

AVIFAUNA OF THE OUED BOUHELLOU VALLEY (MOROCCO): REMARKABLE DIVERSITY, FIVE NEW BREEDING CASES AND MAPPING OF NESTING SITES

Hamid Achiban^a, Ismail Mansouri^{b*}, Wafae Squalli^b, Hassan Achiban^a, Hasnae Lagsaibi^a, Miloud Afenzar^c and Ali Taous^a

^aLaboratory of Geo-Environmental Analysis and Sustainable Development Planning, University, Sidi Mohamed Ben Abdelah, Fez, Morocco; ^bLaboratory of Functional Ecology and Genie of Environment, Faculty of sciences and technology, USMBA, Fez, Morocco; ^cLaboratory of History, Dynamics and Sustainable Development, Polydisciplinary Faculty of Taza, Sidi Mohamed Ben Abdelah University, Taza, Morocco

*Corresponding author. Email: Mankhori@gmail.com

Ismail Mansouri: https://orcid.org/0000-0002-3679-6050

[©] Wafae Squalli: https://orcid.org/0000-0002-5480-8617

Achiban H., Mansouri I., Squalli W., Achiban H., Lagsaibi H., Afenzar M., Taous A. 2022. Avifauna of the Oued Bouhellou Valley (Morocco): remarkable diversity, five new breeding cases and mapping of nesting sites. *Zoology and Ecology* 32(1), 36–48. https://doi.org/10.35513/21658005.2022.1.5

Article history Received: 09 February 2022;

accepted: 06 April 2022,

Keywords: Avifaunistic diversity; Watershed; breeding species; richness; Oued Bouhello

Abstract. In this study, we surveyed and documented diversity and nesting of avian species and their foraging and breeding resources along the Oued Bouhellou watershed (North-Eastern Morocco). A total of 120 field visits were conducted between 2018 and 2022. We recorded 85 avian species of migrants and residents, belonging to 25 families and 8 orders. The families of Accipitridae (12 species) and Muscicapidae (10 species) were the most abundant, while the observed families of Corvidae, Sturnidae, Prunellidae, Caprimulgidae, and Ciconiidae were represented less abundantly, i.e., by one species each. Equally, nests of 17 breeding species were recorded and mapped along the watershed, breeding counts of the globally endangered Egyptian vulture and the globally vulnerable Turtle Dove pairs were done, and the first breeding cases of the Western Bonelli's Warbler, Woodchat Shrike, Great Grey Shrike, Common Nightingale, Black Kite, and the North African Long-legged Buzzard were confirmed. The nesting sites were distributed along the watershed depending on specific requirements of each species, with nesting sites of passerines separated from those of raptors. The species richness of birds is supported by the availability of both foraging and breeding resources. In summary, in this study, we recorded the avian diversity, mapped the nesting sites of the breeding bird species, and confirmed the first breeding cases for five species, thus significantly contributing to the ornithology of Morocco and the Southern slope of the Mediterranean basin.

INTRODUCTION

To date, nearly 11.000 bird species have been recorded in the world (Neate-Clegg et al. 2020). Of these, 7.886 species are classified as birds of least concern for conservation, 1.373 species are described as threatened with extinction, 959 as near threatened, 145 species are confirmed as extinct, and the conservation status of 62 species is not yet determined due to the lack of statistics and data (Birdlife International 2012). Bird species are classified as either sedentary, i.e. those whose breeding and wintering habitat is limited to specific areas (Michel et al. 2019), or migratory species that breed and overwinter in different ecosystems or habitats (Samplonius et al. 2018; Mansouri et al. 2021b). Therefore, monitoring of the habitat use and abundance of avian species at both breeding and wintering sites is supposed to help determine their conservation status.

Due to its location at the crossroads between Europe and Africa, and due to the diversity of its ecosystems (forests, coastlines, mountains, etc.), Morocco hosts 582 avian species (Mansouri et al. 2021d; Bergier et al. 2022). Likewise, millions of migratory birds cross the Moroccan ecosystems during winter and spring (Scholer et al. 2016; Khelifa et al. 2017; Ouassou et al. 2021; Verhoeven et al. 2021). Despite this diversity and fertility, many Moroccan ecosystems, especially those in the eastern and southern provinces, are still unexplored. Many of them are under human and natural pressure, with most of them being moderately-to-severely degraded (De Waroux and Lambin 2012; Cherkaoui et al. 2015). Therefore, it is urgently needed to perform the analysis of the diversity and habitat use of the unexplored birds (at least of the threatened species) and to update the data available on the studied ones. The understanding of the abundance and distribution of these species will help to update their conservation status and, based on the new data, to implement appropriate management (Factoria actions (McClure et al. 2018).

