Llanura de Moulouya.

documented in every study site (taking account the number of transects and study period). In parallel, the birds were divided following orders, families, phenological status, and conservation status. The diversity indices, total species, and breeding population were estimated (five years and 12 months) and compared for all ecosystems using ANOVA. All analysis was executed using SPSS 18 (SPSS IBM, 2009).

RESULTS

Diversity of avian species

The diversity, phenology, and conservation status of documented avian species throughout the Moulouya high plain are presented in Table 2.

Table 2 (part 1 of 4). Phenological status (b: Breeding, m: migration, r: resident, s: summering w: wintering), IUCN conservation status (LC: Least Concern, VU: Vulnerable, NT: Near threatened, E: Endangered), and abundance of documented avian species in Moulouya High Plain.

Tabla 2 (parte 1 de 4). Estado fenológico (b: reproducción, m: migración, r: residente, s: veraneo, w: invernada), estado de conservación UICN (LC: preocupación menor, VU: vulnerable, NT: casi amenazado, E: en peligro) y abundancia de especies de aves documentadas en la alta llanura de Moulouya.

Documented orders	Families	Species	Phenological Status in Morocco	Phenological status in Moulouya high plain	Conservation Status	Abundance (lowest and highest estimation)
Passeriformes	Corvidae	<i>Garrulus glandarius</i>	b, r	b, r	LC	1500-2100
		<i>Corvus corax</i>	b, r	b, r	LC	869-110
	Passeridae	<i>Pica mauritanica</i>	b, r	b, r	LC	1050-1150
		<i>Pyrrhocorax pyrrhocorax</i>	b, r	b, r	LC	950-1200
		<i>Passer hispaniolensis</i>	b, r	b, r	LC	35500-9500
	Pycnonotidae	<i>Passer domesticus</i>	b, r	b, r	LC	55000-95000
		<i>Pycnonotus barbatus</i>	b, r	b, r	LC	700-1050
	Sturnidae	<i>Sturnus unicolor</i>	b, r	b, r	LC	2550-3500
		<i>Turdus viscivorus</i>	b, r	b, r	LC	1800-2100
	Turdidae	<i>Turdus merula</i>	b, r	b, r	LC	31000-49000
		<i>Monticola solitarius</i>	b, r	b, r	LC	210-290
	Fringillidae	<i>Monticola saxatilis</i>	b, r	b, r	LC	180-230
		<i>Erithacus rubecula</i>	b, r	b, r	LC	670-980
		<i>Fringilla coelebs</i>	b, r	b, r	LC	84000-105000
		<i>Serinus serinus</i>	b, r	b, r	LC	108000-139000
		<i>Carduelis carduelis</i>	b, r	b, r	LC	19000-27500
		<i>Linaria cannabina</i>	b, r	b, r	LC	95000-108000
		<i>Bucanetes githagineus</i>	b, r	b, r	LC	3400-4200
		<i>Coccothraustes coccothraustes</i>	b, r	b, r	LC	650-850
		<i>Chloris chloris</i>	b, r	b, r	LC	1900-2500
		<i>Hirundo rustica</i>	m, r	m, r	LC	2100-2800
	Hirundinidae	<i>Ptyonoprogne rupestris</i>	m, r	m, r	LC	1040-1570
		<i>Cecropis daurica</i>	m	m	LC	860-1400
		<i>Delichon urbicum</i>	m, r	m, r	LC	7200-8700
		<i>Riparia riparia</i>	b, r	b, r	LC	860-1100
	Sylviidae	<i>Sylvia undata</i>	b, r	b, r	LC	1450-1650
		<i>Sylvia melanocephala</i>	b, r	b, r	LC	18000-21700
		<i>Sylvia deserti</i>	b, r	b, r	LC	180-210
		<i>Sylvia deserticola</i>	b, r	b, r	LC	254-312
	Phylloscopidae	<i>Sylvia atricapilla</i>	b, r	b, r	LC	750-960
		<i>Phylloscopus sibilatrix</i>	b, r	b, r	LC	5600-5960
		<i>Phylloscopus trochilus</i>	b, r	b, r	LC	950-1150
		<i>Phylloscopus collybita</i>	m, w	m, w	LC	1700-1950
		<i>Phylloscopus bonelli</i>	b, r	b, r	LC	4300-4900

Table 2 (part 2 of 4). Phenological status (b: Breeding, m: migration, r: resident, s: summering w: wintering), IUCN conservation status (LC: Least Concern, VU: Vulnerable, NT: Near threatened, E: Endangered), and abundance of documented avian species in Moulouya High Plain.

Tabla 2 (parte 2 de 4). Estado fenológico (b: reproducción, m: migración, r: residente, s: veraneo, w: invernada), estado de conservación UICN (LC: preocupación menor, VU: vulnerable, NT: casi amenazado, E: en peligro) y abundancia de especies de aves documentadas en la alta llanura de Moulouya.

