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Bat fauna and conservation assessment of Kurdistan caves, Iran

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Abstract

The populations of cave-dwelling bat species are encountering a remarkable decline all over the world. To plan effective conservation projects for bats and their cave roosts, collecting data on their distribution in a particular region is essential. Furthermore, developing an applicable index that incorporates both biotic and abiotic parameters relevant to caves is useful to prioritize caves for conservation management. Recently, there has been a growing interest in studying bat fauna of Iran. The Kurdistan province in west of the country is entirely mountainous, having a suitable geological substratum for formation of caves. Previously, five bat species were reported from Kurdistan. The current study has improved the data by doubling the number of cave-dwelling bat species of the province. A total number of 61 records of 10 species were documented. Overall, of 28 caves studied, 26 caves were used by bats. Each cave hosted one to six bat species. To prioritize Kurdistan caves for conservation programs, the Bat Cave Vulnerability Index (BCVI) was employed for 26 caves explored in this study. Four caves, including Karaftu, Kamtaran, Darvish Ouliya, and Kouna Sham-Sham, were highlighted due to their highest BCVI value. The other 22 caves received medium or low priority values. In the current study, we provided data on the bat fauna of Kurdistan caves, in addition to evaluate their conservation priorities by applying an assessing index for the first time in the country.

Keywords

Bat, BCVI, cave, conservation priority, fauna, Kurdistan province

Introduction

Caves are considered as appropriate roosts that provide a relatively cool and stable environment for many organisms, including bats. Some bat species use caves only for hibernacula, while others dwell in caves year-round using them also as mating and nursery, as well as day roosts (McCracken 1989). Therefore, the survival of many bat species depends on the presence of natural caves (Mickleburgh et al. 2002). Protecting caves is essential for maintaining their unique biodiversity, as a large number of species are highly specialized to live only underground (Moldovan et al. 2018).

Bats are an important part of cave biodiversity and inseparable components of the cave biota. Their guano provides the main source of energy and nutrient for other cavernicolous organisms. Additionally, settling various kinds of parasites, bats in fact, carry a considerable proportion of cave biodiversity with them. Changes in bat-cave relation can accurately reflect the changes in the cave ecosystem; so, bats are used as a reliable criterion in evaluating the degree of alteration and vulnerability of caves. However, bats are exposed to many threats. Cultural attitudes and social unawareness are the main reasons why bat protection is often overlooked, particularly in Iran. Bats have the reputation of being undesirable animals in Iran. Due to plenty of pesticides use in agriculture, bat populations decrease (Karami et al. 2016). According to the results of a recent study, 24 species out of 51 bat species known from Iran are regionally vulnerable, near threatened or data deficient (Yusefi et al. 2019). Although at the global scale, only 13 out of 51 species were classified as vulnerable, near threatened, data deficient, or not evaluated (Yusefi et al. 2019). The results clearly show that we need an extra effort toward bat conservation in Iran.

A prerequisite for any cave conservation program is to have accurate data about its fauna, along with different natural characteristics including location, surface vegetation, water sources, accessibility, etc., and anthropogenic threats such as unsustainable tourism, vandalism, and various human uses. Additionally, to develop strategies for the conservation of caves and their biota, caves should be primarily prioritized using applicable indices. To design an effective and easy-to-apply index to assess cave vulnerability and importance, both biotic and abiotic affinities of caves should be considered.

Furman and Ozgul (2002) designed a simple grading system to evaluate the conservation status of caves as important roosts for bats. This scheme was developed based on bat species abundance data and their conservation status. Tanalgo et al. (2018) introduced a more comprehensive assessment that included different affinities of bat species along with cave geophysical features and human disturbance. They developed the Bat Cave Vulnerability Index (BCVI) which has been used by some other authors in their studies (Deleva and Chaverri 2018).

Since 1865, several researchers have studied the mammalian fauna of Iran including bats (De Filippi 1865; Lay 1967; Farhang Azad 1969; Karami et al. 2008, 2016; Yusefi et al. 2019). In his review of bat research in Iran until the late 1970s, DeBlase (1980) reported 375 records of 38 bat species from Iran along with useful comments on their biology and taxonomy. Benda et al. (2012) presented the most comprehensive