The present study aimed to evaluate the diversity of avian species along the Oued Bouhellou Watershed. Equally, we identified and mapped the nesting and foraging habitats used by the most commonly observed raptors and passerines. Moreover, this study also aimed to investigate if there is a segregation between the breeding resources of cohabiting birds, and this attempt is the first of its kind in this North African ecosystem.

MATERIALS AND METHODS

Study zone

This investigation was conducted in the Oued Bouhellou watershed situated in the Middle Atlas Mountains

4°32'0"W

(Figure 1), between the Sais plain (Eastern side of Fez) and the Southern slope of the Rif mountains. Geographically, the studied watershed with the perimeter of 112.6 km and the estimated area of 312 km² (Figure 1) belongs to the Oued Inaouène hydrological basin, which drains the northern slope of the Middle Atlas Mountains west of Taza city.

The climatic conditions in the study area range from humid in the mountains to semi-arid downstream. Diurnal temperatures range from 4 to 15 °C in January (winter) and from 17 to 34 °C in July (summer). Equally, the rainfall is higher during the winter period between (November-February), while the summer period (June–September) is dominated by drought. The average rainfall is around 500 mm/year.

The area is dominated by woodlands of Holm Oak (Quercus ilex), Atlas cedar (Cedrus atlantica), Euro-

4°18'0"W



4°25'0"W

Figure 1. Geographical location of the Oued Bouhellou watershed (Morocco) and the prospected sites.

pean Fan Palm (*Chamaerops humilis*), and wild olives (*Olea europea* L. subsp. *europaea* var. *sylvestris* Lehr), farmlands of olives, cereals, prunes, and peaches, and wetlands including the dam of Bab Louta and rivers, principally the Oued Bouhellou, Azher, and the Qawane (Figure 1).

Bird surveys

Before undertaking the survey of avian species, the study zone was divided into natural ecosystems such as forests, cliffs, steppes, and rivers, and human-made landscapes including farmlands (cereals, and orchards) and dams, according to the land occupancy in the watershed. From January 2018 to December 2021, avian species (migrant, wintering visitors, and resident birds) were surveyed during wintering and breeding periods. In open areas (crops and steppes), bird species were recorded using the "point-counts" method, which is based on direct observations and acoustic monitoring. In dense habitats (forests, orchards, and riparian vegetation), the monitoring of birds was based on acoustic calls because of the dense vegetation, which reduced the observation range (from 3 to 5 m in dense forests, and less than 0.5 m in riparian vegetation). On cliffs and in dams, birds were recorded at the observation points, which were selected at high topographic sites (permitting the panoramic view of the monitored sites). In total, 13 observation points (separated by 0.5 to 1 km) were selected and monitored two times per month (1248 visits were conducted between January 2018 and December 2021). During each visit we recorded the avian species and their abundance from 06.00 AM to 06.00 PM.

Breeding and foraging resources

Besides bird surveys, we also conducted the monitoring of the species breeding at the studied sites, which was based only on nests. Breeding couples or juveniles were not taken into consideration due to the difficulty in confirming their nesting sites. For mapping purposes, nesting sites and support (trees or rocks) of breeding species were recorded with a GPS device. In parallel, we documented the foraging sites (foraging habitats where the breeding birds were observed searching for food) and resources (wild and cultivated seeds for granivorous birds; insects and small arthropods for insectivorous species; mammals and carrion for carnivorous species; and landfills for the birds feeding on dumps) of the breeding species in order to explain the potential separation between them (Supplementary Table 1). At each observation point, potential foraging resources were examined within a radius of 1 to 1000 m.

The study area was divided into three zones (Upstream, Intermediate zone, and Downstream), and five habitats, i.e., forests, aquatic systems (river, dams, water bodies), farmlands (farms, orchards, cereals), cliffs (cliffs and cavities), and human-made structures (buildings, bridges, pylons, ornamental vegetation). The potential foraging (fruits, seeds, arthropods, reptiles, and mammals) and breeding resources were explored by walking along 1 km-long transects based on the transects of bird surveys (selected on the basis of the surface covered by each habitat and the number of nests recorded; habitats where nests were more numerous were explored extensively since feeding of nestlings requires more food resources). Depending on their condition, the collected and photographed specimens or their remains were identified either to the species level or to that of the family using identification guides (available for Morocco and the updated ones) for plant (fruit trees) (Valdés 2002), mammal (Denys et al. 2015), reptile (Stoetzel et al. 2010), and insect species (Louveaux and ben Halima 1986; Bigot et al. 1988). These components are expected to explain the diversity of avian species since the majority of the explored habitats are used by birds for feeding or nesting, as well as the distribution of breeding species since the affinity between birds is assumed to vary in accordance with the distribution and dynamics of these resources in the watershed.