Documented orders	Families	Species	Phenological Status in Morocco	Phenological status in Moulouya high plain	Conservation Status	Abundance (lowest and highest estimation)
Acrocephalidae	Muscicapidae	<i>Hippolais polyglotta</i>	b, r	b, r	LC	3100-3800
		<i>Luscinia megarhynchos</i>	b, r	b, r	LC	9800-13500
		<i>Cyanistes teneriffae ultramarinus</i>	b, r	b, r	LC	21500-24500
		<i>Pariparus ater</i>	b, r	b, r	LC	530-750
		<i>Parus major</i>	b, r	b, r	LC	11000-14500
		<i>Ficedula hypoleuca</i>	b, m	b, s	LC	640-780
		<i>Muscicapa striata</i>	b, r	b, r	LC	1570-1965
		<i>Phoenicurus moussieri</i>	b, r	b, r	LC	1750-1950
		<i>Oenanthe leucopyga</i>	b, r	b, r	LC	467-650
		<i>Oenanthe hispanica</i>	b, r	b, s	LC	1340-1680
Alaudidae	Alaudidae	<i>Oenanthe deserti</i>	b, r	b, r	LC	2950-3580
		<i>Oenanthe oenanthe</i>	b, r	b, s	LC	469-650
		<i>Oenanthe leucura</i>	b, r	b, r	LC	2150-2560
		<i>Oenanthe moesta</i>	b, m	b, s	LC	540-750
		<i>Alaudala rufescens</i>	b, r	b, r	LC	15800-18900
		<i>Calandrella brachydactyla</i>	b, r	b, r	LC	1860-1990
		<i>Galerida cristata</i>	b, r	b, r	LC	23500-25980
		<i>Eremophila bilopha</i>	b, r	b, r	LC	1570-1890
		<i>Eremophila alpestris</i>	m, w	m, w	LC	1450-1650
		<i>Melanocorypha calandra</i>	b, r	b, r	LC	1660-1970
Laniidae	Laniidae	<i>Chersophilus duponti</i>	b, r	b, r	V	167-189
		<i>Ammomanes deserti</i>	b, r	b, r	LC	570-650
		<i>Ammomanes cinctura</i>	b, r	b, r	LC	860-1050
		<i>Lanius excubitor</i>	b, r	b, s	LC	850-960
		<i>Lanius senator</i>	b, r	b, s	LC	4500-6750
		<i>Prunella collaris</i>	m, w	w	LC	950-1120
		<i>Emberiza calandra</i>	b, r	m, w	LC	9650-1050
		<i>Emberiza cirius</i>	b, r	m, w	LC	642-865
		<i>Emberiza cia</i>	b, r	m, w	LC	1900-2350
		<i>Emberiza sahari</i>	b, r	m, w	LC	1250-1390
Motacillidae	Motacillidae	<i>Anthus campestris</i>	m, w	m, w	LC	432-654
		<i>Anthus spinoletta</i>	m, w	m, w	LC	754-963
		<i>Anthus pratensis</i>	m, w	m, w	LC	1750-1560
		<i>Motacilla cinerea</i>	b, r	b, r	LC	3650-3830

Table 2 (part 3 of 4). Phenological status (b: Breeding, m: migration, r: resident, s: summering w: wintering), IUCN conservation status (LC: Least Concern, VU: Vulnerable, NT: Near threatened, E: Endangered), and abundance of documented avian species in Moulouya High Plain.

Tabla 2 (parte 3 de 4). Estado fenológico (b: reproducción, m: migración, r: residente, s: veraneo, w: invernada), estado de conservación UICN (LC: preocupación menor, VU: vulnerable, NT: casi amenazado, E: en peligro) y abundancia de especies de aves documentadas en la alta llanura de Moulouya.

Documented orders	Families	Species	Phenological Status in Morocco	Phenological status in Moulouya high plain	Conservation Status	Abundance (lowest and highest estimation)
Columbiformes	Oriolidae	<i>Motacilla flava</i>	b, r	b, r	LC	1230-1460
		<i>Motacilla alba</i>	b, r	b, r	LC	2350-2660
	Troglodytidae	<i>Oriolus oriolus</i>	m, w	w	LC	230-250
		<i>Troglodytes troglodytes</i>	b, r	b, r	LC	850-670
		<i>Columba livia</i>	b, r	b, r	LC	65000-75000
Piciformes	Columbidae	<i>Columba palumbus</i>	b, r	b, r	LC	9900-13500
		<i>Streptopelia decaocto</i>	b, r	b, r	LC	13000-15000
		<i>Streptopelia turtur</i>	m, r	b, s, w	VU	19000-21000
		<i>Picus vaillantii</i>	b, r	r	LC	49-95
		<i>Dendrocopos major</i>	b, r	r	LC	560-800
Apodiformes	Apodidae	<i>Tachymarptis melba</i>	m	m	LC	5700-6400
Galliformes	Phasianidae	<i>Apus apus</i>	b, r	b, r	LC	36000-39500
		<i>Alectoris barbara</i>	b, r	b, r	LC	1750-2160
Pteroclidiformes	Pteroclididae	<i>Coturnix coturnix</i>	m, r	s, r	LC	2100-2460
		<i>Pterocles orientalis</i>	b, r	b, r	LC	4300-5700
		<i>Pterocles coronatus</i>	b, r	b, r	LC	1630-1740
		<i>Pterocles alchata</i>	b, r	b, r	LC	2010-2450
Otidiformes	Otididae	<i>Chlamydotis undulata sensu stricto</i>	b, r	b, r	VU	22-34
Charadriiformes	Burhinidae	<i>Burhinus oedinenus</i>	b, r	b, r	LC	210-295
	Glareolidae	<i>Cursorius cursor</i>	b, r	b, r	LC	870-990
Bucerotiformes	Upupidae	<i>Upupa epops</i>	b, r	b, r	LC	760-990
Coraciiformes	Meropidae	<i>Merops apiaster</i>	b, r	b, r	LC	1780-2170
	Alcedinidae	<i>Alcedo atthis</i>	m, w	m, w	LC	17-23
Caprimulgiformes	Coraciidae	<i>Coracias garrulus</i>	m, w	m, w	LC	670-850
	Caprimulgidae	<i>Caprimulgus europaeus</i>	b, r	b, r	LC	640-730
Anseriformes	Anatidae	<i>Anas platyrhynchos</i>	b, r	b, r	LC	1050-1357
		<i>Anas crecca</i>	m, w	m, w	LC	340-360
		<i>Anas clypeata</i>	m, w	m, w	LC	350-390
		<i>Spatula querquedula</i>	m, w	m, w	LC	230-248
		<i>Mareca penelope</i>	m, w	m, w	LC	16-19
Podicipediformes	Podicipédidae	<i>Tadorna ferruginea</i>	b, r	m, w	LC	860-880
		<i>Aythya nyroca</i>	b, m, w	m, w	NT	245-285
		<i>Podiceps cristatus</i>	m, w	m, w	LC	65-82
		<i>Podiceps nigricollis</i>	m, w	m, w	LC	162-210

Table 2 (part 4 of 4). Phenological status (b: Breeding, m: migration, r: resident, s: summering w: wintering), UICN conservation status (LC: Least Concern, VU: Vulnerable, NT: Near threatened, E: Endangered), and abundance of documented avian species in Moulouya High Plain.

