Chapter

Diversity and Conservation of Bats in Jordan

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Abstract

The diversity and the conservation status of bats in Jordan are discussed based on recent studies. The bat fauna of Jordan consists of 26 bat species belonging to nine families (Emballonuridae, Hipposideridae, Pteropodidae, Miniopteridae, Molossidae, Nycteridae, Rhinolophidae, Rhinopomatidae, and Vespertilionidae). Bat echolocation calls for some selected species are included. Conservation status based on regional assessment according to the IUCN standards is amended, along with the current legislative laws for the conservation of bats. Threats affecting the bats of Jordan are highlighted including the recent introduction of wind farms and other mining activities. In addition, the role of bats in disease transmission is included.

Keywords: bat, diversity, threats, Jordan

1. Introduction

Jordan is situated at a crossroad between three continents and with diverse habitats (Mediterranean, Saharo-Arabian, Irano-Turanian, and Afro-tropical). Although Jordan is a small country, the bat fauna is diverse with 26 species representing nine families. Within the past four decades, our knowledge of the bats of Jordan expanded significantly, adding new records [1–3], distributional data [4–12], ectoparasites [13], karyotypic studies [14, 15], activity patterns [16], and conservation [17]. Yet, these studies also pointed out a significant shortage in our knowledge especially about the ecology and conservation of the bat fauna of this country. Benda et al. [18] published the most comprehensive and up-to-date manuscript on the bats of Jordan, including distributional data, ecology, echolocation, ectoparasites, and zoogeographical analysis.

This summary on the bats of Jordan is based on cumulative research and field observation since 1978. Over the past four decades, the senior author was involved in numerous studies on various aspects of the mammalian fauna of Jordan, including bats. As a result, several additional records of the bat fauna were added, and further knowledge on habitat preference and threats affecting bats in Jordan was gained. As a developed country, Jordan witnessed accelerated changes in its natural setting (water resources, agricultural practices, urination, mining, etc.), which, in turn, affected the well-being of several species of animals, including bats.

2. Biogeography of Jordan

Jordan is influenced by four major biogeographic regions (**Figure 1**). Vegetation cover, soil texture, altitude, and annual rainfall are among the major factors that shaped these biogeographic regions. Several types of habitats are present in Jordan, ranging from extreme desertic to mild-forested Mediterranean (**Figure 2**). It was agreed on the delineation of these four regions based on vegetation cover as well as animal distribution in Jordan [19, 20].

2.1 The Mediterranean region

This area is represented by mountain ranges extending from Irbid in the north near to the south around Ra's Al Naqb. This region is characterized by the presence of several types of forests (The Phoenician juniper, *Juniperus phoenicea*, Mt. Atlas mastic tree, *Pistacia atlantica*, Aleppo pine, *Pinus halepensis*, Palestine oak, *Quercus calliprinos*, kermes oak, *Quercus coccifera* and Mount Tabor oak, *Quercus ithaburensis*). Non-forested areas are characterized by a dense cover of the Thorny Burnet, *Sarcopoterium spinosum*. Altitude ranges from 700 to 1500 m asl, with 400–600 mm average annual rainfall and snowfall during winter. Several types of soil are found, including calcareous, *terra rosa*, sandy, and sandy-loamy caused by erosion of the Nubian sandstone that is common in the south [20].

2.2 Irano-Turanian region

This area surrounds the Mediterranean region from the west and the east. It extends to the Syrian Desert to the northeast. Few scattered trees can be observed, mainly *J. phoenicea* and *P. atlantica* trees. Shrubs of *Anabasis articulata*, *Artemesia herba-alba*, *Astragulus spinosum*, *Retama raetam*, *Urginea maritima*, *Ziziphus lotus*,

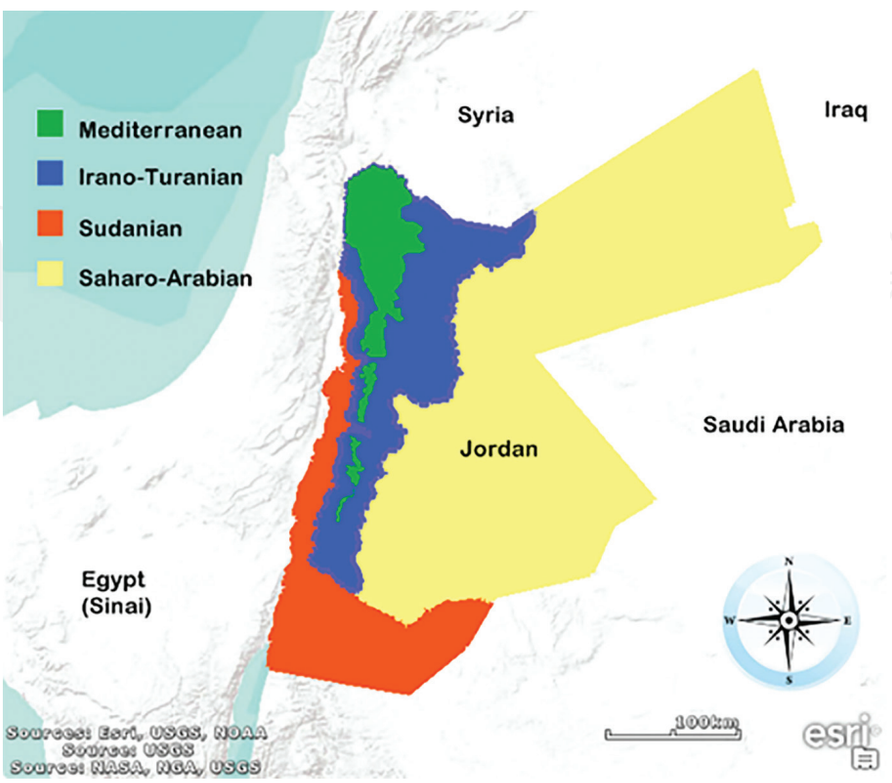

Figure 1.
The biogeographic regions of Jordan (modified after Al-Eisawi [19]).