Mapping of breeding and foraging sites

Maps of the study area and of the dominant habitats (forests, farmlands, aquatic systems, and cliffs) were generated using QGIS 3.14 (2020). To realistically represent the studied area and to increase the accuracy of maps, the data for the last five years (2017-2022) were used. The spectral data sources of the Landsat Enhanced Thematic Mapper Plus (ETM1) images from January 2017 to December 2021 were used in the classification procedure with 30 m resolution beam records and seven distinct groups of two levels of spectral data including red, near infrared bands and their NDVI ratios. The slope variation allows us to determine the limits of the valley, the alluvial plain, and to distinguish between mountain, plateau and plain zones. Multi-date images were used to identify and delimit the dominant habitats. A total of 56.455 training pixels were generated for the classification of the 907.429 pixels falling within the study area. Arrangements of training habitats were established for study habitats, forests, farmlands, dams and rivers, and cliff cover using recently digitized data acquired from the 1:22.000 colour, infrared (CIR), aerial photography of the monitored zone and on-site assessments (mainly to illustrate the farming and other human activities in the watershed). Likewise, field visits were performed to confirm satellite images. The spatio-temporal analysis of the vegetation cover was carried out based on the Landsat satellite images for the period 2018-2022 and the NDVI index (Normalized Difference Vegetation Index), which was calculated by subtracting the red band (R) from the near infrared band (PIR) and expressed as NDVI = (PIR-R)/(PIR+R), where the value of each included pixel ranges between -1 and +1, the negative values correspond to the surfaces of water, the values close to 0 represent bare surfaces and the positive values represent the vegetation cover whose density increases as the value of NDVI approaches +1. Finally, the classifications of the Landsat satellite images using the QGIS software allow us to map the spatial distribution of various plant types and, consequently, the land use (forests, agriculture, etc.).

Statistical analysis

The recorded species were grouped into families and orders. The number and percentage of breeding (number of breeders/total species), resident (number of residents/total species), migrant (number of migrants/ total species) and wintering (number of winterers/total species) species were calculated for the entire watershed. Equally, we compared the most frequent families and orders based on the species observed. We compared the total numbers of nests in each of the three zones of the watershed using a one-way ANOVA test, and the total numbers of raptor nests in upstream and downstream zones using the independent *t*-test. Statistics were performed using STATGRAPHICS Centurion software, version XVI.I. The raptors of the intermediate zone were not included into the statistical analysis because of their movement between downstream and upstream zones.

Before running the statistics, the breeding sites located along the watershed gradient were divided into three zones, i.e., into upstream, intermediate and downstream zones. The composition of breeding species was compared between the watershed zones. A Detrended Correspondence Analysis (DCA) considering nesting sites (downstream, intermediate zone, and upstream) as factors (independent variables), and breeding species (n = 21) as response variables, was conducted to describe the affinity of birds to breeding habitats and to reveal the potential separation of nesting sites (Lee and Rotenberry 2005; Mansouri et al. 2021a), (Mansouri et al. 2021c; Squalli et al. 2022). In our case, only two axes were generated and selected (with eigenvalues >1). The scores of each observation for the multivariate axes were used to read the breeding site utilization by each set of breeding birds. Breeding sites were included in the model as random factors, while bird species were included as the fixed ones.

RESULTS

Diversity of avifauna in the Bouhellou

The diversity of avian species recorded in the Bouhelou

watershed between 2018 and 2021 is presented in Figure 2. A total of 85 avian species belonging to 8 orders and 25 families were recorded. The Passeriformes (61 species and 20 families) and Accipitriformes (12 species and one family) were the most abundant orders, while Caprimulgiformes, Ciconiiformes, and Bucerotiformes were the least observed ones with one species recorded for each of them. Accipitridae (12 species), Muscicapidae (10 species), Motacillidae (6 species), and Fringillidae (6 species) were the most diverse families, while Troglodytidae, Oriolidae, Sturnidae, Prunellidae, Meropidae, and Upupidae were the least diverse ones with one species observed for each.



Figure 2. Diversity of the bird orders and families recorded in the Bouhellou Watershed.

As regards the phenological status (Supplementary Table 2), there were 56 resident and 39 migrant species identified, 10 of which were wintering. In parallel, three species of conservation concern were documented: the vulnerable Turtle Dove and the Golden Finch, and the endangered Egyptian Vulture.