Tabla 2 (parte 4 de 4). Estado fenológico (b: reproducción, m: migración, r: residente, s: verano, w: invierno), estado de conservación UICN (LC: preocupación menor, VU: vulnerable, NT: casi amenazado, E: en peligro) y abundancia de especies de aves documentadas en la alta llanura de Moulouya.

Documented orders	Families	Species	Phenological Status in Morocco	Phenological status in Moulouya high plain	Conservation Status	Abundance (lowest and highest estimation)
Suliformes	Phalacrocoracidae	<i>Tachybaptus ruficollis</i>	m, w	m, w	LC	67-78
		<i>Phalacrocorax carbo</i>	m, w	m, w	LC	130-140
		<i>Egretta garzetta</i>	m, w	m, w	LC	32-42
Pelecaniformes	Ardeidae	<i>Ardea cinerea</i>	m, w	m, w	LC	64-71
		<i>Bubulcus ibis</i>	b, r	b, r	LC	7359-9421
		<i>Ciconia ciconia</i>	b, r	b, r	LC	932-1080
Ciconiiformes	Ciconiidae	<i>Fulica cristata</i>	b, r	b, r	LC	421-542
		<i>Fulica atra</i>	b, r	b, r	LC	532-643
		<i>Rallus aquaticus</i>	b, r	b, r	LC	43-58
Gruiformes	Rallidae	<i>Gallinula chloropus</i>	b, r	b, r	LC	17-29
		<i>Tringa ochropus</i>	b, r	b, r	LC	41-59
		<i>Actitis hypoleucos</i>	b, r	b, r	LC	57-80
Charadriiformes	Scolopacidae	<i>Charadrius hiaticula</i>	b, r	b, r	LC	21-34
		<i>Charadrius dubius</i>	b, r	b, r	LC	150-185
		<i>Falco peregrinus</i>	b, r	b, r	LC	214-252
Falconiformes	Falconidae	<i>Falco naumanni</i>	b, r	b, r	LC	1104-1360
		<i>Falco tinnunculus</i>	b, r	b, r	LC	860-980
		<i>Bubo bubo</i>	b, r	b, r	LC	16-18
Strigiformes	Strigidae	<i>Strix aluco</i>	b, r	b, r	LC	34-63
		<i>Athene noctua</i>	b, r	b, r	LC	1250-1360
		<i>Milvus migrans</i>	m, w	m, w	LC	42-54
Accipitriformes	Accipitridae	<i>Elanus caeruleus</i>	b, r	b, r	LC	32-41
		<i>Hieraaetus pennatus</i>	b, r	b, r	LC	33-41
		<i>Gyps fulvus</i>	m, w	m, w	LC	31-62
		<i>Aquila chrysaetos</i>	b, r	b, r	LC	06-08
		<i>Aquila fasciata</i>	b, r	b, r	LC	14-32
		<i>Accipiter nisus</i>	b, r	b, r	LC	64-85
		<i>Circus aeruginosus</i>	b, r	b, r	LC	103-170
		<i>Pernis apivorus</i>	m, w	m, w	LC	540-740
		<i>Circus aeruginosus</i>	m, w	m, w	LC	17-19
		<i>Buteo rufinus</i>	b, r	b, r	LC	85-105
		<i>Neophron percnopterus</i>	m, w	m, w	E	22-34
		<i>Gypaetus barbatus</i>	b, r	s	NT	23-45

From 2015 to 2020, 136 species, divided into 44 families, and 21 orders, were documented in the upper Moulouya. Passeriformes with 71 species and 20 families were the most documented orders, followed by Accipitri-formes with 13 species and one family, whereas Ciconiiformes, Suliformes, Caprimulgiformes, Bucerotiformes, and Otidiformes were the less frequently observed orders with one family and one species for each. Equally, Accipitridae with 13 species, Alaudidae with 9 birds, and Muscicapidae with 9 birds were the furthestmost recorded families, while Caprimulgidae, Trog-lodytidae, Oriolidae, Phalacrocoracidae, Ciconiidae, and Upupidae were the less important families recorded in the Moulouya high plain, with one bird for each family. The Fringillidae family was the most observed (in term of abundance) in the study area, mostly *Serinus serinus* and *Linaria cannabina*, while the family of Accipitridae represented by *Neophron percnopterus* and *Gypaetus barbatus* were the less frequently observed avian species.

The Moulouya high plain had 95 resident species (42.22%), 103 breeding birds (45.77%), and 27 migrant species, including 25 wintering (11.11%) and 2 summering species (0.89%). Furthermore, among the documented species, five birds were as a species of conservation concern namely: (i) the Endangered *Neophron percnopterus* (migrant); (ii) the Near Threatened *Aythya nyroca* (wintering) and *Gypaetus barbatus* (summering); (iii) the Vulnerable *Streptopelia turtur* (migrant breeder), and *Chersophilus duponti* (resident breeder). The occurrence of bird species in Moulouya High Plain is presented in Figure 3. As mentioned above various bird species were found abundantly in the studied area, including *Passer domesticus*, *Passer hispaniolensis*, *Turdus merula*, *Serinus serinus*, *Fringilla coelebs*, *Carduelis carduelis*, *Linaria cannabina*, *Sylvia melanocephala*, *Cyanistes teneriffae ultramarinus*, *Parus major*, *Alauda rufescens*, and *Galerida cristata*. The abundant bird species in the studied area were concentrated in positive part of coordinate 1, whereas the species with lowest frequency were concentrated in the negative part of coordinate 1 (Figure 3).