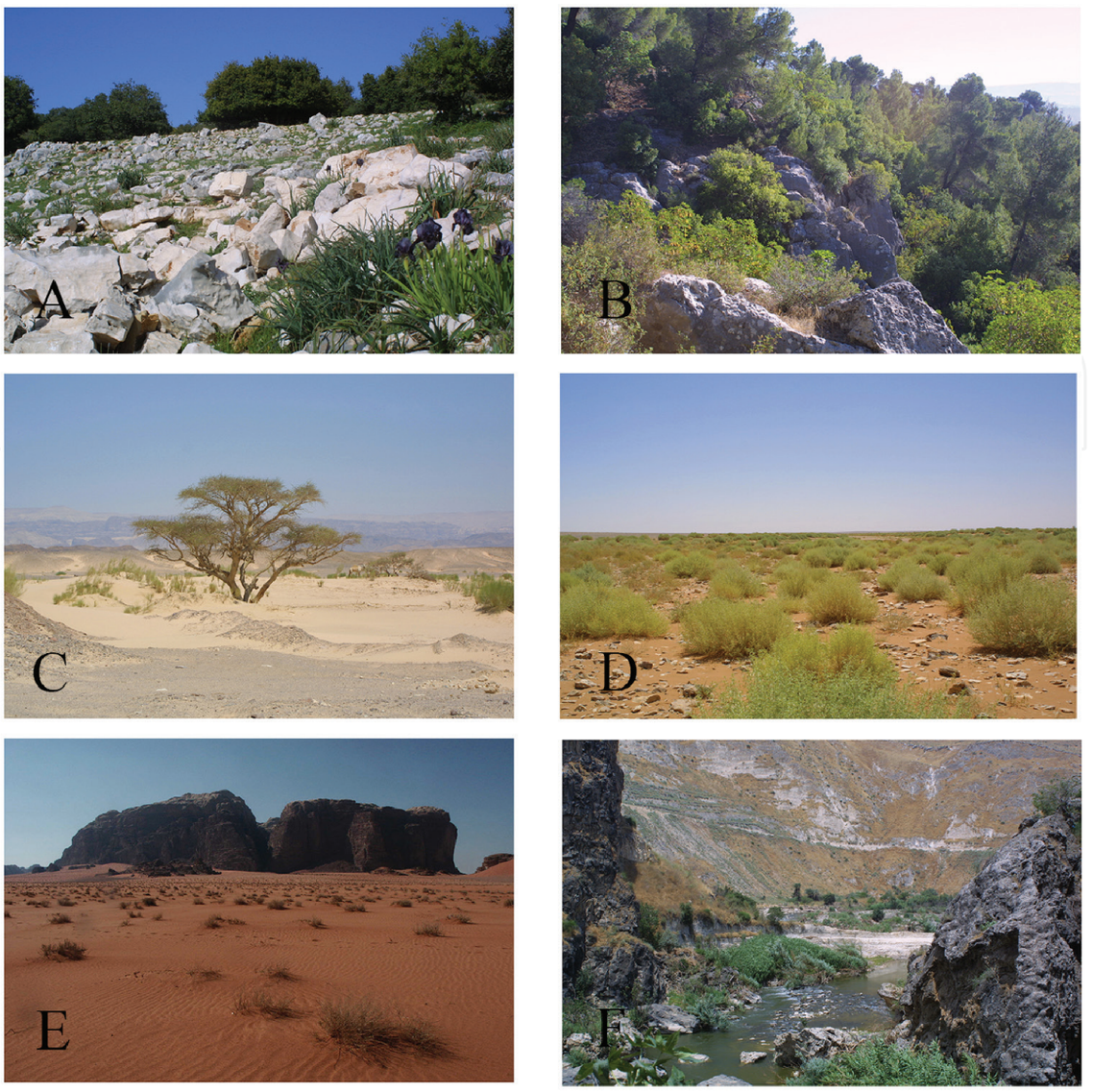

Figure 2.
Habitat types: (A, B) Temperate Mediterranean habitat with an abundance of evergreen oak (Quercus sp.) and pine forests in northern Jordan. (C) Sand dunes with Haloxylon shrubs and Acacia trees in Wadi Araba. (D) Open Hamada in eastern Jordan with ample bushes of Seidlitzia rosmarinus. (E) Wadi Ramm with sandstone mountains. (F) The riparian habitat at the Yarmouk River Basin in northern Jordan.

Zygophyllum dumosum are dominant. Altitudes range from 400 to 700 m asl, with 50–100 mm average annual rainfall. Surface soil is very thin or absent in some instances, while surface rock outcrops are very high [20].

2.3 Sudanian penetration region

This ecozone extends from southern Jordan near Aqaba Gulf along Wadi Araba reaching the southern part of the Jordan Valley near Dayr Alla northward. It also extends to southeastern Jordan near Wadi Ram, the largest sandstone mountain formation and granite mountains to the east. Altitudes range from 400 m bls around the Dead Sea area to as high as 1734 m asl for Jabal Ram mountain. Precipitation is of less than 50 mm annually. Two species of Acacia occur in this region in varying densities, *Acacia raddiana* and *Acacia tortilis*. *Tamarix* spp. and *Ziziphus spina-christi* are also found along wadi beds. A variety of shrubs, *Anabasis articulata*, *Gymnocarpos decandrum*, *Haloxylon persicum*, and *Lycium* sp. are abundant. The soil is mostly sandy for most of the region, interrupted with some rocky areas [20].

2.4 Saharo-Arabian region

This region constitutes the largest biogeographical region, covering about 70% of Jordan. It spreads to the east bordering the Irano-Turanian region from the west and the Sudanian Penetration region from the southwest. *Haloxylon persicum*, *Hammada scoparia*, and *Ochradenus baccatus* are the typical sand dune vegetation. *Achillea fragrantissima*, *Artemisia herba-alba*, and *Astragalus* sp. are usually associated with wadi beds, and in certain areas east of Ma'an, few scattered *Acacia tortilis* are also found. The soil is mostly gravel, sandy Hamada, saline, and sandy. Altitude ranges from 100 m to 800 m asl, with annual rainfall not exceeding 50 mm. Azraq Oasis, one of the most important nature reserves in Jordan, is located in the middle of the eastern desert [20].

3. Bat diversity in Jordan

The bat fauna of Jordan consists of 26 bat species belonging to nine families (Emballonuridae, Hipposideridae, Pteropodidae, Miniopteridae, Molossidae, Nycteridae, Rhinolophidae, Rhinopomatidae, and Vespertilionidae). **Figure 3** shows some representative species.

3.1 Family Pteropodidae

This family of fruit bats includes a single species, the Egyptian fruit bat, *Rousettus aegyptiacus*. This species is distributed along the eastern mountains and the Jordan Valley, extending from the extreme north near Lake Tiberius reaching as far as Aqaba to the south. The Egyptian fruit bat does not penetrate into the eastern desert [18, 20].

3.2 Family Rhinopomatidae

This family is represented by two species, the greater rat-tailed bat, *Rhinopoma microphyllum* and the lesser mouse-tailed bat, *Rhinopoma cystops*. The later species is widely distributed in localized Mediterranean areas as well as around the Dead Sea basin. *Rhinopoma microphyllum* was reported from fewer localities, mostly in the Mediterranean mountains [18, 20].