Selection of breeding sites

The distribution of breeding species in the Bouhelou watershed is summarized in Figure 3. In the upstream zone, the same breeding sites along the riverbanks were found to be shared by the following raptor and passerine

species: raptors including Aquila fasciata, Hieraaetus pennatus, Circus aeruginosus, Buteo rufinus, Elanus caeruleus, Lanius senator, and Lanius excubitor in the rocky escarpment created by erosion along the upstream zone and passerines including Serinus, Turdus merula, Phylloscopus bonelli, and Luscinia megarhynchos in the riparian vegetation of the river. On the contrary, in the intermediate and downstream zones, the breeding sites of passerines were separated from those of raptors. In the intermediate zone, the breeding sites of such raptors as Falco tinnunculus, Falco naumanni, Circus aeruginosus, Buteo rufinus, Elanus caeruleus, Lanius senator, and Lanius excubitor were separated from those of the passerine species represented by Streptopelia turtur, Serinus, Passer hispaniolensis, Passer domesticus, Turdus merula, Phylloscopus bonelli, and Luscinia megarhynchos. Similarly, in the downstream zone, the breeding passerines including Streptopelia turtur, Serinus, Turdus merula, Phylloscopus bonelli, and Luscinia megarhynchos were found in the riparian vegetation along the river stream, while nests of the raptors including Falco tinnunculus, Falco naumanni, Circus aeruginosus, Buteo rufinus, Elanus caeruleus, Lanius senator, and Lanius excubitor were observed on the cliffs located far from the river stream.

Spatial distribution of nesting sites

The spatial distribution of the breeding sites selected by avian species is presented in Figure 4. The distribution of passerine species nesting sites along the watershed gradient shows the following pattern: the majority of nesting sites are concentrated in the downstream zone (n = 1114 nests) followed by those in intermediate

(n = 620 nests) and upstream zones (n = 304 nests) (ANOVA test, df = 2, f = 47.69, p < 0.001). On the contrary, location of the nesting sites of birds of prey was limited to the upstream (n = 66 nests) and intermediate zones (n = 97 nests) (df = 6, t = -1.99, p = 0.09). On the other hand, breeding passerines selected nesting in farmlands, forests, and in the river-associated riparian vegetation, while nesting sites of raptors were on cliffs and in surrounding forests far from the river principal floodplain.

Potential nesting and foraging resources

Land occupancy significantly varies between the watershed sections (Figure 4 and Table 1). In the upstream zone, there are four ecosystem types found: forests (41%) (dominated by woodlands of Holm Oak (Quercus rotandifolia), Cork Oak (Quercus suber), Juniper (Juniperus oxycedrus), and European Fan Palm (Chamaerops *humilis*), and Wild olives (*Olea europea*)), farmlands (37%) dominated by cereals (Maize, Soft wheat, Barley, and lentils), orchards of olives, oranges, and Common pomegranate, Cliffs (17%), and aquatic systems (5%) including the Oued Bouhellou upstream and the Bab Louta dam with the banks overgrown with Oleander (Nerium oleander), Tamaris sp., Reed sp., Typha sp., Poplar sp. The intermediate zone is dominated by forests (56%) and cliffs (27%), while areas of farmlands and those of river streams account for just 15% and 2%, respectively. In the downstream zone, farmlands (98%) dominated the ecosystems, with the river floodplain constituting 2%, while cliffs and forests were not present. On the other hand, the foraging resources available for breeding (to ensure feeding of broods) and wintering avian species



Figure 3. DCA plot representing the selection of breeding sites in three different zones (Upstream, Downstream and Intermediate) of the Bouhellou watershed.

(to face harsh conditions) are widely diverse and include fruits, seeds, flowers, dumps, and animals (Table 1). These breeding and foraging resources are supposed to support the diversity of avian species during breeding and wintering seasons.

DISCUSSION

In this study, we investigated the avian diversity and potential foraging resources in the Bouhelou watershed located in the Northeast of Morocco. Additionally,