Habitat use in Moulouya High Plain

Comparisons of avian diversity and habitat use are presented in Figure 2 and Table 3. The total observed species, breeding populations, and foraging communities were higher in forest and wetland ecosystems (Figure 2). In contrast, farmlands were the less occupied habitats for breeding and feeding by avian species (Table 4). Equally, forest and wetlands were the largely diverse and rich habitats, based on Shannon-Wiener and Margalef indices.

DISCUSSION

This is the first in-depth analysis of bird diversity on the Moulouya High plain, based on a literature review. Our primary goals were to provide de-

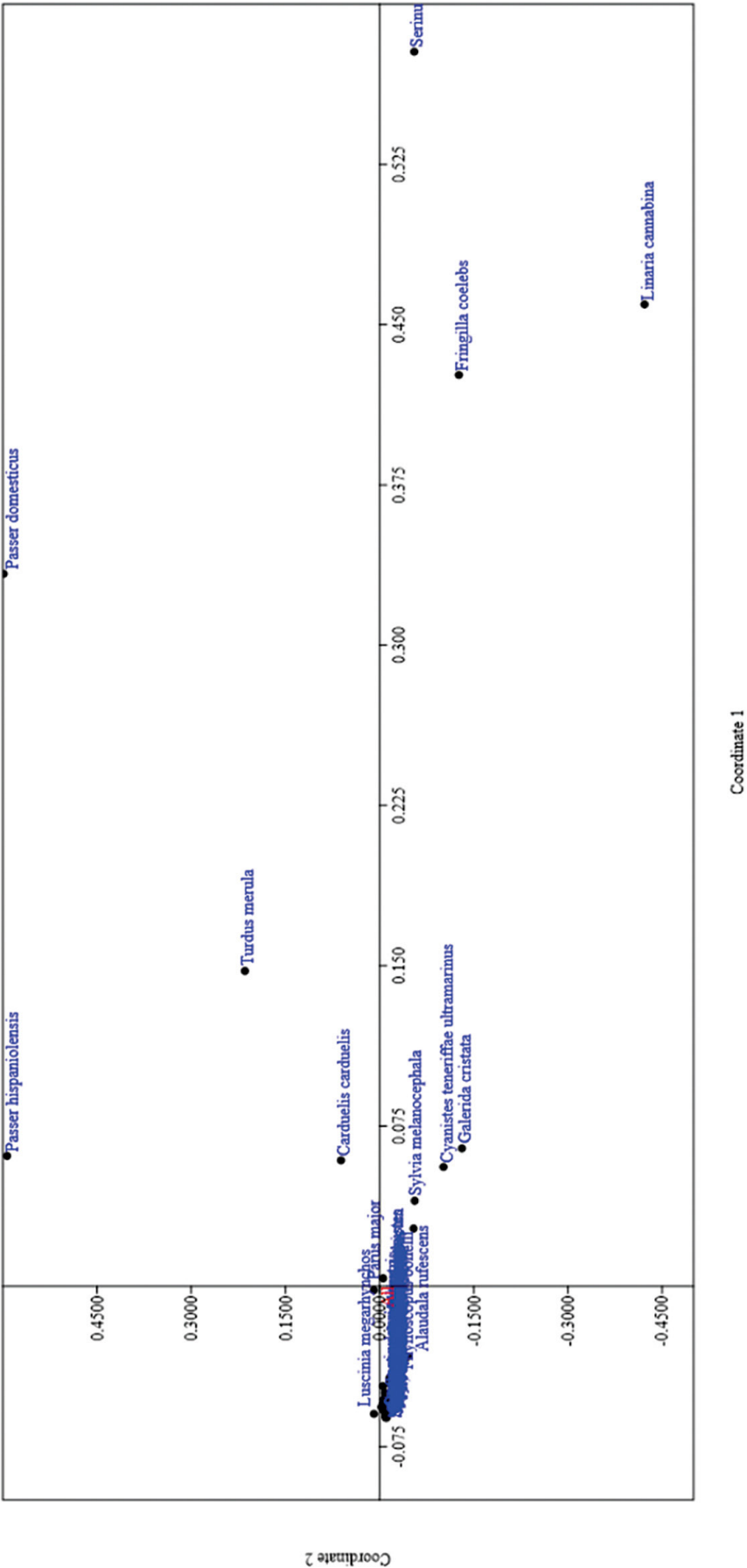


Figure 3. Occurrence of bird species in Moulouya High Plain.
Figura 3. Presencia de especies de aves en la Alta Llanura de Moulouya.

Table 3. Comparison of avian diversity among selected ecosystems in the upper Moulouya.**Tabla 3.** Comparación de la diversidad de aves entre ecosistemas seleccionados en el Alto Moulouya.

Parameter	Forest	Farmland	Wetland	F	P-value
Total counted species	94	52	85	15.654	<0.001
Total Breeding species	65	34	56	19.934	<0.001
Total Foraging species	92	51	95	8.386	<0.001
Shannon_H	4.543	3.951	4.443	3.153	<0.05
Simpson_1-D	0.9894	0.9808	0.9882	2.432	0.076
Margalef	20.47	12.91	18.91	7.256	0.003

Table 4. Multiple Range Test comparing one-by-one habitats used by avian species for foraging and breeding activities in Moulouya High Plain.**Tabla 4.** Prueba de rango múltiple que compara uno por uno los hábitats utilizados por las especies de aves para actividades de alimentación y reproducción en la Alta Planicie de Moulouya.