3.3 Family Rhinolophidae

This family includes six species inhabiting a variety of habitats. Geoffroy's horseshoe bat, *Rhinolophus clivosus*, and Mehely's horseshoe bat, *Rhinolophus mehelyi* were recorded from arid regions, while the Mediterranean horseshoe bat, *Rhinolophus euryale*, and the larger horseshoe bat, *Rhinolophus ferrumequinum*, are strictly confined to forested areas in northern Jordan. The lesser horseshoe bat, *Rhinolophus hipposideros* and Blasius's horseshoe bat, *Rhinolophus blasii* were recorded from both Mediterranean areas in the north and arid regions in southern Jordan [18, 20].

3.4 Family Emballonuridae

The tomb bat, *Taphozous perforatus* and the naked bellied tomb bat, *Taphozous nudiventris*, were recorded from Jordan. Both species were reported from the middle

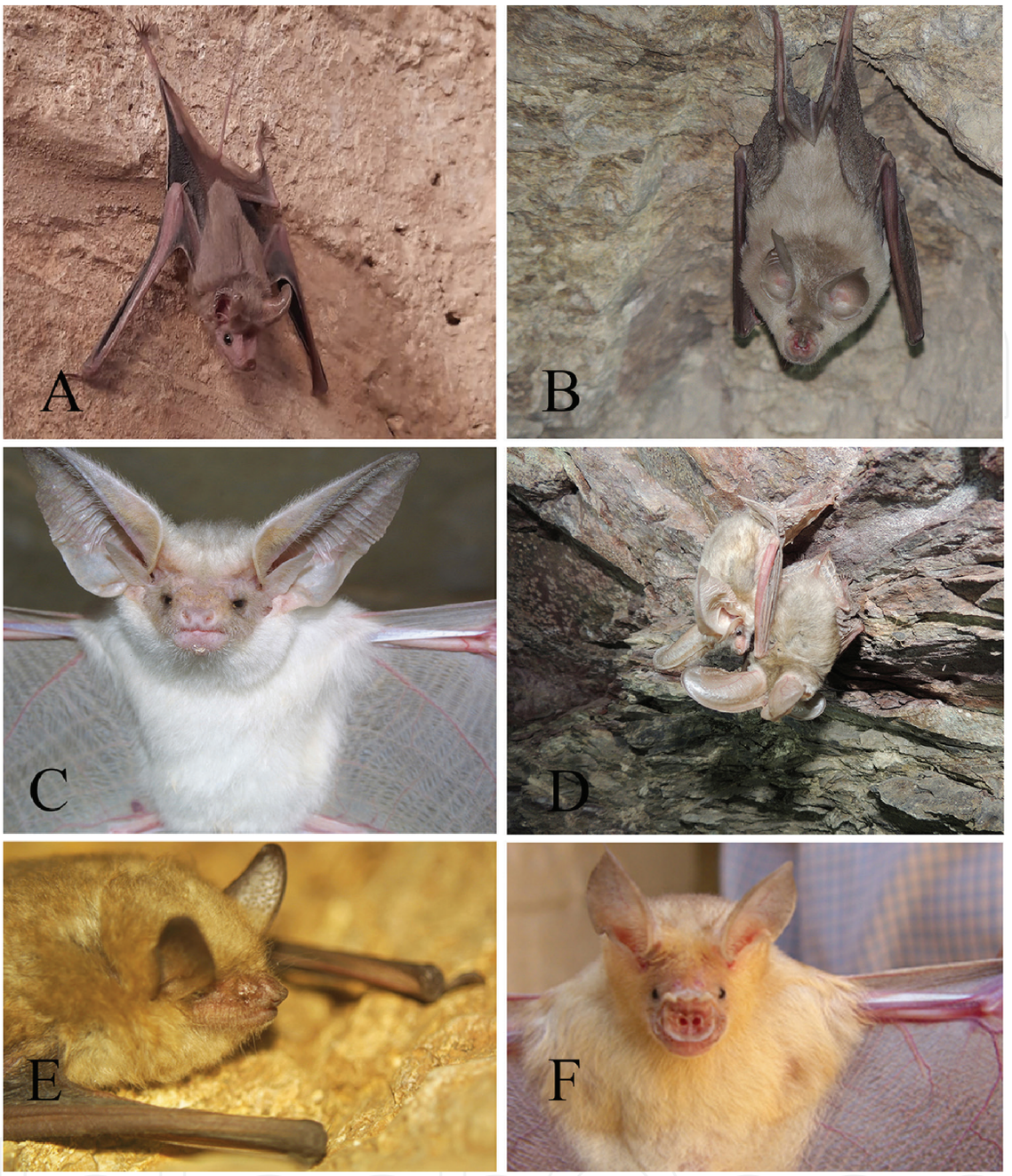

Figure 3.
(A) The lesser mouse-tailed bat, Rhinopoma cystops. (B) Geoffroy's horseshoe bat, Rhinolophus clivosus. (C) The desert long-eared bat, Otonycteris hemprichii. (D) Christie's big-eared bat, Plecotus christii. (E) The notch-eared bat, Myotis emarginatus. (F) The trident leaf-nosed bat, Asellia tridens.

part of the Rift Valley of Jordan, surrounding the Dead Sea area. They are found close to open waterbodies such as rivers and creeks [18, 20].

3.5 Family Hipposideridae

The trident leaf-nosed bat, *Asellia tridens*, is an inhabitant of extreme arid areas. It was recorded from several localities in Wadi Araba [18, 20].

3.6 Family Miniopteridae

Miniopterus pallidus is confined to the Mediterranean regions of Jordan forming a large mixed colonies with other bats [18, 20].

3.7 Family Molossidae

The European free-tailed bat, *Tadarida teniotis*, is widely distributed in Jordan. Besides its presence in mild Mediterranean areas, this species can live in extremely dry habitats in the eastern desert of Jordan [18, 20].

3.8 Family Nycteridae

The Egyptian slit-faced bat, *Nycteris thebaica*, is known from the southern parts of Jordan inhabiting barren mountainous areas overlooking the Dead Sea [18, 20].

3.9 Family Vespertilionidae

This is the most diverse family in Jordan and is presented by seven genera (*Barbastella*, *Eptesicus*, *Hypsugo*, *Myotis*, *Otonycteris*, *Pipistrellus*, and *Plecotus*) with 11 species [18, 20].

The Asian barbastelle, *Barbastella leucomelas*, was recorded from the southern regions of Jordan with the semi-arid Mediterranean and extreme desert habitats. It is considered as an endemic species to arid regions around the most northern parts of the Red Sea. Botta's serotine bat, *Eptesicus bottae*, is found in a wide range of semi-arid habitats including the semi-arid Mediterranean regions, as well as lowlands and rocky mountains. This is a crevice-dwelling species, inhabiting buildings, ruins, and natural rock crevices [18, 20].