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Wetershill	Breeding	resources	Foraging resources			
watershed zones	Humane-made	Natural	Humane-made	Natural		
Upstream	 Orchards: Trees of olives, puns, amends, Aleppo pine, Orange, Common pomegranate, Fig, -Reforestation: Aleppo pine, -Ornamental plants: fir, Eucalyptus, <i>Acacia</i> sp. -Infrastructures: buildings, bridges, Dams, electric pylons, Forestry centres, Irrigation canals 	 -Forests: Holm oak, Carob, European Fan Palm, Wild olives, Pistachio lentils, Common strawberry, Cork Oak, Juniper, -Rivers: Oleander, <i>Tamaris</i> sp., Reed sp., <i>Typha</i> sp., <i>Poplar</i> sp., -Dam: <i>Tamaris</i> sp., <i>Reed</i> sp., <i>Typha</i> sp, <i>Poplar</i> sp., -Cliffs and cavities 	 -Fruits: Orange, fig, Common pomegranate, Date, Tomatoes, -Cereals and cultivated seeds: Maize, Soft wheat, Barley, Chickpeas, Beans, Faba bean, lentils, Peas, -Dumps: Matmata uncontrolled dumps, -Domestic animals: Carrion of goats, cows, donkeys, dogs, chicken, turkeys, rabbits 	 Wild fruits: Carob, Juniper, Common strawberry, Cork Oak, European Fan Palm, Wild olives, Pistachio lentils, Common strawberry, Asparagus, Wild seeds and flours: Spergularia sp., coarse- seeded oats, Bluish canary grass, Field bindweed, Stiff tares, Ryegrass, Scorpiurus sp., Wild Animals: Arthropods and Insects, Reptiles, amphibians, Mammals, birds (passerines are potential forage for raptors), Aquatic vertebrates 		
Intermediate zone	-Orchards: Trees of olives, puns, amends, Aleppo pine, Orange, Common pomegranate, Fig, -Reforestation: Aleppo pine, -Ornamental plants: fir, Eucalyptus, <i>Acacia</i> sp., -Infrastructures: buildings, bridges, electric pylons, Forestry centres	 -Forests: Trees of European Fan Palm, Wild olives, Jujube -Rivers: Trees of Oleander, <i>Tamaris</i> sp., <i>Reed</i> sp., <i>Typha</i> sp., <i>Poplar</i> sp., -Cliffs and cavities 	-Fruits: Orange, fig, Common pomegranate, Date, Tomatoes, -Cereals and cultivated seeds: Maize, Soft wheat, Barley, Chickpeas, Beans, Faba bean, lentils, Peas, -Domestic animals: Carrion of goats, cows, donkeys, dogs, chicken, turkeys, rabbits	 -Wild fruits: Carob, Juniper, Common strawberry, Cork Oak, European Fan Palm, Wild olives, Pistachio lentils, Common strawberry, Asparagus, -Wild seeds and flours: Spergularia sp., coarse- seeded oats, Bluish canary grass, Field bindweed, Stiff tares, Ryegrass, Scorpiurus sp., -Wild Animals: Arthropods and Insects, Reptiles, amphibians, Mammals, birds (passerines are potential forage for raptors), Aquatic vertebrates 		
Downstream	-Orchards: Trees of olives, puns, amends, Aleppo pine, Orange, Common pomegranate, Fig, -Reforestation: Aleppo pine, -Ornamental plants: fir, Eucalyptus, Snowshoe cactus, Phoenix palm, Acacia sp., -Infrastructures: buildings, bridges, electric pylons, Forestry centres	-Forests: Trees of European Fan Palm, Wild olives, Jujube -Rivers: Trees of Oleander, <i>Tamaris</i> sp., <i>Reed</i> sp., <i>Typha</i> sp., <i>Poplar</i> sp., Cavities	-Fruits: Orange, fig, Common pomegranate, Date, Tomatoes, -Cereals and cultivated seeds: Maize, Soft wheat, Barley, Chickpeas, Beans, Faba bean, lentils, Peas, -Dumps: Matmata uncontrolled dumps, -Domestic animals: Carrion of goats, cows, donkeys, dogs, chicken, turkeys, rabbits	 -Wild fruits: Carob, Juniper, European Fan Palm, Wild olives, Pistachio lentils, Blackberry, Asparagus, -Wild seeds and flowers: Spergularia sp., coarse- seeded oats, Bluish canary grass, Field bindweed, Stiff tares, Ryegrass, Scorpiurus sp., -Wild Animals: Arthropods and Insects, Reptiles, amphibians, Mammals, birds (passerines are potential forage for raptors), Aquatic vertebrates 		



Figure 4. Land cover of the studied habitats along the gradient of the watershed.

breeding species and their nesting sites were documented and mapped with high precision. The obtained results are the first of this kind to be reported for Moroccan and Northwest African ecosystems. Moreover, importance of these data lies in their applicability for conservation efforts.

Our investigation provides a clear and comprehensive picture of the bird diversity in the Bouhelou watershed. Indeed, 85 bird species including resident and migrant species were observed in the areas studied. Similar results were reported for the Midelt province (131 bird species), which is located in Southern regions of Morocco (Mansouri et al. 2019), and the cork oak forest of Maamora (63 species) located in the Northwest of Morocco (Cherkaoui et al. 2009). The rich diversity of birds in the study area is supported by the availability of both breeding and foraging resources, which in the Bouhelou watershed are abundant.

The availability of forests, riparian vegetation, and cultivated trees attracts forest species such as the Rock Pigeon (*Columba palumbus*) and the Eurasian Jay (*Gar-rulus glandarius*) (Kurek et al. 2019; Mansouri et al. 2021d), riparian species such as the Common Chaffinch (*Fringilla coelebs*) and the Barn Swallow (*Hirundo rustica*) (Keten et al. 2020), and farmland birds such as the Turtle Dove and the Collared Dove (Mansouri et al. 2021b; Squalli et al. 2021). Equally, the dam of Bab Louta offers adequate habitat for aquatic species such as the Mallard Duck (Ouassou et al. 2021), while cliffs provide breeding habitat for cavernous species of the Falconidae such as the Lesser Kestrel (*Falco naumanni*), the Eurasian Kestrel (*Falco tinnunculus*) (Espinosa et al.