Habitat use	Contrast	Significance *	Difference	+/- Limits
Total observed species	Farmland - Forest	*	-0.318519	0.114478
	Farmland - Wetland	*	-0.244444	0.114478
	Forest - Wetland		0.0740741	0.114478
Breeding species	Farmland - Forest	*	-0.231481	0.114063
	Farmland - Wetland	*	-0.161765	0.113852
	Forest - Wetland		0.0697168	0.114063
Foraging species	Farmland - Forest		-0.59854	1.65216
	Farmland - Wetland		-0.642336	1.65216
	Forest - Wetland		-0.0437956	1.65216

tailed information on habitat use and bird richness in several ecosystems that predominate in the region. We obtained unique and valuable data on habitat use and bird richness. At least for the most endangered birds, our findings provide the first and only information on the richness of avifauna in the Moulouya High Plain and the entire high plains of North Africa. This information is crucial for long-term conservation measures and future comparative monitoring. Different measures should be implemented to conserve avifauna diversity, including preventing the cutting of trees, and overuse of chemical agents, and the development of protected areas according to their status.

Our study highlights the bird diversity on the Moulouya High plain. The results showed that avian diversity (total documented birds) and habitat-specific richness (documented species for each ecosystem) were significantly higher. In total, 136 avian species were documented in the study area. This wealth belongs to 21 orders and 44 families. A recent study conducted in the Eastern and Central High Atlas between 2015 and 2021 reported a total of 175 bird species, including resident breeders, migrants, and accidental-visitors (Salma Wakass, 2023). Mounir et al., reported that bird species richness decreased as altitude increased, but there was no relationship between height and abundance. The authors found that richness and abundance significantly increased during high-productivity seasons (Mounir et al., 2024).

Passeriformes and Accipitriformes were the most frequently observed orders, while Ciconiiformes, Suliformes, Caprimulgiformes, Bucerotiformes, and Otidiformes were less frequently observed. Similarly, Accipitridae, Alaudidae, and Muscicapidae were the most recorded families, while Caprimulgidae, Troglodytidae, Oriolidae, Phalacrocoracidae, Ciconiidae, and Upupidae were the least recorded families. These results agree with those mentioned by (Mansouri et al., 2020a, 2021a, 2021c) in Midelt Province, which is located upstream of the Moulouya watershed. Moreover, our results highlight the importance of the Moulouya High plain for local Moroccans (Hingrat, Saint, Chalah, Orhant, Lacroix, 2008; Cherkaoui, Hanane, Magri, El Agbani, Dakki, 2015; El Hassani et al., 2021) and Western Palearctic avian species visitors to the Moroccan ecosystem (Dakki, Qninba, El Agbani, Benhoussa, Beaubrun, 2001; Schaub, Jenni, Bairlein, 2008; Touhami, Bazairi, Badaoui, Benhoussa, 2017; Ouassou, Dakki, El Agbani, Qninba, El Hammoumi, 2021). In total, 103 breeding birds (including 95 resident species) and 27 migrant species were documented in the study area. Among these, five species of conservation concern were documented: Endangered *Neophron percnopterus* (as migrant; (Meyburg, Gallardo, Meyburg, Dimitrova, 2004)); Near Threatened *Aythya nyroca* as wintering; (Ouassou, Dakki, Lahrouz, El Agbani, Qninba, 2018) with remarkable numbers in some marshlands (Sidi Boughaba, Fouwarate, Bargha, Bas Loukkos, etc. and *Gypaetus barbatus* (summering; (Streicher, Kruger, Loercher, Willows-Munro, 2021)); Vulnerable *Streptopelia turtur* (migrant breeder, (Mansouri et al., 2020b)), and *Chersophilus duponti* (resident breeder; (Valverde-Garcia, Santiago-Alvarez, Thomas, Garrido-Jurado, Quesada-Moraga, 2018)). Human-driven modifications, changes in food availability and ongoing conservation measures play a pivotal role in the preservation process of endangered bird species, such as the Egyptian vulture (Cerecedo Iglesias, 2024) social well-being and environmental care is maintained. This concept implies the need for a reduction in human environmental impact if wildlife species are to be preserved and the adequate functioning of ecosystems is to be guaranteed. Obligate avian scavengers, one of the most globally threatened of all groups of vertebrates, play a vital role in the nature-ecosystem services-human well-being dynamic. However, the pursuit of sustainable development can negatively impact vulture conservation and all that it entails. In this thesis, we explore the conservation challenges facing the Egyptian vulture *Neophron percnopterus*, a globally threatened migrant species, within the current context of sustainability. Specifically, we assess the impact of human-driven transformations, changes in food availability and on-going conservation measures on the spatial ecology of this species of great conservation concern. By using novel technologies such as GPS and information generated by classical long-term monitoring schemes, we aimed to increase the knowledge of the environmental factors that have shaped the spatial distribution and movement patterns of this species up to the present day and assess the spatial coverage

of the main conservation tool, the Protected Areas (PAs). The use of novel technologies, including GPS, could be of great importance in addressing long-term monitoring schemes to create protected areas for endangered avian species. Furthermore, reintroduction and restocking are excellent tools to boost the recolonization of living areas of endangered bird species as they develop the demographic growth of these species (Agostini, Panuccio, Hardenberg, Von Monti, 2023).

These findings indicate that the Moulouya High plain is a great zone for breeding birds (including both resident and migratory species), migrant species that use the area for wintering and as a stopover, mainly during winter (Ouassou, Dakki, Lahrouz, El Agbani, Qninba, 2018, Ouassou, Dakki, El Agbani, Qninba, El Hamoumi, 2021; Popoff et al., 2021) thanks to the diversity and richness of its ecosystems. The International Waterbird Census (IWC). Therefore, the conservation of the area should be one of the most important objectives for local, national and international scientists.