Christie's big-eared bat, *Plecotus christii*, is a rather common species in Jordan, with distribution limited to the arid regions to the southwestern parts of the country. The desert long-eared bat, *Otonycteris hemprichii* was reported from the northeastern deserts and the arid southwestern parts of Jordan [18, 20].

Kuhl's pipistrelle, *Pipistrellus kuhlii*, is the most common species in Jordan inhabiting all biogeographical regions including the Mediterranean and semi-desert zones. It is very common in urban areas as well. The common pipistrelle, *Pipistrellus pipistrellus*, is distributed along with the western parts of the country in forested areas as well as the arid region. The desert pipistrelle, *Hypsugo ariel*, is known to occur in the arid regions around the Dead Sea basin and the Wadi Ramm desert [18, 20].

The lesser mouse-eared bat, *Myotis blythii*, is restricted to the Mediterranean region of northern Jordan. It forages in scrub and grassland habitats, including farmland and gardens. Maternity colonies are usually found in underground habitats such as caves and old mines. The long-fingered bat, *Myotis capaccinii*, was reported from one locality, Tabqat Fahl, adjacent to the Jordan Valley. The notch-eared bat, *Myotis emarginatus*, was recorded from a limited area of the Ajlun Mountains within the Mediterranean biogeographical region. Natterer's Bat, *Myotis nattereri*, was found in the northwestern forests and from mountainous habitats of the Dhana-Shawbak region in the Southern highlands [18, 20].

4. Bat echolocation calls

Bat echolocation calls for 11 bat species from Jordan are documented. **Figure 4** and **Table 1** show recorded calls and durations and frequency variables using Song meter from different localities.

Species of the genus *Rhinolophus* are characterized by calls with a long and strictly constant-frequency component (**Figure 4**). The four species studied are very distinct; whereas *Rh. ferrumequinum* has the least frequency variables (75.7 ± 4 for SF, and 77.9 ± 6.5 for EF) as compared to *Rh. clivosus*, *Rh. euryale*, and *Rh. hipposideros*

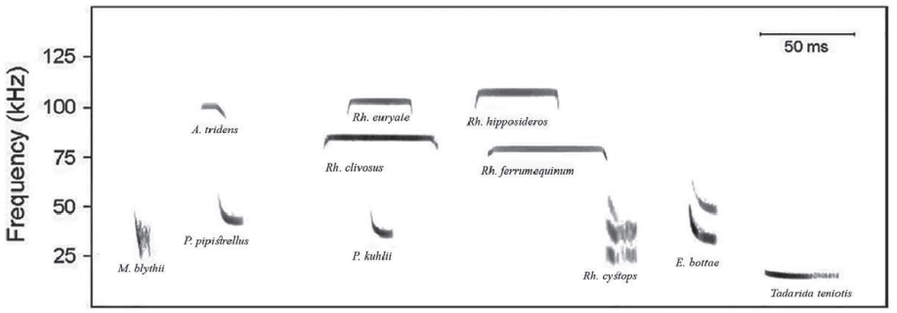

Figure 4.
Representative echolocation calls for 11 species from Jordan.

Species	No. of calls	D [ms]	SF [kHz]	EF [kHz]	PF [kHz]
Rh. clivosus	116	28.7 ± 12.3	85.8 ± 1.7	85.9 ± 1.7	86.2 ± 0.8
Rh. euryale	7	23.4 ± 15.2	105.3 ± 0.9	98.5 ± 7.4	105.8 ± 0.5
Rh. ferrumequinum	107	42 ± 10.5	75.7 ± 4	77.9 ± 6.5	82.2 ± 0.5
Rh. hipposideros	145	29.8 ± 13	107 ± 4.8	107 ± 5.1	111 ± 1.39
Rh. cystops	14	3.6 ± 2.25	35.2 ± 1.9	28.94 ± 0.9	31.2 ± 0.85
A. tridens	103	8.7 ± 3.3	115 ± 2	109 ± 6.2	116 ± 2
E. bottae	105	5.6 ± 2	38.1 ± 4	30.8 ± 1	32.6 ± 1.2
P. kuhlii	76	5.53 ± 1.57	50.5 ± 6.3	39.3 ± 2.2	40.4 ± 2.2
P. pipistrellus	130	5 ± 2	51.7 ± 5	47.9 ± 2.6	48.4 ± 2.4
M. blythii	7	2.3 ± 0.9	46.8 ± 3.5	37.2 ± 3.5	41.8 ± 3
T. teniotis	26	66 ± 1.02	20.2 ± 2.3	15.06 ± 0.12	15.2 ± 0.5

D, call duration; SF, start frequency; EF, end frequency; PF, peak frequency.

Table 1.
Echolocation calls for 11 species recorded from Jordan.

Cave	Type	Number of bat species recorded	Species observed	References
Al Hamma	Karstic	1	*R. aegyptiacus*	[7, 18]
Al Majdal	Karstic	2	*Rh. cystops*, *Rh. microphyllum*	[11]
Al Wardeh		5	*Rh. blasii*, *Rh. euryale*, *M. blythii*, *M. emarginatus*, *M. pallidus*	[18]
Al-Mahhatta	Pressure ridge	1	*R. aegyptiacus*	[1]
Ar Raddass		1	*T. nudiventris*	[18]
Arjan		2	*M. emarginatus*, *P. kuhlii*	[18]
Bir Hamma cave	Lava	1	*O. hemprichii*	[18]
Dhana village caves	Sandstone	2	*E. bottae*, *P. christii*	[18]
Dibbin Forest caves		4	*Rh. cystops*, *Rh. euryale*, *Rh. ferrumequinum*, *Rh. hipposideros*	[1, 11, 14, 18]