2021), vultures such as the Egyptian Vulture (*Neophron percnopterus*) (Panthi et al. 2021), and eagles such as the Bonelli's Eagle (*Hieraaetus fasciatus*) (Gil-Sánchez et al. 2004).

The abundance of wild and cultivated seeds-fruits including Rubus fruticosus, Ziziphus lotus, Rosa canina, Triticum sp., possibly offers forage for granivorous species such as the Sturnidae, Turdidae, and Columbidae (Mansouri et al. 2019; Teichmann et al. 2020). The availability of insects such as Formicidae, Apoidea, Coccinellidae is supposed to feed insectivorous birds of the Paridae, Hirundinidae, Sylviidae, and Phylloscopidae as has been proved currently (Goffová et al. 2021; Rajemison et al. 2021), small arthropods and reptiles such as the Scorpionidae, Lacertidae, Gekkonidae, and Chamaeleonidae feed Falconiformes and Strigiformes (Varasteh Moradi 2018; Krištín et al. 2020), while carrion of big mammals such as the Erinaceidae, Canidae, and Leporidae, etc., can be regarded as a foraging resource for vultures and eagles (Martínez-Miranzo et al. 2019; Cabrera-García et al. 2020). The most important habitat components supporting bird diversity in this area are the abundance and combination of both foraging and breeding resources. Their importance is reinforced by the fact that the Moroccan ecosystems are the only stopover sites for the refuelling of migratory birds that use the Western Palearctic migratory route before crossing the arid and harsh Sahara (Maggini and Bairlein 2011; Mansouri et al. 2021d). Therefore, more in-depth studies are needed to clarify the importance of Moroccan ecosystems for biodiversity and conservation purposes.

This study has revealed an important breeding population consisting of migrant and resident avian species, which is similar to the investigation results reported for other Moroccan ecosystems. However, the most significant finding of our study is the recorded breeding of such threatened bird species as the globally endangered Egyptian Vulture (Panthi et al. 2021) and the globally vulnerable Turtle Dove (Mansouri et al. 2021b) as well as the confirmation of the first breeding cases of the Western Bonelli's Warbler Phylloscopus bonelli, the Woodchat Shrike (Lanius senator), the Great Grey Shrike (Lanius excubitor), the Common nightingales (Luscinia megarhynchos), the Black Kite (Milvus migrans) and the North African Long-legged Buzzard (Buteo rufinus cirtensis). Cases of these species breeding were previously documented only on the Northern slope of the Mediterranean basin (Isenmann and Fradet 1998; Antczak et al. 2004; Kiefer et al. 2009; Chamorro et al. 2017; Olioso et al. 2020). On the other hand, the concentration of breeding raptors in the upstream and intermediate zones of the watershed and their separation from nesting passerines is governed by the affinity of each group and the distribution of both breeding and foraging resources along the watershed. Indeed, large raptors such as the Egyptian Vulture and the Bonelli's Eagle, and the North African Long-legged Buzzard known as a cave bird (Chamorro et al. 2017; Panthi et al. 2021) nested only in the mountainous areas, where the presence of cliffs and abundance of big mammals ensure the availability of nesting sites and foraging resources for their nestlings, while passerines were abundant along the rivers due to their flexibility in breeding and foraging requirements. Equally, the selection of breeding sites far from raptors is supposed to protect passerine broods from predation attacks (Mönkkönen et al. 2007).

CONCLUSION

In summary, throughout this study, we documented the avifauna diversity in the Oued Bouhellou watershed located in the North-East of Morocco. Our study results revealed a remarkable avian diversity as well as an abundance of foraging and breeding resources. Equally, we recorded important breeding populations and the nesting of two globally threatened bird species and confirmed the first breeding cases in Morocco and Northwest Africa for another five species. These findings and especially those regarding the nesting sites of globally threatened birds are of great interest for conservation purposes as well as for the future comparative research. To ensure protection of this important ecosystem from such adverse anthropogenic impacts as deforestation, pasturage, hunting, urbanization, and intense agriculture and to enhance the conservation of such ecosystem components as the vegetation cover and the associated fauna, it has to be designated an area of biological and ecological interest, which in turn urgently requires that more studies be performed into the ecological roles of this important ecosystem.

ACKNOWLEDGMENTS

We thank the anonymous reviewers and the Editor of the journal for their comments and advice.

Funding

Not applicable.

Data availability

The data used to support the findings of this study are included within the article.