In terms of habitat use, forests and wetlands were the most populated ecosystems in the Moulouya High plain. These habitats offer foraging and breeding resources for avian species, in contrast to agrosystems. Similar results were documented by (Mansouri et al., 2021c) in the same area, where wetlands and farmlands were the most populated habitats by avian species. The availability of foraging resources, including water and nutrients, as well as breeding resources, counting nesting trees and sites in forests and wetlands are suggested to be the central reasons behind this diversity (Hamza and Selmi, 2018; Melin, Hinsley, Broughton, Bellamy, Hill, 2018; Mukhopadhyay and Mazumdar, 2019). In fact, the Moulouya High plain is rich in rivers, lakes, dams and other artificial reservoirs that host water populations, counting resident and migrant avian species (Bouzekri, El Hachimi, Kara, El Mahi, Lotfi, 2020; Taybi Abdelkhaleq, Chavanon, Berrahou, Millan, 2020). Similarly, Moulouya forests are rich in trees and other small plants that are suggested to be used for nesting by avian species (Aguilar et al., 2016; Mansouri et al., 2021d), as the case of the European Turtle dove (*Streptopelia turtur*), the European Blackbird (*Turdus merula*), and the European serin (*Serinus serinus*) that profit from breeding and foraging resources offered in the Moulouya High plain (El Hassani et al., 2021; Mansouri et al., 2021d, 2021b). On the other hand, despite the abundance of nesting trees (Mansouri et al., 2021d) and foraging resources (Mansouri et al., 2019), farmland habitats are known by farming activities that impact avian species, such as the use of hail nets and pesticides that have been proven to impact the breeding performances of birds in High Moulouya apple orchards (Mansouri et al., 2020a, 2020b).

CONCLUSION

This present study shed light on the biological diversity of the Moulouya high plain. These data will be important for enriching the bird diversity databases in the studied region. Various aquatic, forest, and farmland ecosystems of the Moulouya High plain sustain significant avian diversity, which includes 136 resident, migratory, and wintering birds. These findings may be crucial for future conservation legislation, mainly to protect endangered habitats and populations, in addition to their potential significance for national and regional comparative studies of biological diversity in other Moroccan and North African zones. The results of this study suggest that maintaining aquatic ecosystems and vegetation cover in the study area could ensure that the most endangered bird species have larger populations by giving them access to safer and more appropriate breeding resources as well as adequate foraging opportunities. Further investigations are required to fully understand the impact of human activities and climate change on avian biodiversity in the region under study.

CONFLICTS OF INTEREST/COMPETING INTERESTS

The authors declare that they have no conflict of interest.

ETHICS APPROVAL

This article does not contain any studies with human participants or animals performed by any of the authors.

AVAILABILITY OF DATA AND MATERIAL

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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AUTHOR'S CONTRIBUTION

Conceptualization, HM. and IM.; Methodology, IM.; Validation, IM., LEG and WS.; Formal Analysis, IM, Investigation, WS.; Resources, IM.; Writing – Original Draft Preparation, IM.; Writing – Review & Editing, AZ, AEL, WS.; Visualization, IM, LEG, WS, HM.;

REFERENCES

- Agostini, N., Panuccio, M., Hardenberg, J. von, Monti, F. (2023): Potential importance of wind patterns and guidance opportunities for the conservation of the Egyptian Vulture *Neophron percnopterus* in Italy. *Bird Conservation International* 33: e13.
- Aguilar, F.J., Nemmaoui, A., Aguilar, M.A., Chourak, M., Zarhloule, Y., García Lorca, A.M. (2016): A quantitative assessment of forest cover change in the moulouya river watershed (Morocco) by the integration of a subpixel-based and object-based analysis of Landsat data. *Forests* 7: 23.
- Arabi, M., Mechkirrou, L., Malki, M.E., Alaoui, K., Chaieb, A., Maaroufi, F., Karmich, S. (2024): Overview of Ecological Dynamics in Morocco – Biodiversity, Water Scarcity, Climate Change, Anthropogenic Pressures, and Energy Resources – Navigating Towards Ecosolutions and Sustainable Development. *E3S Web Conf.* 527: 01001.
- Bani, L., Massimino, D., Bottoni, L., Massa, R. (2006): A multiscale method for selecting indicator species and priority conservation areas: a case study for broadleaved forests in Lombardy, Italy. *Conserv Biol* 20: 512–526.
- Bibby, C., Burgess, N., Hill, D., Mustoe, S. (2000): *Bird Census Techniques*. Academic Press, London, 2nd edition.
- Bouzekri, S., El Hachimi, M.L., Kara, K., El Mahi, M., Lotfi, E.M. (2020): Metal pollution assessment of surface water from the abandoned Pb mine Zaida, high Moulouya-Morocco. *Geosystem Engineering* 23: 226–233.
- Cerecedo Iglesias, C. (2024): *Spatial Ecology of the Endangered Egyptian Vulture: from Distribution and Movement to Biological Conservation*. Tesis Doctorals - Departament - Biologia Evolutiva, Ecologia i Ciències Ambientals.
- Cherkaoui, S.I., Hanane, S., Magri, N., El Agbani, M.-A., Dakki, M. (2015): Factors influencing species-richness of breeding waterbirds in Moroccan IBA and Ramsar wetlands: a macroecological approach. *Wetlands* 35: 913–922.
- Cherkaoui, S.I., Magri, N., Hanane, S. (2016): Factors Predicting Ramsar Site Occupancy by Threatened Waterfowl: The Case of the Marbled Teal *Marmaronetta angustirostris* and Ferruginous Duck *Aythya nyroca*