list of bat fauna from Iran. They documented 902 records of 50 bat species in addition to new findings of various aspects of these flying mammals' life. Furthermore, Naderi et al. (2017) added one species to the list of the bat fauna of the country, increasing the number of documented species to 51 including 20 genera from 9 families. In recent years, Iranian researchers have conducted several studies in different parts of the country and provided invaluable information about various aspects of bats' biology in Iran (Akmali et al. 2011a, 2011b, 2015; Fathipour et al. 2016; Shahabi et al. 2017a, 2017b, 2019; Akmali et al. 2019a; Mehdizadeh et al. 2019, 2020; Najafi et al. 2019a, 2019b, 2019c; Akmali 2020; Kafaei et al. 2020a, 2020b). Additionally, Yusefi et al. (2019) provided a comprehensive review of all literature published on terrestrial mammals of Iran including bats along with their latest taxonomic revisions and updated distribution ranges. Several studies on bats of Iran provided some scattered information about the chiropteran fauna of Kurdistan caves (DeBlase 1980; Hemmati 2001; Benda et al. 2012). In these surveys, the occurrence of *Rhinolophus ferrumequinum*, *R. mehelyi*, *R. euryale*, *Myotis blythii*, and *Miniopterus pallidus* was documented. This is the first study that focuses on cave-dwelling bat species from Kurdistan province. It also ranks the caves of the region using BCVI for future conservation management.

The objectives of this study are collecting information about cave-dwelling bats in Kurdistan province in order to upgrade faunal information of the country, and also to be used in future studies including conservation programs. Furthermore, we tried to use a proofed index in order to prioritize Kurdistan caves for future conservation management.

Materials and methods

Description of the Kurdistan province

Kurdistan is located in the west of Iran between 34°44'N to 36°30'N and 45°31'E to 48°16'E, and shares about 200 km of its western political border with Iraq. It neighbors Western Azerbaijan at the north, Hamadan and Zanjan at the east, and Kermanshah province at the south. The altitude range of the region varies from 900 meters in Alout region of Baneh to 3300 meters in Shahou Mountain. Kurdistan can be separated into eastern and western parts which differ in geology and topography, as well as climatic conditions. The eastern part (61% percent of the province area) has a cold and arid climate, while in the western part (39% of the province area), warm and humid climate is dominant. Here, the annual average precipitation is higher than in the eastern part. The western part also includes more forests and rangelands (Gholizadeh and Zarei 2014).

The list of caves in the province was compiled using several information sources. Cooperation was requested from the Environmental Protection Service, the Cultural Heritage and Tourism Organization, as well as other organizations such as caving and mountaineering clubs. All available literature and websites were also surveyed. A total of 28 caves were listed and scheduled for visits.

Field work and data on bat distribution

This study was carried out from 2015 to 2017. To collect information on cave-dwelling bat species in Kurdistan province, several expedition trips were taken in the region. We used direct count method for the caves with a few individuals; and photograph count and population estimation for large colonies. In each cave, a few individuals were captured with the aid of hand-nets and identified according to morphological characteristics using identification keys (DeBlase 1980; Dietz and Von Helversen 2004), then photographed, and released at the same location. The geographical position and altitude of each cave were recorded by Garmin GPS unit (GPSMAP 60CSx; Garmin International, Inc., Olathe, Kansas, USA).

The distribution map of each bat species was drawn by ArcGIS software version 10.2 (ESRI, 2013), using the coordinates obtained during the field work.

Assessing cave conservation vulnerability

Data on cave geophysical characteristics and human activities were obtained from our direct observation during field works. Accessibility to the cave sites, cave openings, and effort of exploration in the caves were determined by direct observation, experience, and comparison of different caves. Data about tourism activity, cave use, and Land-use change activities within cave vicinity were gathered from direct observation, local people and, tourism companies. All the information was listed; each parameter was separately scored for each cave in comparison with other caves.

We used the Bat Cave Vulnerability Index (**BCVI**) proposed by Tanalgo et al. (2018) to measure the conservation priorities of Kurdistan caves. The index has two components including Biotic Potential (**BP**) and Biotic Vulnerability (**BV**) which are separately calculated. The final value which is represented as an alphanumeric index is a combination of the scores from both components for each cave. BP and BV are calculated in different ways. Based on our data sources, we calculated the value of each component and then scored them according to Tanalgo et al. (2018).

BP value for each cave is the sum of the computed scores for individual bat species, multiplied by total species richness. The numeric values of abundance, relative abundance, endemism, and conservation status, and species-site commonness of bat species are the basis of this assessment

Species richness is the number of bat species per cave, using information from our field work.

Species abundance is the number of individuals of each species per cave.

Species relative abundance was calculated using the number of individuals of each species in a specific cave dividing by average abundance of that species from all caves where the species was observed.

Species-site commonness is a value for determining the rarity of species. This parameter is calculated using the formula below:

"The number of all caves assessed in the study/ frequency of the species occurrence", where the frequency means the number of caves that a specific species was observed.

Determining the endemism and conservation status of each species were done by using the latest information from the International Union for the Conservation of Nature (IUCN) Red List (www.iucnredlist.org). Each category then was translated to a score according to the scoring system as in Tanalgo et al. (2018). In this system, widespread, regional endemism, country endemism and restricted or data deficient are given 2, 3, 4 and 5 scores, respectively. Also, least concern, least concern with decreasing population, near threatened, vulnerable, and endangered are given 2, 3, 4 and 5 scores, respectively. Score 6 goes to critically endangered, near extinction, and data deficient species (Tanalgo et al. 2018). After listing all the scores, we applied the formula proposed by Tanalgo et al. (2018).