Conflicts of interest/competing interests

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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	Family	Species	Conservation status
Plants	Apocynaceae	Nerum oleander	LC
	Cyperaceae	Carex panicalata	LC
	Asteraceae	Xanthium spinosum	LC
	Asteraceae	Conyza canadensis	LC
	Cyperaceae	Cyperus badius	LC
	Tamaricaceae	Tamarix aphylla	LC
	Poaceae	Arundo donax	LC
	Salicaceae	Populus alba	LC
	Juncaceae	Juncus effusus	LC
	Asteraceae	Dittrichia graveolens	LC
	Asteraceae	Dittrichia viscosa	LC
	Rosaceae	Rubus fruticosus	LC
	Potamogetonaceae	Potamogeton nodosus	LC
	Typhaceae	Typha latifolia	LC
	Salicaceae	Salix alba	LC
	Amaranthaceae	Chenopodium album	LC
	Myrtaceae	Eucalyptus sideroxylon	LC
	Liliaceae	Asparagus albus	LC
	Oleaceae	Fraxinus angustifolia	LC
	Lamiaceae	Mentha pulegium	LC
	Lamiaceae	Marrubium vulgare	NT
	Lamiaceae	Mentha suaveolens	LC
	Polygonaceae	Emex spinosa	LC
	Euphorbiaceae	Ricinus communis	LC
	Asteraceae	Chamaemelum nobile	LC
	Caprifoliaceae	Lonicera periclymenum	LC
	Ulmaceae	Celtis australis	LC
	Pteridaceae	Adiantum capillus-veneris	LC
	Capparaceae	Capparis spinosa	LC
	Arecaceae	Chamaerops humilis	LC
	Oleaceae	Olea europaea	LC
	Asparagaceae	Drima maritima	LC
	Rhamnaceae	Zizifus lotus	LC
	Fabaceae	Ceratonia siliqua	LC
Mammals	Leporidae	Lepus capensis	LC
	Suidae	Sus scrofa barbarus	LC
	Erinaceidae	Atelerix algirus	LC
	Canidae	Vulpes vulpes	LC
Reptiles	Agamidae	Agama bibronii	LC
	Chamaeleonidae	Chamaeleo chamaeleon	LC
	Lacertidae	Timon tangitanus	LC
	Testudinidae	Testudo graeca marokkensis	LC
	Lamprophiidae	Malpolon monspessulanus	LC
	Lacertidae	Psammodromus algirus	LC
Amphibians	Ranidae	Pelophylax saharicus	LC
Insects	Oedipodinae	Oedipoda caerulescens	LC
	Oedipodinae	Oedipoda miniata	LC
	Oedipodinae	Oedipoda fuscocincta	LC
	Coccinellidae		
	Tenebrionidae		
	Scarabaeidae		
	Aphodiidae		
	Carabidae		
	Curculionidae		
	Apidae	Apis mellifera	LC

Supplementary Table 1. Recorded animal and plant species constituting potential foraging resources for avian species.

Supplementary Table 2. Phenological status (RB: Resident breeder, BM: Breeding Migrant PM: Passage Migrant, W: Wintering) and UICN conservation status (E: Endangered, LC: Least Concern, VU: Vulnerable) of the species recorded in Oued Bouhello.