Cave	Type	Number of bat species recorded	Species observed	References
Iraq Al Amir	Artificial	6	*R. aegyptiacus*, *Rh. cystops*, *Rh. blasii*, *M. nattereri*, *P. kuhlii*, *T. teniotis*	[18]
Iraq Al Wahaj	Karstic	6	*R. aegyptiacus*, *Rh. blasii*, *Rh. euryale*, *M. blythii*, *M. emarginatus*, *M. nattereri*	[18]
Jabal Al Bayda	Sandstone	2	*Rh. clivosus*, *P. christii*	[18]
Jesus' cave		1	*Rh. hipposideros*	[18]
Lot's cave		1	*Rh. cystops*	[18]
Mahjub cave	Sandstone	3	*Rh. clivosus*, *M. nattereri*, *P. christii*	[18]
Malka cave	Artificial	1	*Rh. ferrumequinum*	[18]
Mgharet Issa		1	*Rh. cystops*	[18]
Mogharet Al-Roum Cave		1	*Rh. blasii*	[1]
Mukawir		1	*P. christii*	[18]
Qaraiqira cave		1	*Rh. cystops*	[11]
Tabaqat Fahl	Artificial	5	*R. aegyptiacus*, *Rh. microphyllum*, *Rh. blasii*, *Rh. ferrumequinum*, *M. capaccinii*	[14, 18]
Umm Al Iraq		1	*Rh. ferrumequinum*	[18]
Wadi Al Hasa		1	*N. thebaica*	[18]
Wadi Ben Hammad	Limestone	1	*R. aegyptiacus*	[20]
Wadi Dhana	Sandstone	1	*R. aegyptiacus*	[18]
Wadi Dharih	Karstic	1	*Rh. clivosus*	[18]
Wadi Shu'ayb		1	*Rh. cystops*	[18]
Zubiya	Karstic	6	*R. blasii*, *Rh. euryale*, *Rh. ferrumequinum*, *Rh. hipposideros*, *M. emarginatus*, *M. nattereri*	[18]

Table 2.
Important bat caves with recorded species.

(**Table 1**). *Rhinopoma cystops* exhibits two harmonics; the first around 33 kHz and the second at 32–35 kHz. The end frequency for *E. bottae* is typically between 34 and 38 kHz and 50–53 kHz; *P. kuhlii* 38–41 kHz; and *T. teniotis* 14–16 kHz [21, 22].

All of the calls are within the range of previous studies in the Middle East [21–23]. **Table 2** lists frequencies for bats recorded from the Negev desert on the opposite side of Jordan. It clearly shows that calls reported in our study are similar for most species.

5. Bat caves in Jordan

A total of 142 caves and dwelling areas suitable for bats have been mapped (**Figure 5**). Caves are classified, as lava tunnel, pressure ridge, artificial, limestone,

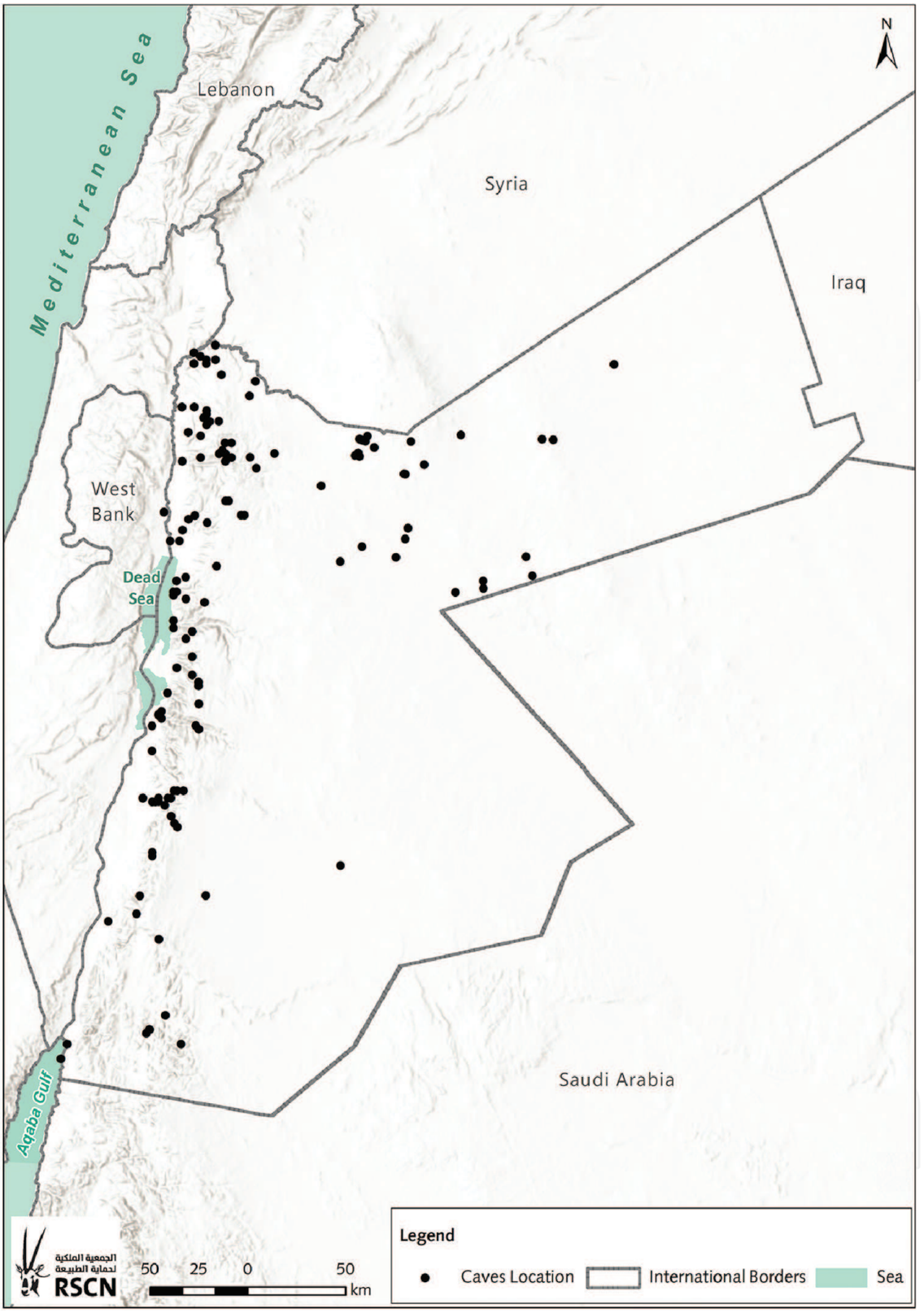

Figure 5.
Map of Jordan showing caves and other suitable bat-dwelling areas.

karstic, and sandstone caves. Most of the caves are located along the mountainous ridge extending from the north to the south on the western side of the country. Other sites include historical castles, mine-shafts, man-made tunnels, and rock crevices.