BV value is obtained by scoring the geophysical and anthropogenic status of the caves. Geophysical and anthropogenic characteristics include six parameters as shown in Table 5. Accessibility to cave sites, cave openings, the effort of exploration, tourism activity, cave use, and Land-use change activities within cave vicinity are the six parameters that are considered in the study.

Calculating BCVI values

The next step is to combine BP and BV indices to construct BCVI values. As shown in Fig. 1 adopted from Tanalgo et al. (2018), 16 possible ranks are derived by combining the BP and BV values, which are categorized under three levels of priority: high, moderate, and low.

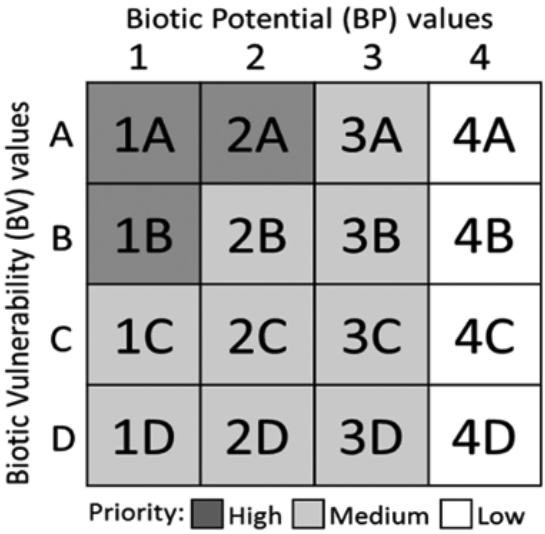

Figure 1. 16 possible alphanumerical BCVI values resulted from a combination of BP and BV scores. Cave priorities are categorized into three groups: High priority, medium priority, and Low priority.

Results

New bat records from inventories in 2015–2017

From 28 explored caves, all but two caves (Div Zendan and Kani Gureh) were occupied with at least one bat species (Tables 1; Suppl. material 1: Fig. S1). Six caves with one species, ten caves with two, six caves harboring three species, two caves with four species, as well as one cave with five and another one with six species were recorded (Table 2).

Overall, 10 bat species belonging to four families were documented in the region under study (Tables 1, 2). Furthermore, in two caves including Davazdah Emam and Golestaneh, unidentified rhinolophid bats were observed that we refer them to *Rhinolophus* sp. (Tables 1, 2).

Table 1. The list of 28 caves investigated in Kurdistan Province, with closest town and geographic coordinates of the cave entrances. If a bat was recorded, a plus sign is given. Species names are coded with numbers: 1 – *Rhinolophus ferrumequinum*, 2 – *R. mehelyi*, 3 – *R. euryale*, 4 – *R. blasii*, 5 – *R. hipposideros*, 6 – *Myotis blythii*, 7 – *M. emarginatus*, 8 – *Plecotus macrobullaris*, 9 – *Miniopterus pallidus*, 10 – *Tadarida teniotis*, 11 – *Rhinolophus* sp. The total number of species is given in the last column.