Orders	Families	Species (scientific name)	Status	Conservation Status	Phenological Status in the Bouhellou Watershed
Passeriformes		Snilonelia senegalensis	RB	IC	Breeding and feeding
1 usseritorities		Streptopelia decaocto	RB	LC	Breeding and feeding
		Columba palumbus	RB		Breeding and feeding
		Columba livia	RB	LC	Breeding and feeding
	Passeridae	Passer domesticus	RB	LC	Breeding and feeding
		Passer hispaniolensis	RB	LC	Breeding and feeding
	Muscicapidae	Muscicapa striata	BM	LC	Breeding and feeding
		Ficedula hypoleuca	PM	LC	Feeding
		Phoenicurus moussieri	RB	LC	Breeding and feeding
		Oenanthe leucura	RB	LC	Breeding and feeding
		Oenanthe hispanica	RB	LC	Breeding and feeding
		Oenanthe oenanthe	RB	LC	Breeding and feeding
		Oenanthe deserti	RB	LC	Breeding and feeding
		Erithacus rubecula	RB	LC	Breeding and feeding
		Luscinia megarhynchos	RB	LC	Breeding and feeding
	Fringillidae	Serinus serinus	RB	LC	Breeding and feeding
		Fringilla coelebs	RB	LC	Breeding and feeding
		Linaria cannabina	RB	LC	Breeding and feeding
		Carduelis carduelis	RB	LC	Breeding and feeding
		Chloris chloris	RB	LC	Breeding and feeding
		Coccothraustes	RB	LC	Breeding and feeding
	Motacillidae	Motacilla alba	RB	LC	Breeding and feeding
		Motacilla cinerea	RB	LC	Breeding and feeding
		Motacilla flava	RB	LC	Breeding and feeding
		Anthus pratensis	PM, W	LC	Feeding
		Anthus spinoletta	W	LC	Feeding
		Anthus campestris	BM, PM	LC	Breeding and feeding
	Phylloscopidae	Phylloscopus bonelli	BM, PM	LC	Feeding
		Phylloscopus sibilatrix	PM	LC	Feeding
		Phylloscopus collybita	PM, W	LC	Feeding
		Phylloscopus trochilus	PM	LC	Feeding
	Alaudidae	Eremophila alpestris	RB	LC	Breeding and feeding
		Eremophila bilopha	RB	LC	Breeding and feeding
		Calandrella brachydactyla	BM, PM	LC	Breeding and feeding
		Galerida cristata	RB	LC	Breeding and feeding
		Melanocorypha calandra	RB	LC	Breeding and feeding
	Emberizidae	Emberiza calandra	RB	LC	Breeding and feeding
		Emberiza cia	RB	LC	Breeding and feeding
		Emberiza cirlus	RB	LC	Breeding and feeding
		Emberiza sahari	RB	LC	Breeding and feeding
	Sylviidae	Sylvia melanocephala	RB	LC	Breeding and feeding
		Sylvia undata	RB	LC	Breeding and feeding
		Sylvia atricapilla	RB, PM, W	LC	Breeding and feeding
	Hirundinidae	Hirundo rustica	BM	LC	Feeding
		Delichon urbicum	BM, PM	LC	Feeding
		Cecropis daurica	BM, PM	LC	Feeding
	Paridae	<i>Cyanistes teneriffae ultramarinus</i>	RB	LC	Breeding and feeding

Orders	Families	Species (scientific name)	Status	Conservation Status	Phenological Status in the Bouhellou Watershed
		Periparus ater	RB	LC	Breeding and feeding
		Parus major	RB	LC	Breeding and feeding
	Turdidae	Turdus merula	RB	LC	Breeding and feeding
		Turdus viscivorus	RB	LC	Breeding and feeding
	Troglodytidae	Troglodytes troglodytes	RB	LC	Breeding and feeding
	Oriolidae	Oriolus oriolus	BM	LC	Breeding and feeding
	Laniidae	Lanius senator	BM	LC	Breeding and feeding
		Lanius excubitor	RB	LC	Breeding and feeding
	Corvidae	Corvus corax	RB	LC	Breeding and feeding
	Sturnidae	Sturnus unicolor	RB	LC	Breeding and feeding
	Prunellidae	Prunella collaris	RB, W	LC	Breeding and feeding
	Sittidae	Sitta europaea	RB	LC	Breeding and feeding
	Certhiidae	Certhia brachydactyla	RB	LC	Breeding and feeding
Columbiformes	Columbidae	Streptopelia turtur	BM	VU	Breeding and feeding
Caprimulgiformes	Caprimulgidae	Caprimulgus europaeus	BM, PM	LC	Breeding and feeding
Ciconiiformes	Ciconiidae	Ciconia ciconia	BM, PM, W	LC	Breeding and feeding
Anseriformes	Anatidae	Anas platyrhynchos	RB, W	LC	Breeding and feeding
Pelecaniformes	Ardeidae	Bulbucus ibis	RB	LC	Breeding and feeding
		Ardea cinerea	W	LC	Feeding
		ycticorax nycticorax	BM, PM	LC	Breeding and feeding
Falconiformes	Falconidae	Falco tinnunculus	RB	LC	Breeding and feeding
		Falco naumanni	BM, PM	LC	Breeding and feeding
		Falco peregrinus	RB	LC	Breeding and feeding
Accipitriformes	Accipitridae	Buteo rufinus cirtensis	RB	LC	Breeding and feeding
		Pernis apivorus	PM	LC	Migration
		Circaetus gallicus	BM, PM	LC	Feeding
		Circus aeruginosus	RB, PM, W	LC	Breeding and feeding
		Accipiter nisus	RB	LC	Breeding and feeding
		Milvus migrans	BM	LC	Breeding and feeding
		Hieraaetus pennatus	BM	LC	Breeding and feeding
		Aquila fasciata	BM	LC	Breeding and feeding
		Aquila chrysaetos	RB	LC	Breeding and feeding
		Elanus caeruleus	RB	LC	Breeding and feeding
		Gyps fulvus	PM, W	LC	Feeding
		Neophron percnopterus	BM, PM	Е	Breeding and feeding
Strigiformes	Strigidae	Asio otus	RB	LC	Breeding and feeding
		Athene noctua	RB	LC	Breeding and feeding