- in Morocco. *Ardeola*, 63(2):295-309 (2016). <https://doi.org/10.13157/arla.63.2.2016.ra5>
- Chiapuris, J. (1979): The Ait Ayash of the High Molouya Plain: Rural Social Organization in Morocco. U OF M MUSEUM ANTHRO ARCHAEOLOGY.
- Colwell, R.K., Coddington, J.A. (1994): Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 345: 101–118.
- Dakki, M., El FELLah, B., Qninba, A. (2020): Rivers' natural reservoirs: new inputs to the classification of Mediterranean and Saharan wetlands. *Bulletin de l'Institut Scientifique, Rabat, Série Sciences de La Vie* 1–14.
- Dakki, M., Menioui, M., Amhaouch, Z. (2016): Nationale et plan d'action 2015-2024 pour les Zones Hu-mides du Maroc. HCEFLCD/DLG/GIZ, 54 pp.
- Dakki, M., Qninba, A., El Agbani, M.A., Benhoussa, A., Beaubrun, P.C. (2001): Waders wintering in Morocco: national population estimates, trends and site-assessments. *Wader Study Group Bull.* 96: 47-59. 96: 47–59.
- Depreux, B., Lefèvre, D., Berger, J.-F., Segaoui, F., Boudad, L., El Harradji, A., Degeai, J.-P., Limondin-Lozouet, N. (2021): Alluvial records of the African Humid Period from the NW African highlands (Moulouya basin, NE Morocco). *Quaternary Science Reviews* 255: 106807.
- Dobson, A. (2005): Monitoring global rates of biodiversity change: challenges that arise in meeting the Convention on Biological Diversity (CBD) 2010 goals. *Philosophical Transactions of the Royal Society B: Biological Sciences* 360: 229–241.
- El Hassani, A., Mansouri, I., Squalli, W., El Agy, A., Assouguem, A., Bouayad, K., Markou, A., Mounir, M., Achiban, H., Dakki, M., El Ghadraoui, L. (2021): Breeding Performances of the European Blackbird (*Turdus merula*) in Morocco: Habitat Selection, Breeding Phenology, and Breeding Success. *International Journal of Zoology* 2021: 7742894.
- Farris, J. (1976): An Introduction to Numerical Classification. *Zool.* 25.
- Fouzi, T.A., Youness, M., Guy, C., Ali, B., Andrés, M. (2020): The alien boatman *Trichocorixa verticalis verticalis* (Hemiptera: Corixidae) is expanding in Morocco. *Limnetica* 39: 49–59.
- Gervasi, V., Aragno, P., Salvatori, V., Caniglia, R., De Angelis, D., Fabbri, E., La Morgia, V., Marucco, F., Velli, E., Genovesi, P. (2024): Estimating distribution and abundance of wide-ranging species with integrated spatial models: Opportunities revealed by the first wolf assessment in south-central Italy. *Ecology and Evolution* 14: e11285.
- Hamza, F., Selmi, S. (2018): Diversity of waterbirds wintering in Douz wetlands (south Tunisia): factors affecting wetland occupancy and species richness. *Ecological Research* 33: 917–925.

- Hingrat, Y., Saint Jalme, M., Chalah, T., Orhant, N., Lacroix, F. (2008): Environmental and social constraints on breeding site selection. Does the exploded-lek and hotspot model apply to the Houbara bustard *Chlamydotis undulata undulata*? *Journal of Avian Biology* 39: 393–404.
- Kassout, J., Terral, J.-F., El Ouahrani, A., Houssni, M., Ivorra, S., Kadaoui, K., El Mahroussi, M., Paradis, L., Ater, M. (2022): Species Distribution Based-Modelling Under Climate Change: The Case of Two Native Wild *Olea europaea* Subspecies in Morocco, *O. e. subsp. europaea* var. *sylvestris* and *O. e. subsp. maroccana*. In: *Climate Change in the Mediterranean and Middle Eastern Region*, p. 21–43. Leal Filho, W., Manolas, E., Eds. Cham, Springer International Publishing.
- Maggini, I., Bairlein, F. (2011): Body condition and stopover of trans-Saharan spring migrant passerines caught at a site in southern Morocco. *Ringling & Migration*. 26(1): 31–37.
- Magurran, A.E. (2013): *Measuring Biological Diversity*. Blackwell Publishing, Oxford, 256 p. John Wiley & Sons.
- Mansouri, I., Al-Sadoon, M.K., Rochdi, M., Paray, B.A., Dakki, M., Elghadraoui, L. (2019): Diversity of feeding habitats and diet composition in the turtle doves *Streptopelia turtur* to buffer loss and modification of natural habitats during breeding season. *Saudi Journal of Biological Sciences* 26: 957–962.
- Mansouri, I., Mounir, M., Squalli, W., Elhanafi, L., Dakki, M., El Ghadraoui, L. (2020a): Migratory Dates, Breeding Phenology, and Reproductive Success of European Turtle Doves between Lowlands and Highest Breeding Habitats in North Africa. *International Journal of Zoology* 2020: e8816577.
- Mansouri, I., Ousaaïd, D., Squalli, W., El Agy, A., EL-Hassani, A., Mounir, M., Elghadraoui, L., Dakki, M. (2021a): New Data on Migration Time, Breeding Phenology, and Breeding Success of European Turtle Doves in Their Highest Breeding Habitats in North Africa. *International Journal of Zoology* 2021: e6629285.
- Mansouri, I., Ousaaïd, D., Squalli, W., Sqalli, H., El Ghadraoui, L., Ghadraoui, E., Dakki, M. (2020b): The turtle dove (*Streptopelia turtur*) in Midelt plain, Morocco: nesting preferences and breeding success versus the impact of predation and agricultural practices. *Journal of Animal Behaviour and Biometeorology* 8: 206–214.
- Mansouri, I., Squalli, W., Dakki, M., Assouguem, A., El-Hassani, A., Belarbi, C., Dbiba, Y., Kouali, H., Ghadraoui, L. (2021b): Breeding Biology, Chronology, and Reproductive Success of the European Serin (*Serinus serinus*) at Moulouya High Plain (Morocco). *International Journal of Zoology* 2021: 8 pages.
- Mansouri, I., Squalli, W., El Agy, A., Ben Hichou, B., El Hassani, A., El Ghadraoui, L., Dakki, M. (2021c): Avifauna Diversity in the Gate between Humid Atlas and Saharan Desert: Midelt Province, Morocco. *International Journal of Zoology* 2021: e5557921.