No.	Cave name	Town	Coordinates	1	2	3	4	5	6	7	8	9	10	11	Total	Date of observation
1	Sayel Mayel	Bijar	36°00'27"N, 47°35'03"E	+	+	+				+					4	7,7,2016
2	Salavat Abad	Bijar	36°00'58"N, 47°34'53"E	+											1	10,5,2016
3	Soltan Abad	Bijar	36°19'27"N, 47°26'47"E						+			+			2	21,7,2016
4	Zaqeh Rash	Bijar	36°10'15"N, 47°36'47"E						+			+			2	22,7,2016
5	Zaqeh Tarik	Bijar	35°47'23"N, 47°29'24"E			+			+			+			3	17,5,2017
6	Davazdah Emam	Bijar	35°48'20"N, 47°26'48"E									+		+	2	17,5,2017
7	KaniRahman Qiseh	Bijar	35°55'15"N, 47°28'51"E	+							+				2	26,5,2017
8	Gar Emam	Bijar	35°57'53"N, 47°33'23"E									+			1	23,7,2016
9	Kamtaran	Bijar	36°00'12" N, 47°34'54"E	+	+	+	+		+			+			6	2,8,2016
10	Garchang Siyah	Bijar	36°00'31"N, 47°32'44"E										+		1	5,9,2016
11	Seyyed Bolqaa	Bijar	36°01'01"N, 47°40'03"E	+					+	+		+			4	20,5,2017
12	Posht-e Darband	Bijar	36°00'39"N, 47°35'39"E	+	+										2	25,5,2017
13	Nesar	Bijar	35°52'26"N, 47°33'49"E									+			1	26,5,2017
14	Golestaneh	Bijar	35°54'53"N, 47°54'53"E									+		+	2	14,6,2015
15	Div Zendan	Qorveh	35°07'52"N, 47°42'34"E												0	16,11,2016
16	Farhad Tash	Qorveh	35°01'17"N, 47°08'00"E						+			+			2	23,5,2017
17	Charmeh Savar	Qorveh	35°33'08"N, 47°48'13"E	+					+			+			3	24,5,2017
18	Mohammad Saleh	Qorveh	35°33'45"N, 47°47'07"E	+											1	24,5,2017
19	Zaqeh Guri	Qorveh	35°07'44"N, 47°35'41"E	+					+						2	23,5,2017
20	Kulava	Qorveh	35°09'23"N, 47°46'22"E						+			+			2	27,5,2017
21	Kani Gureh	Dehgolan	35°26'12"N, 47°33'01"E												0	15,11,2016
22	Samangan	Divan Dareh	36°07'47"N, 47°03'11"E	+											1	12,6,2015
23	Tarik	Divan Dareh	36°07'01"N, 47°05'07"E		+						+	+			3	13,6,2015
24	Tarik 2	Divan Dareh	36°07'06"N, 47°05'15"E		+							+			2	13,6,2015
25	Karaftu	Divan Dareh	36°19'08"N, 46°52'06"E	+	+			+	+			+			5	16,6,2015
26	Shouvi	Baneh	36°00'18"N, 45°53'45"E			+	+		+						3	16,6,2015
27	Darvish Ouliya	Marivan	35°37'14"N, 46°37'59"E		+		+		+						3	10,5,2016
28	Kouna Sham- Sham	Sanandaj	35°41'10"N, 46°26'36"E	+					+			+			3	11,5,2016

Table 2. The number of caves for each species, as well as their altitudinal ranges and observation time.

No.	Species	Number of caves	Altitudinal range (m)	Observation time
1	*Rhinolophus ferrumequinum*	12	1621–2249	Spring and summer
2	*R. mehelyi*	7	1621–2160	Spring and summer
3	*R. euryale*	4	1642–2013	Spring and summer
4	*R. blasii*	3	1804–2160	Spring and summer
5	*R. hipposideros*	1	2000	Spring
6	*Myotis blythii*	13	1626–2263	Spring and summer
7	*M. emarginatus*	2	1626–1642	Summer and autumn
8	*Plecotus macrobullaris*	2	1915–2176	Spring and summer
9	*Miniopterus pallidus*	16	1626–2348	Spring and summer
10	*Tadarida teniotis*	1	1666	Summer
11	*Rhinolophus* sp.	2	1810–1959	Spring and summer

Table 3. Composition of the bat fauna of Kurdistan province and the number of records for each species based on Benda et al. (2012) compared with the new records from the current study.

Family	Species	Benda et al. (2012)	The current study	Total records for Kurdistan	Total records for Iran based on Yusefi et al. (2019) and Akmali et al. (2019a)
Rhinolophidae	*Rhinolophus ferrumequinum*	2	12	14	111
	Rhinolophus hipposideros	0	1	1	55
	Rhinolophus euryale	2	4	6	28
	Rhinolophus mehelyi	4	7	11	18
	Rhinolophus blasii	0	3	3	38
Vespertilionidae	*Myotis blythii*	9	13	22	150
	Myotis emarginatus	0	2	2	23
	Plecotus macrobullaris	0	2	2	14
Molossidae	*Tadarida teniotis*	0	1	1	26
Miniopteridae	*Miniopterus pallidus*	8	16	24	76
Total		25	61	86	539

The most widespread species was *Miniopterus pallidus* which was observed in 16 caves (Tables 1, 2; Suppl. material 1: Figs S1, S2). *R. hipposideros* and *T. teniotis* have the lowest distribution ranges, each occurring only in one cave. The largest colonies belong to *M. pallidus* and *Myotis blythii*. Besides, *T. teniotis*, and *P. macrobullaris* have the smallest population size with two individuals observed for each species

In Table 3, we give overview of records for each species for Kurdistan region before our study, and information on increase in number of records, as result of our investigations.

Identifying priority caves for bat conservation

The results from the calculations of BCVI for 26 caves are shown in Table 5. Population size and species richness are also given for each cave. Information about endemicity and conservation status of each species and their scoring are presented in Table 4.

Table 5 summarizes all the scores and calculated BP, BV scores and the resulting BCVI index values.

Table 4. Endemism and conservation status and scores for each species observed in Kurdistan caves. Score number follows the methodology in Tanalgo et al. 2018.