Based on previous studies over the past 30 years, the bat faunae for 28 caves are summarized in **Table 2**. The number of bat species per cave ranged from six to one, whereas Al Wardeh, Iraq Al Amir, Iraq Al Wahaj, and Zubiya caves harbored

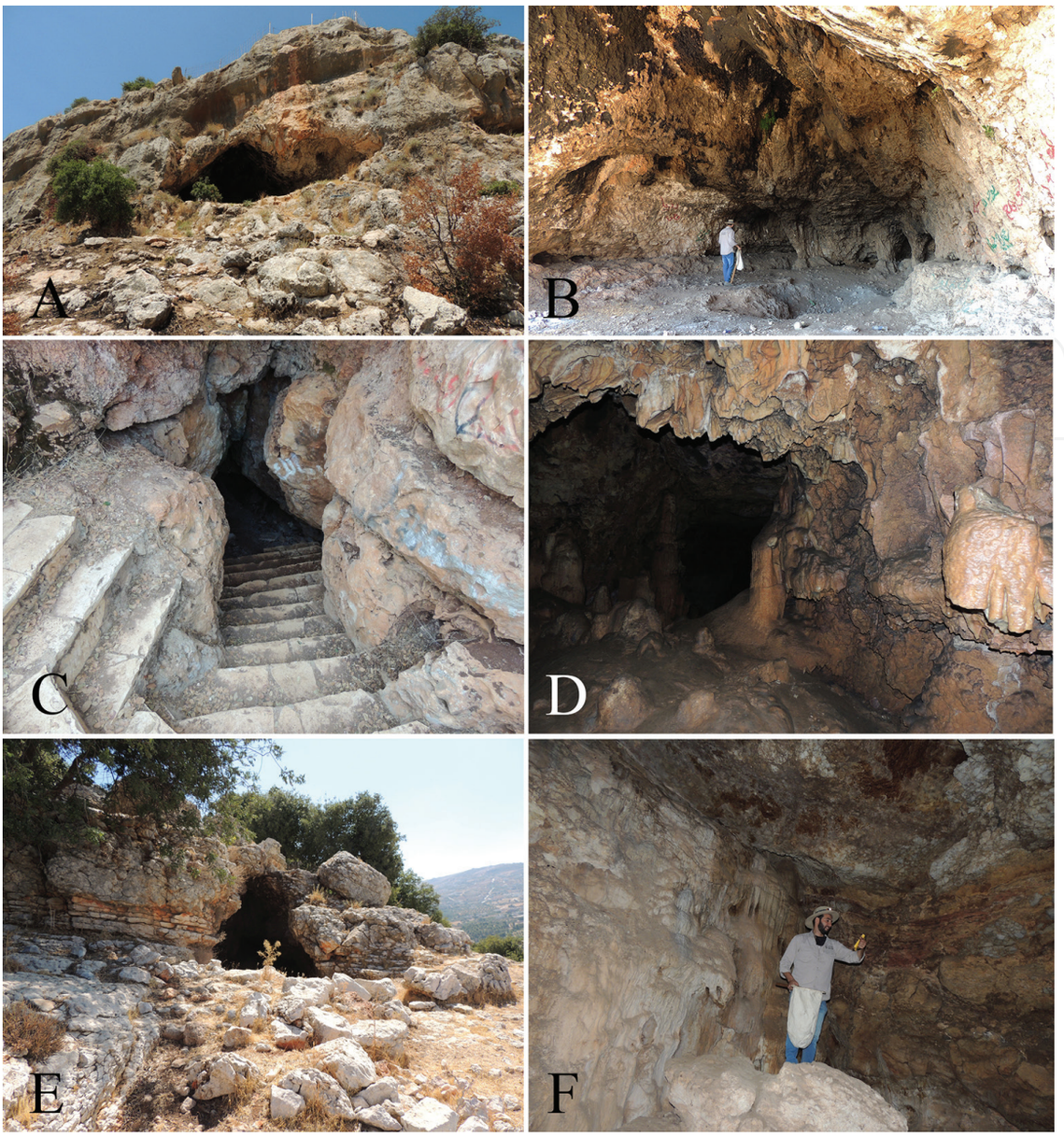

Figure 6.
Some caves in northern Jordan. (A) Arjan cave entrance. (B) Arjan cave from inside. (C) Zubiya cave entrance after development. (D) Zubiya cave from inside. (E) Iraq Al Wahaj cave entrance. (F) Iraq Al Wahaj cave from inside.

six species. It seems that cave size is related to the number of bat species recorded; Zubiya, Al Wardeh, Dibbin Forest caves, and Iraq Al Wahaj are large caves extending over 300–500 m, while smaller caves usually are inhabited by a single bat species (**Table 2**). Other bat species such as *Barbastella leucomelas* and *Pipistrellus pipistrellus* were never observed to form colonies in caves in Jordan. The same is true for the Al Wardeh cave, which was entirely destroyed due to mining activities (**Figure 6**).

Our current projects on the bats of Jordan are to study the bat fauna associated with caves and identify threats that can affect bat populations. On the other hand, a campaign to protect bat important cave areas through legislative authorities is among high-priority issues.

6. IUCN conservation status of bats in Jordan

Eid et al. [24] compiled the national red list for the mammals of Jordan. Of the 26 bat's species, one, nine, and three species were listed as critically endangered,

endangered, and near threatened, respectively (**Table 3**). At the global level, *Rhinolophus euryale* and *Myotis capaccinii* are listed as near threatened and vulnerable, respectively.

Jordan is a member of several conventions, treaties, and agreements related to the provide protection for wildlife (Convention on Biological Diversity, Convention on International Trade in Endangered Species of Wild Fauna and Flora, Treaty of Conservation of Migratory Species of Wild Animals, Convention on the Protection of Marine Pollution by Preventing the Disposal of Waste and other Materials, RAMSAR, United Nations Convention to Combat Desertification). Several national laws have been enacted at the national level. In addition, the Agriculture Law No. 13 of 2015 addresses to a large extent Jordan obligations related to the protection of wildlife under these conventions [20].

Species	Common name	National IUCN status	Global IURCN status
Rhinolophus mehelyi	Mehely's horseshoe bat	CR	VU
Rhinolophus euryale	Mediterranean horseshoe bat	EN	NT
Rhinolophus ferrumequinum	Greater horseshoe bat	EN	LC
Rhinopoma microphyllum	Greater mouse-tailed bat	EN	LC
Taphozous perforatus	Egyptian tomb bat	EN	LC
Taphozous nudiventris	Naked-rumped tomb bat	EN	LC
Nycteris thebaica	Egyptian slit-faced bat	EN	LC
Miniopterus pallidus	Pale bent-wing bat	EN	LC
Myotis blythii	Lesser mouse-eared bat	EN	LC
Myotis emarginatus	Geoffroy's bat	EN	LC
Asellia tridens	Trident leaf-nosed bat	VU	LC
Rousettus aegyptiacus	Egyptian fruit bat	NT	LC
Rhinolophus hipposideros	Lesser horseshoe bat	NT	LC
Barbastella leucomelas	Asian barbastelle	NT	LC
Myotis capaccinii	Long-fingered bat	DD	VU
Rhinolophus blasii	Blasius's horseshoe bat	LC	LC
Rhinolophus clivosus	Geoffroy's horseshoe bat	LC	LC
Rhinopoma cystops	Egyptian mouse-tailed bat	LC	LC
Tadarida teniotis	European free-tailed bat	LC	LC
Eptesicus bottae	Botta's serotine	LC	LC
Hypsugo ariel	Desert pipistrelle	LC	DD
Myotis nattereri	Natterer's bat	LC	LC
Otonycteris hemprichi	Desert long-eared bat	LC	LC
Pipistrellus kuhli	Kuhl's pipistrelle	LC	LC
Pipistrellus pipistrellus	Common pipistrelle	LC	LC
Plecotus christii	Christie's big-eared bat	LC	DD

DD, data deficient; CR, critically endangered; EN, endangered; LC, least concern; NT, near threatened; VU, vulnerable.