- Mansouri, I., Squalli, W., El Agy, A., El-Hassani, A., El Ghadraoui, L., Dakki, M. (2021d): Comparison of Nesting Features and Breeding Success of Turtle Dove *Streptopelia turtur* between Orchards and Riparian Habitats. *International Journal of Zoology* 2021: e5566398.
- Martínez-Ortega, M.M., Delgado, L., Albach, D.C., Elena-Rosselló, J.A., Rico, E. (2004): Species Boundaries and Phylogeographic Patterns in Cryptic Taxa Inferred from AFLP Markers: *Veronica* Subgen. *Pentasepalae* (Scrophulariaceae) in the Western Mediterranean. *Systematic Botany* 29: 965–986.
- Melin, M., Hinsley, S.A., Broughton, R.K., Bellamy, P., Hill, R.A. (2018): Living on the edge: utilising lidar data to assess the importance of vegetation structure for avian diversity in fragmented woodlands and their edges. *Landscape Ecology* 33: 895–910.
- Meyburg, B.-U., Gallardo, M., Meyburg, C., Dimitrova, E. (2004): Migrations and sojourn in Africa of Egyptian vultures (*Neophron percnopterus*) tracked by satellite. *Journal of Ornithology* 145: 273–280.
- Moukrim, S., Lahssini, S., Rhazi, M., Alaoui, H.M., Benabou, A., Wahby, I., El Madihi, M., Arahou, M., Rhazi, L. (2019): Climate change impacts on potential distribution of multipurpose agro-forestry species: *Argania spinosa* (L.) Skeels as case study. *Agroforest Syst* 93: 1209–1219.
- Mounir, M., Dakki, M., Douini, I., Benka, E.-M., Nouri, A., Mansouri, I., Hammada, S. (2024): Large-Scale Monitoring of Bird Communities along an Altitudinal Gradient in Two Central High Atlas Valleys. *International Journal of Zoology* 2024: 1–14.
- Mukhopadhyay, S., Mazumdar, S. (2019): Habitat-wise composition and foraging guilds of avian community in a suburban landscape of lower Gangetic plains, West Bengal, India. *Biologia* 74: 1001–1010.
- Ouassou, A., Dakki, M., El Agbani, M.-A., Qninba, A., El Hamoumi, R. (2021): Distribution and Numbers of Three Globally Threatened Waterbird Species Wintering in Morocco: The Common Pochard, Marbled Teal, and White-Headed Duck. *International Journal of Zoology* 2021: e8846203.
- Ouassou, A., Dakki, M., Lahrouz, S., El Agbani, M.A., Qninba, A. (2018): Status and Trends of the Ferruginous Duck's (*Aythya nyroca*) Wintering Population in Morocco: Analysis of 35 Years of Winter Census Data (1983-2017). *International Journal of Zoology* 2018: e5767194.
- Poff, N.L., Ward, J.V. (1990): Physical habitat template of lotic systems: recovery in the context of historical pattern of spatiotemporal heterogeneity. *Environmental Management* 14: 629.
- Popoff, N., Gaget, E., Béchet, A., Dami, L., Rau, P.D. du, Geijzendorffer, I., Guelmami, A., Mondain-Monval, J.-Y., Perennou, C., Suet, M. (2021): Gap analysis of the Ramsar site network at 50: over 150 important Mediterranean sites for wintering waterbirds omitted. *Biodiversity and Conservation* 1–19.

- Salma Wakass, M.M. (2023): Diversity of avian species, their ecosystems and climate conditions in two zones of High Atlas (central Morocco) for ecotouristic purposes. *Diversity of Avian Species, Their Ecosystems and Climate Conditions in Two Zones of High Atlas (Central Morocco) for Ecotouristic Purposes* 11: 0–0.
- Sander, M.M., Eccard, J.A., Heim, W. (2017): Flight range estimation of migrant Yellow-browed Warblers *Phylloscopus inornatus* on the East Asian Flyway. *Null* 64: 569–572.
- Schaub, M., Jenni, L., Bairlein, F. (2008): Fuel stores, fuel accumulation, and the decision to depart from a migration stopover site. *Behavioral Ecology* 19: 657–666.
- Selmi, S., Boulinier, T. (2003): Does time of season influence bird species number determined from point-count data? A capture-recapture approach. *Forn* 74: 349–356.
- Streicher, M., Krüger, S., Loercher, F., Willows-Munro, S. (2021): Evidence of genetic structure in the wide-ranging bearded vulture (*Gypaetus barbatus* (Linnaeus, 1758)). *BMC Ecology and Evolution* 21: 1–11.
- Taybi Abdelkhaleq, F., Chavanon, G., Berrahou, A., Millán, A. (2020): The alien boatman *Trichocorixa verticalis verticalis* (Hemiptera: Corixidae) is expanding in Morocco. *Limnetica* 39: 49–59.
- Touhami, F., Bazairi, H., Badaoui, B., Benhoussa, A. (2017): The impact of wader predation on benthic macrofauna in Merja Zerga lagoon, Morocco: an enclosure experiment. *Wader Study* 124: 225–237.
- Tramblay, Y., Badi, W., Driouech, F., El Adlouni, S., Neppel, L., Servat, E. (2012): Climate change impacts on extreme precipitation in Morocco. *Global and Planetary Change* 82–83: 104–114.
- Valverde-Garcia, P., Santiago-Alvarez, C., Thomas, M.B., Garrido-Jurado, I., Quesada-Moraga, E. (2018): Comparative effects of temperature and thermoregulation on candidate strains of entomopathogenic fungi for Moroccan locust *Dociostaurus maroccanus* control. *BioControl* 63: 819–831.