No.	Species	Endemism	Score	Conservation status	Score
1	*Rhinolophus ferrumequinum*	Regional endemic	3	Least concern with decreasing population	3
2	*Rhinolophus hipposideros*	Regional endemic	3	Least concern with decreasing population	3
3	*Rhinolophus euryale*	Regional endemic	3	Near threatened	3
4	*Rhinolophus mehelyi*	Regional endemic	3	Vulnerable	4
5	*Rhinolophus blasii*	Regional endemic	3	Least concern with decreasing population	3
6	*Myotis blythii*	Regional endemic	3	Least concern with decreasing population	3
7	*Myotis emarginatus*	Regional endemic	3	Least concern	2
8	*Plecotus macrobullaris*	Regional endemic	3	Least concern with decreasing population	3
9	*Tadarida teniotis*	Regional endemic	3	Least concern	2
10	*Miniopterus pallidus*	Regional endemic	3	Near threatened	3

Table 5. BCVI values and total BCVI scores for Kurdistan caves. Geophysical and human activity features are classified as below: 1 – Accessibility to cave sites, 2 – Cave openings, 3 – Effort of exploration, 4 – Tourism Activity, 5 – Cave use, 6 – Land-use change activities within cave vicinity. Scores follow the methods in Tanaglo et al. 2018.

No.	cave	Estimated population	Species richness	BP Score	BP Index	Geophysical and human activity features						BV Score	BV Index	Total BCVI Value
						1	2	3	4	5	6			
1	Sayel Mayel	134	4	18787.60	4	2	1	2	2	4	2	2.16	B	4B
2	Salavat Abad	20	1	134.48	4	2	1	2	4	4	3	2.66	B	4B
3	Soltan Abad	500	2	23742.72	3	2	2	2	3	4	3	2.66	B	3B
4	Zaqeh Rash	30	2	111.11	4	2	1	2	3	4	3	2.5	B	4B
5	Zaqeh Tarik	20	3	170.19	4	2	2	2	4	4	2	2.66	B	4B
6	Davazdah Emam	2	2	0.49	4	2	2	2	4	4	2	2.66	B	4B
7	Kani Rahman Qiseh	7	2	16.54	4	2	1	1	4	4	2	2.33	B	4B
8	Gar Emam	1	1	0.11	4	2	2	2	4	4	2	2.66	B	4B
9	Kamtaran	850	6	229986.90	1	2	1	2	2	3	3	2.16	B	1B
10	Garchang Siyah	2	1	348	4	1	2	1	3	4	2	2.16	B	4B
11	Seyyed Bolqaa	500	4	70054.60	2	2	3	3	4	4	3	3.16	C	2B
12	Posht-e Darband	5	2	11.47	4	2	2	2	4	4	3	2.83	B	4B
13	Nesar	2	1	0.48	4	1	1	2	3	4	3	2.33	B	4B
14	Golestaneh	101	2	1254.30	4	2	3	3	3	4	3	3	C	4B
15	Farhad Tash	30	2	111.10	4	2	3	2	4	4	3	3	C	4C
16	Charmeh Savar	30	3	140.90	4	2	1	1	4	4	3	2.5	B	4B
17	Mohammad Saleh	3	1	3.05	4	2	1	1	4	4	3	2.5	B	4B
18	Zaqeh Guri	30	2	201.90	4	2	1	2	4	4	3	2.66	B	4B
19	Kulava	15	2	28.68	4	1	2	2	4	4	3	2.66	B	4B
20	Samangan	2	1	1.34	4	2	3	2	4	4	3	3	C	4C
21	Tarik	111	3	4603.93	4	2	1	1	4	3	4	2.5	B	4B
22	Tarik 2	470	2	57741.39	3	2	1	1	4	4	4	2.66	B	3B
23	Karaftu	1150	5	427904.73	1	2	2	2	1	4	4	2.5	B	1B
24	Shouvi	185	3	10199.94	4	2	2	2	4	4	2	2.66	B	4B
25	Darvish Ouliya	770	3	187896.72	1	2	2	2	3	3	3	2.5	B	1B
26	Kouna Sham-Sham	1200	3	144332.28	1	2	1	2	2	3	3	2.16	B	1B

Four caves including Kamtaran, Karaftu, Darvish Ouliya, and Kouna Sham-Sham (Fig. 2) received the highest priority getting a 1B value. All these caves were the most populous in this study (with 770–1200 estimated individuals). Species richness of

these four caves varies from 3 to 6. All of them are easily accessible and the entrances are rather easy to pass with minimum obstacles inside them. Three caves including Soltan Abad and Tarik2 (3B), and Seyyed Bolqaa (2C) are moderately vulnerable. In these three caves, no or minimum sign of cave use, tourism, and land-use change activities were observed. About 500 individuals were counted in each of these three caves at the time of the investigation. The remaining 19 caves get 4B or 4C values which are commented to have the lowest priority. Although bat diversity of these 19 caves ranges from one to four species, only 30 or fewer individuals were counted in 15 of them. It is concluded that population size is the most effective parameter in computing the final BCVI value for studied caves in Kurdistan province. For example, both Sayel Mayel and Seyyed Bolqaa caves harbor four bat species, but the former with 134 individuals is classified as low, and the latter with 500 shows the moderate priority. Additionally, Shouvi with 185 and Kouna Sham-Sham with 1200 individuals get low and high priority index, respectively. Both are the same in term of their bat diversity.