Table 3.
Conservation status of bats in Jordan according to the global and national IUCN red lists.

Common name	Scientific name
Egyptian Fruit Bat	*Rousettus aegyptiacus*
Long-fingered Bat	*Myotis capaccini*
Natterer's Bat	*Myotis nattereri*

Table 4.
Bats listed in appendix III of bylaw no. 43 for the year 2008.

Regulation No. Z/2 for the year 2021 regulates wildlife protection, hunting, and trade. This bylaw was issued in accordance with article No. 56, of the Agriculture Law No (13) for the year 2015. Bylaw No. 43 for the year 2008 categorized mammals and other wildlife banned from hunting according to its level of protection (**Table 4**). This bylaw was issued in accordance with article No. 56, paragraph (H) of the Agriculture Law No (13) for the year 2015. In addition, Regulation No (Z/2) for the year 2021 includes instructions of regulating the International Trade in Endangered Species of Wild Fauna and Flora under Article (56) of the Agriculture Law No (13) for the year 2015 [20].

7. Threats affecting the bats of Jordan

7.1 Deforestation

Rhinolophus blasii, *Rh. euryale*, *Rh. ferrumequinum*, *M. capaccini*, *M. emarginatus*, and *M. nattereri* are inhabitants of natural forests in northern Jordan. Clearing forests for agricultural or housing projects is one of the major threats for bat populations, whereas bats loss roosting sites and feeding areas. This is true in Ajlun and Dibbin oak and pine forests since much of these forests are under development, where the noticeable decline was observed over the past decade, especially fo *Rh. ferrumequinum* in Dibbin Nature Reserve.

7.2 Urbanization

Over the past 70 years, the population of Jordan increased 17-folds during reaching 10,320,000 by 2021. A great burden on the natural and wild habitats due to this accelerated population increase became evident with the expansion of cities, towns, and villages. Construction style using cement was by far the most important factor that affected bat populations. Previously, old houses were built using mud, wood, or stone, creating suitable habitat for bat roosting. Many of these old houses are by now demolished and replaced by modern buildings [17]. Al Mahatta cave in Amman that used to harbor a population of the Egyptian Fruit Bat is by now void of bats due to housing projects that changed its integrity.

Noise and light pollution and heavy traffic disturbed many bats populations that are sensitive to human activity. One of the most evident examples of the disturbance that affected bat habitats is the disappearance of a healthy population of *Rh. ferrumequinum* was observed in 1959 in Swialeh [25], a township close to Amman. This area was entirely disturbed due to several forms of human activities including urbanization and population increase [17].

7.3 Tourism and vacationing

Tourism and outdoor activities in wild habitats (e.g., Dibbin Forests, Wadi Ram, and Zubiya) have a direct impact on the roosting populations of bat species living in

Figure 7.
Cave destruction in Jordan. (A) Asef cave remodeled as a recreation site. (B) Arjan cave with evidence of fire to be used as an animal barn. (C) Al Wardeh cave before mining activities in 2017. (D) Al Wardeh cave after mining activities in 2020.

such habitats. For example, large colonies of *Rh. ferrumequinum* that were common in Dibbin Forests, a national park visited frequently during vacations, disappeared due to outdoor activities in this park. By now, only a few individuals were observed in small caves and shafts. Hiking and cave exploration in Wadi Ram may contribute in declining populations of *E. bottae* and *Rh. hipposideros*.

The Egyptian Fruit Bat populations declined or disappeared from several sites where it used to be in abundance. Al Hemma cave is a classic example, where it used to harbor thousands of bats [7]. By now, only a few hundreds of the fruit bats were present and continued to decline. Also, the population of the Egyptian Fruit Bat in Wadi ben Hammad is declining due to extensive tourism activities within the vicinity of this site. The Zubiya cave, one of the largest karstic caves in Jordan, whereas seven bat species were previously recorded (*Rh. blasii*, *Rh. euryale*, *Rh. ferrumequinum*, *Rh. hipposideros*, *M. emarginatus*, and *M. nattereri*), was washed with high-pressure water and was closed by a gate preventing bats to gain entrance (**Figure 6C** and **D**).

Recently, many caves were turned into restaurants and coffee shops. This was observed in Asef cave where it was remodeled as a recreation site, and all bats were exterminated (**Figure 7A**).

7.4 Mining

In recent years, mining for extraction minerals for the cement industry and rocks for buildings expanded in many parts of the country. This in turn brought many bat populations to their demise. For example, Al Wardeh cave located near Ajlun was inhabited by large colonies of *Rh. blasii*, *M. blythii*, *M. emarginatus*, and *M. pallidus*