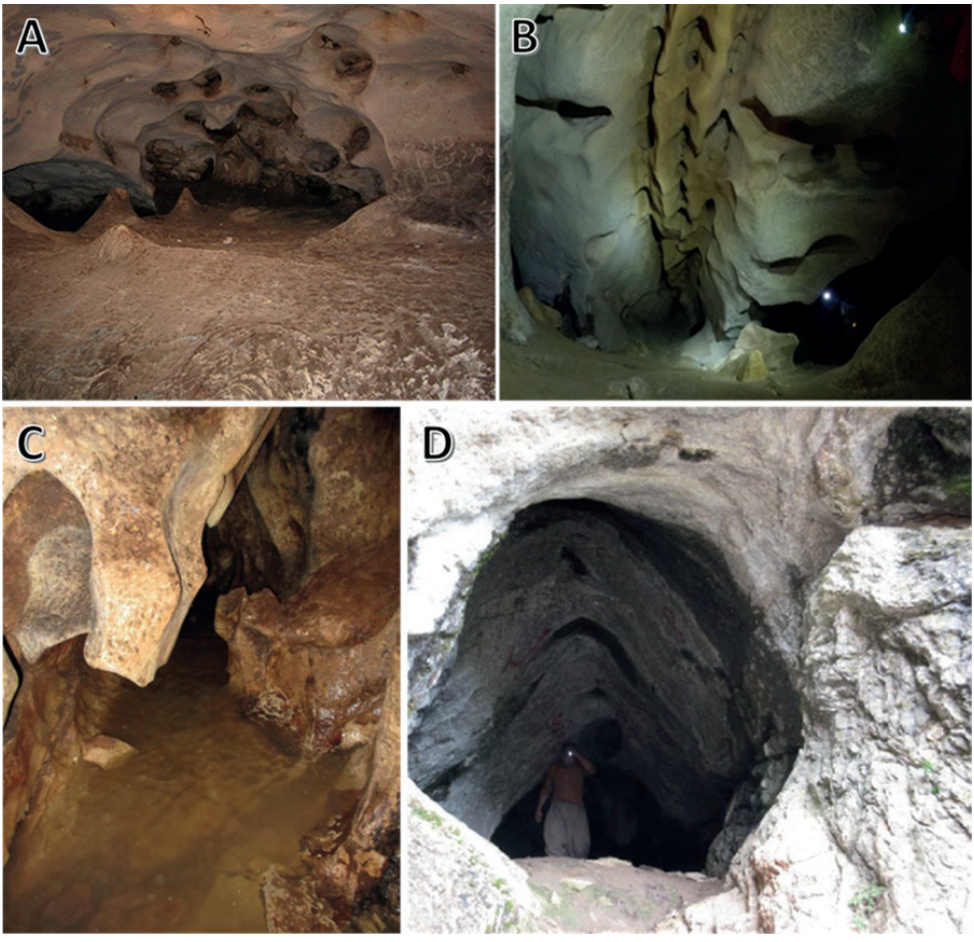

Figure 2. Four caves of Kurdistan with the highest priority for conservation programs: **A** Karaftu **B** Kamtaran **C** Darvish Ouliya **D** Kouna Sham-Sham.

Discussion

Improved knowledge on bat species in the Kurdistan region

Our study increased the number of bat species in Kurdistan to 10. This study demonstrates that the species richness of the region is much higher than previously assumed, and it raises the respective number to 10 species. Out of this number, three species are globally in decline.

So far, up to 1311 bat records have been documented in Iran (Akmali et al. 2019a; Yusefi et al. 2019), from which 25 records refer to Kurdistan province (Benda et al. 2012). The results of the current study upgrade the respective number of Iran to 1372 records. Also, the records of Kurdistan reach 86 which shows the province covers approximately 16 percent of the whole country records on bats.

Only five bat species were recorded in previous studies from Kurdistan province.

Overview of species with comments on distribution and conservation

The identified species represent five genera from four Families and are listed as below:

Family Rhinolophidae Gray, 1825

Rhinolophus ferrumequinum (Schreber, 1774)

The greater horseshoe bat occurs in 12 caves. The abundance of this bat ranges from two to many individuals in mixed colonies. Previously, Benda et al. (2012) had reported this species from Karaftu cave in Divan Dareh. Akmali et al. (2011b) have also observed this species in Karaftu cave.

Rhinolophus mehelyi Matschie, 1901

The Mehely's horseshoe bat, was observed in seven caves. It occurs in different numbers; from a few individuals to small or big colonies mixed with other species. There are several previous reports on the occurrence of this species in Kurdistan caves. In August 1968, DeBlase (1980) reported a huge colony of 30000 individuals mix of *R. mehelyi*, *Myotis blythii* and *Miniopterus pallidus* in Tarik cave, from which 12000 were estimated to be *R. mehelyi*. Tarik cave is one of the caves that was studied in the current work, but a noticeable decline in its bat population was obvious. Furthermore, Hemmati (2001) has recorded a nursery colony in Aftabi cave, one male in zivieh cave, and three male individuals in Karaftu cave.

Rhinolophus euryale Blasius, 1853

The Mediterranean horseshoe bat occurs widely throughout the Zagros Mountain ranges. Previously, DeBlase (1980) had reported this bat from a religious shrine near

Bijar. Additionally, Benda et al. (2012) observed one female individual in Sanandaj, west of Kurdistan. In the current study, *R. euryale* was observed in more caves, where it co-occurs with other species.

Rhinolophus hipposideros (Borkhausen, 1797)

This is the first report on the occurrence of the lesser horseshoe bat in Kurdistan. According to the literature, this species occurs in three adjacent provinces of Kurdistan including Azarbaijan-e Gharbi, Kermanshah and Zanjan (Benda et al. 2012).

Rhinolophus blasii Peters, 1866

There was no previous record of Blasius's horseshoe bat in Kurdistan province (Benda et al. 2012). Although *R. blasii* is one of the most widespread bat species in Iran, it is not widely distributed in the westernmost parts of the country. In this study, *R. blasii* was identified in large colonies co-occurring with other species.

Family Vespertilionidae Gray, 1821

Myotis blythii (Tomes, 1857)

The lesser mouse-eared bat is a very common bat in Iran. It is widely distributed across the mountainous parts of the country in the north, west and south-west (Benda et al. 2012). DeBlase (1980) has documented the observation of three males in a cave north-east of Bijar; and 30 individuals in Karaftu cave, Divan Dareh. Furthermore, Hemmati (2001) has collected nine males from this cave. Observation of three individuals was also reported from Karaftu cave (Benda et al. 2012). From the largest aggregation of *M. blythii* in Iran including 12000 individuals, DeBlase (1980) collected and examined about 300 in Tarik (Gara Tarik) cave, Divan Dareh. Also, Hemmati (2001) visited this cave and collected three males and four females of this species. The same author has recorded four males and five females from a possible nursery roost in Zivieh cave, 40 km away from east of Saqqez in the north-west of the province. Finally, DeBlase (1980) has reported 20 *M. blythii* specimens from a mosque dome in Sanandaj, west of the province.

In this study, *M. blythii* was recorded from 13 caves. Simultaneous occurrence of this species and *Miniopterus pallidus* is evident in 10 out 13 caves in which mixed colonies comprises 10 to hundreds of individuals. There is no cave where the *M. blythii* species occurs solely.

Myotis emarginatus (Geoffroy, 1806)

This is the first report of Geoffroy's bat from Kurdistan province. Previous records from Iran shows that, this species occurs in very different climatic zones, from Caspian

coastal plain to south-easternmost region of the east-Baluchestani mountain ranges. Akmali et al. (2011b) and DeBlase (1980) have reported this species from Kermanshah province, the western neighbor of Kurdistan.

Plecotus macrobullaris Kuzâkin, 1965

This is the first report on the occurrence of Alpine Long-eared bat from Kurdistan; although, it was recorded in three adjacent provinces including Azabaijan-e Gharbi, Zanjan and Hamadan (DeBlase 1980; Benda et al. 2004; Juste et al. 2004; Spitzenberger et al. 2006; Hemmati 2009). Totally, the records on this species are confined to western half of the country. In this study, the observation of two individuals of *P. macrobullaris* from two separate caves was documented.

Family Miniopteridae Dobson, 1875

Miniopterus pallidus Thomas, 1907

Pale Bent-winged Bat is a common bat species in Iran. There are several records on the occurrence of this species in Kurdistan province. DeBlase (1980) has observed a colony of 5500 individuals in Tarik cave. The same author has also reported 25 individuals from Karaftu cave, Divan Dareh. Hemmati (2001) visited this cave and reported 12 male individuals of M. pallidus. Furthermore, Karatas et al. (2008) and Furman et al. (2009, 2010), each collected two individuals from their roost in Karaftu cave. Also, Benda et al. (2012) have reported on the observation of 100 individuals in torpor from the same cave. It's confirmed that Karaftu cave is used by *M. pallidus* as a roost year-round; and this bat has occurred continually over long periods in this cave. In their study, Akmali et al. (2011b) have documented the occurrence of this species in Zivieh cave, Saqqez. One female individual was also collected from Aftabi cave (Hemmati 2001).