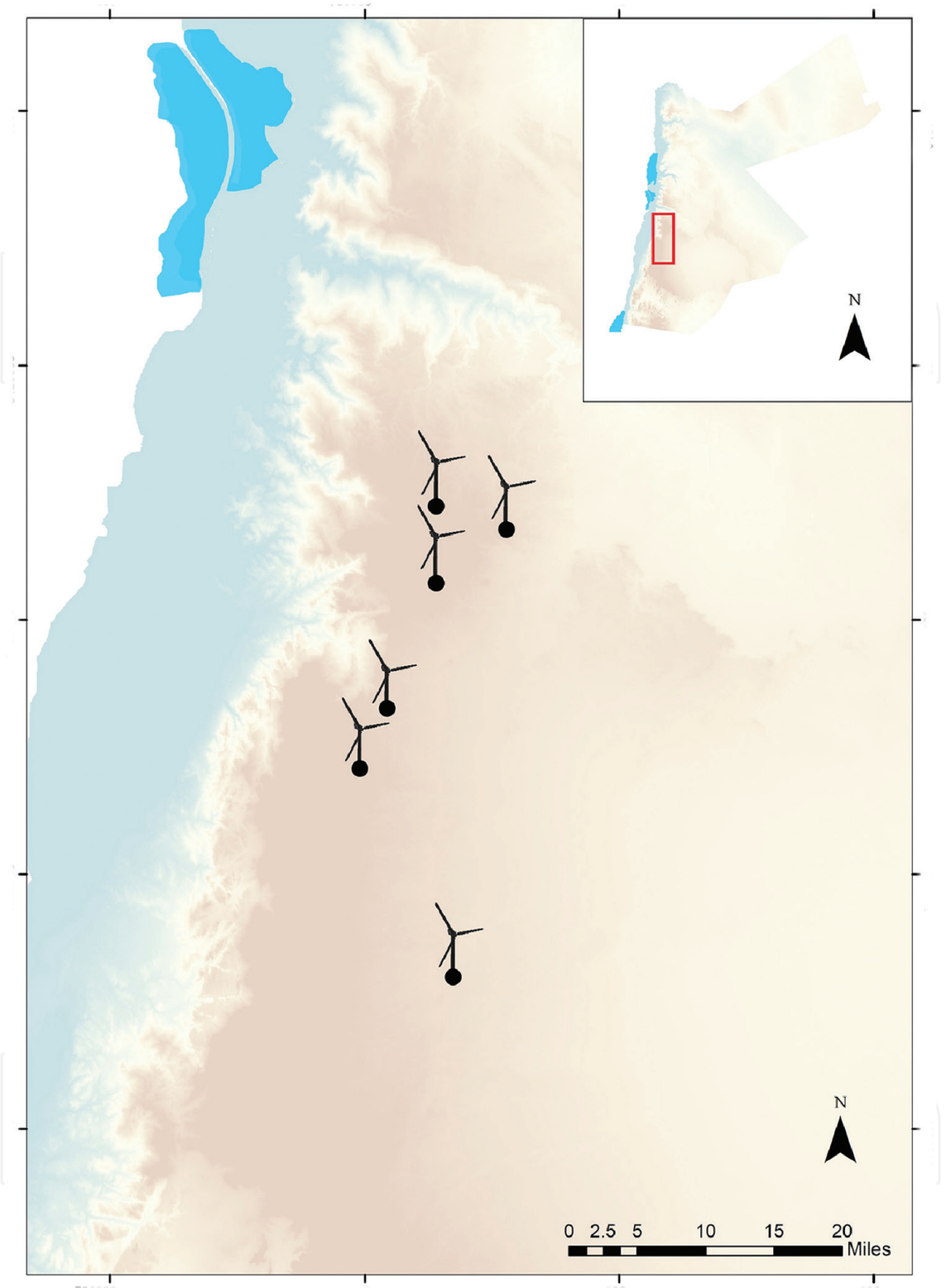

Figure 8.
Location of wind farms in southern Jordan.

for many years. We observed hundreds of bats in this cave all year round. Due to mining activity in this area in 2019, the cave is by now is destroyed and its main entrance has collapsed denying movement of bats in and out (**Figure 7C** and **D**).

Another cave used to harbor a significant population of over 500 individuals of *Rh. cystops* and *Rh. microphyllum* at Al-Majdal cave, located near Jarash, was destroyed and its entrance was closed.

Species	Species sensitivity	Eurobats level of collision risk	Likelihood of effect score	Risk rating
R. aegyptiacus	Low	Unknown	Low	Minor
Rh. blasii	Medium	Low	Negligible	Negligible
Rh. clivosus	High	Low	Negligible	Minor
A. tridens	Low	Unknown	Low	Minor
B. leucomelas	Low	Medium	Medium	Minor
H. ariel	Medium	High	High	Major
P. christii	Medium	Low	Negligible	Minor
N. thebaica	Low	Unknown	Low	Negligible

Source: IFC [26].

Table 5.
Species sensitivity, levels of collision risk, and risk rating for Wind Power Projects.

7.5 Wind power projects

In the past decade, windmills projects increased to reach up to six operational sites mostly in the southwestern part of the country, with a total of 151 turbines (**Figure 8**). Cumulative effect assessment was developed for Al Tafilah site to help in determining bat species that are at the highest risk and to identify potential mitigations and monitoring measures that should be considered by investors [26]. Eight species of bats were identified of major or moderate risk ratings (**Table 5**).

Carcasses of bats are surveyed on a monthly basis in the operational sites. We are aware of bat mortality in these sites; however, data remain undisclosed for the meantime.

7.6 Folk medicine and other practices

Bat blood is prescribed for female infants so no hair will grow under their armpits [27]. Fresh bat's blood is applied to the newborn body. This belief was adopted from the Roman culture and remained practiced by the local people in many parts of the Middle East that were under the Roman Empire, but is not practiced on a large scale.

Search for red mercury became a threat to bats in Jordan in the past 10 years. Many locals strongly believed that red mercury can be found in bat's nests. Caves and colonies in many parts of the country were disturbed in pursue of the red mercury to sell it at a high price. A campaign to educate the public that bats do not form nests through all forms of public media was undertaken.

7.7 Bats caves as animal barns

Scattered caves in the country have been used as sheep or goat's barns. Caves were sat on fire first to remove all kinds of wild animals such as snakes, scorpions, birds, and bats. This practice was observed in the caves of Jarash and Ajlun mountains (**Figure 7B**).

8. Bats and diseases in Jordan

Since the emergence of the Middle East Respiratory Syndrome Coronavirus (MERS-CoV) in Jordan in 2012 [28], health authorities and research institutes

collected blood samples from the Egyptian fruit bat, *R. aegyptiacus*, and the dromedary camels. So far, only antibodies were detected in camels in Jordan, with no active virus, with a seroprevalence rate of MERS-CoV of 81% [29]. Swaps from bats were negative and no antibodies were detected. In Lebanon, HKU9-like viruses were detected in *R. aegyptiacus*, and serum samples tested from 814 bats were negative for MERS-CoV antibodies [30].

Although human rabies is considered very rare in Jordan, six isolates of rabies were found in wild animals (badger and squirrel) and domestic animals (cow, dog, donkey, and goat) [31]. No information is available on rabies caused by bats in Jordan. Further studies should evaluate the role of zoonotic infections that could be possibly transmitted by bats.

9. Conclusion

This study shed the light on the urgent need to conserve the bats of Jordan, taking into consideration the alarming decline in bat populations observed over the past decades affecting their natural habitats. Further studies on the ecological requirements and habitat selection for the bats of Jordan are needed. Such studies will provide baseline data to implement conservation strategies for each species. Other avenues of future research include identification, both quantitatively and qualitatively, the impacts of various man-made changes and threats to the existing bat population.

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