In the current study, *M. pallidus* was found to be the most widespread cave-dwelling species throughout the east Kurdistan, occurring in 16 caves. Its population size differs from a few individuals to large colonies, either solely or mixed with other species.

Family Molossidae

Tadarida teniotis (Rafinesque, 1814)

European Free-tailed bat, *Tadarida teniotis*, is recorded for the first time from Kurdistan. Two individuals were collected from one cave. Excluding the record of echolocation calls from five foraging individuals in Kermanshah (Benda et al. 2012), there is no previous report on the occurrence of this species in Kurdistan and its neighbor provinces.

Rhinolophus mehelyi is categorized as vulnerable (VU) both regionally and globally. Compared with previous reports on this species, a noticeable decline in the population of *R. mehelyi* is obvious in the region under study.

Miniopterus pallidus is the other species that is globally known as near threatened (NT). In the country, this species is classified as VU. In the current study, *M. pallidus* showed a wide distribution range occurring in 16 species and an altitudinal preference from 1626 to 2348 m.

Such extensive occurrence ranges proofs that the caves of Iran, especially those in the Kurdistan region can be utilized as long-term colonization sites and permanent roosts by different bat species. Nevertheless, effective conservation strategies should be adopted to protect them and their biodiversity. A good example is Tarik Cave where DeBlase (1980) observed several thousand bats in a mixed colony of *Rhinolophus mehelyi*, *Myotis blythii*, and *Miniopterus pallidus.*

Rhinolophus euryale is another species that is ranked as NT according to the global IUCN. However, this species is classified in the Least Concern (LC) category in Iran. Reversely, *Rhinplophus hipposideros* and *R. ferrumequinum* which are known as VU in Iran are globally categorized as LC.

Such data can be used to prioritize bat species and consequently, their roost sites in conservation management. This study showed that four species including *Rhinolophus mehelyi*, *R. hipposideros*, *R. ferrumequinum*, and *Miniopterus pallidus* should be considered as a priority. Consequently, the caves that harbor the majority of these threatened species should receive particular attention in any conservation effort. To support this assumption, we conducted a prioritization analysis using the Bat Cave Vulnerability Index (BCVI).

Prioritization of caves according to BCVI values

Only five from 16 possible BCVI values (Tanalgo et al 2018) were obtained for Kurdistan caves. It shows that, regardless high variation in population size (from 1 to 1200 individuals), and diversity (1 to 6 species) per cave, BCVI couldn't adequately categorize Kurdistan caves and more specified parameters are essential for a particular region. In a holistic assessment, all BV parameters get the same weight; so, two caves with similar BV scores do not necessarily have equal conservation importance. As developers of BCVI commented, the parameters should be modified in particular conservation programs with different purposes (Tanalgo et al. 2018). This means that we may manipulate the BV criteria according to our conservation strategy.

Another point is, as some species have different global and regional IUCN statuses (Yusefi et al. 2019), the regional conservation status should also be considered in our assessment if we want to have more accurate results for a particular country.

Karaftu cave is the only cave whose bat fauna contains all four species and this is considered a priority in this study. This cave is one of the longest caves in the region and is divided into two parts: the artificial part and the natural part. A permanent water source exists in the cave and many passages are branched from this four-floored cave. This cave was one of the main summer roosts for bat species in the past (DeBlase 1980). With a bat fauna including five species, this cave deserves to be treated as a hotspot for bats. Another cave that has the highest species richness in the province is Kamtaran

Cave. Besides, some fossil remnants which resemble prehistoric creatures were observed on the floor and roof of this cave. It is one of the main roosts of bats and should be considered a hot spot for them and receive immediate conservational attention. Darvish Ouliya is one of the main roosts for *R. blasii* which is considered a rare species over the region. A water stream is running on the floor finding its way outside the cave. The largest mixed colony is observed in Kouna Sham-Sham with 1200 individuals. This cave is also one of the largest caves with three entrances and numerous inner branches.

Conclusion

This study improved the information on cave dwelling bats and their roosts in Kurdistan province. Although BCVI is a relatively efficient index to prioritize caves, some modifications can be included. Regional IUCN categorization may differ from global IUCN; therefore, it is important to consider it in our assessments. Another important issue is the type of roost in each cave. It is better to score caves according to the particular use by bats. For example, a cave with nursery colonies can be scored higher than a cave with transient roosts. This index could not effectively categorize the caves with low conservation priorities; therefore, we think more than four levels of grading for BC and BV values are needed. Seasonal monitoring of bat populations is also important, since the population size is the most determining parameter in this index. Finally, we suggest designing a more comprehensive index for the caves of Iran in future studies.

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Supplementary material 1

Figures S1, S2

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Data type: images

Explanation note: Figure S1. The geographical location of Kurdistan Province in the west of Iran and 28 caves investigated in the study area. Numbers refer to caves as indicated in Table 1. Figure S2. Separate distribution maps for each bat species with their site numbers.

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