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Cave Dwelling Bat Species and their Cave Preferences in Northwest of Central Anatolia

Emre Barlas[1] and Elif Yamaç[2,*]

[1]*Department of Biology, Graduate School of Sciences, Anadolu University, Eskişehir, Turkey*

[2]*Department of Biology, Faculty of Sciences, Eskişehir Technical University, Eskişehir, Turkey*

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ABSTRACT

Many of the cave-dwelling bat species are under threat, because of destruction of caves such as filling or converting for other uses, human disturbance and loss of foraging habitats. In this study, cave-dwelling bat species and habitat preferences were investigated in Northwest of Central Anatolia in spring, summer and winter. Investigations were performed in 26 caves hosting (15) and not hosting (11) bats. Temperature, humidity, length of caves, distance to nearest settlement, paved road, water source, agricultural area; height, width and orientation of cave entrance and activity of cave values were determined. Seven out of 10 recorded bat species were evaluated as new records for the area. There was a significant preference for caves which were situated at lower altitude, far from paved road and close to water source. Bats were mostly found in longer caves. Caves with entrance oriented to northwest and southeast were preferred by bats. Undertaking effective conservation measures to maintain especially eight threatened bat species which were found in the region should be a priority for conservation management plans.

INTRODUCTION

Because of its different habitat types and climatic conditions, Anatolia hosts a huge number of plant and animal species. This area was a refugium for many temperate species during the last glacial maximum and thereafter a source for expanding populations (Bilgin *et al*., 2009; Fritz *et al*., 2009). As in other vertebrate species, bat diversity is very high in the region with 38 species when compared to the 53 bat species recorded for the whole Europe subcontinent (Eurobats, 2018).

Bat populations, which are used as a biodiversity indicator (Jones *et al*., 2009; Nighat *et al*., 2019), are decreasing and some of the species are at risk of extinction. More than 10 cave-dwelling bat species are "Critically Endangered" over the World, (IUCN, 2018). In Europe and the Middle East four and five cave-dwelling bat species are listed as "Vulnerable" and "Near Threatened" respectively (IUCN, 2018). Four of these nine threatened cave-dwelling bat species are present in Anatolia.

The lack of information on these species makes difficult to develop conservation strategy. In fact, many poorly known species suffer high extinction risks (Brito, 2010; Morais *et al*., 2013; Howard and Bickford, 2014). It is essential to gain knowledge about not only species distribution, richness and abundance (Hoffmann *et al*., 2010; Butchart *et al*., 2012, Tanalgo *et al*., 2018) but also habitat preferences to improve their conservation (Furey and Racey, 2016). It is known that aspects of habitat such as cave size, altitude, geographical location, temperature are crucial for bat species richness and abundance (Ulrich *et al*., 2007, Nagy and Postawa, 2010; Luo *et al*., 2013; Piksa *et al*., 2013). Besides, human activities in roosting area have negative effect for cave-dwelling bat species (Mitchell-Jones *et al*., 2007; Furey and Racey, 2016). Therefore, determining habitat preferences will provide important data for management plan and conservation of cave dwelling bats (Medellin *et al*., 2017).

There are plenty of studies on the distribution of bat species in Turkey (*e.g.* Albayrak and Aşan, 1999; Furman and Özgül, 2002, 2004; Albayrak, 2003; Karataş and Sachanowicz, 2008; Bilgin *et al*., 2009; Yorulmaz, 2010). However, few data are available from certain regions. There are a lot of caves in Northwest of Central Anatolia which could be available for cave-dwelling bat species, but information is restricted to some records (Benda and Horáček, 1998; Karataş *et al*., 2003; Aşan and Albayrak, 2011).

The purposes of this study were (i) to survey cave dwelling bat species occurring in Northwest of Central Anatolia and (ii) to determine characteristics of caves used by roosting bats. Data acquired from this investigation will be helpful for effective bat species conservation strategies over the country.

* Corresponding author: eerdogdu@eskisehir.edu.tr
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MATERIALS AND METHODS

The present study was conducted in Northwest of Central Anatolia (39°93'N, 31°18'E) (Fig. 1). Altitude of the area ranges from 190 to 1818 m. Region is part of Sakarya River. Pine forests of European black pine (*Pinus nigra*), Scots pine (*Pinus sylvestris*) and Turkish pine (*Pinus brutia*) are randomly distributed in the area. Shrub vegetation is widespread and there are semi-arid open land and agricultural areas (Eken *et al*., 2006).

Investigations were performed in February (winter, hibernating period), April-May (spring, transit period) and August-October (summer, reproduction period). A total of 17 caves were visited during 35 days to determine cave dwelling bat species (Fig. 1). Since we did not detect any bat in İnönü and Hacıhüsrev caves, they were excluded from the list. After excluding of these two caves, totally 15 caves were investigated during the study.

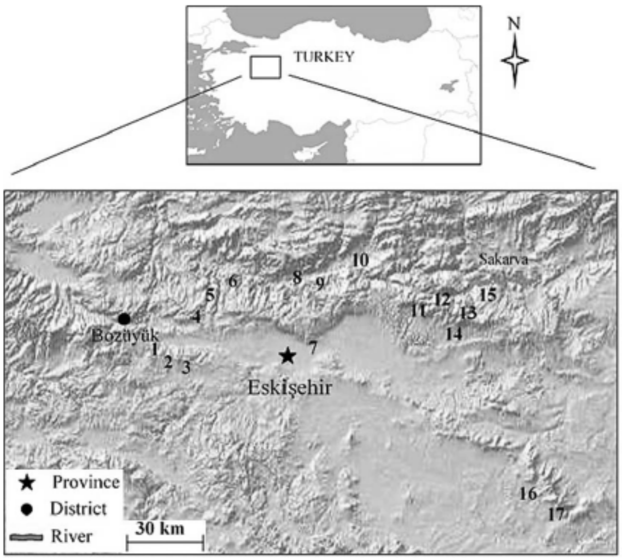

Fig. 1. Study area and distribution of studied caves. 1, İnönü; 2, Hacıhüsrev; 3, Dumanlıkaya; 4, Makaralı; 5, Yarasaini; 6, Tozman; 7, Mantarini; 8, Mayıslar; 9, Deliklikaya; 10, Beyyayla; 11, Kötüfatma; 12, Karamıkini; 13, Köçekkıran; 14, Ulubük; 15, Gürleyik; 16, Yelinüstü; 17, Yelini.

Roost count method was used to assess colony size of bats in caves (Battersby, 2010). Groups which are included fewer than 30 individuals were count directly. Other bat groups were estimated by ratio of individuals in selected area to total area covered by bats (Furman and Özgül, 2004).

Randomly selected bats were caught by a hand trap and identified according to morphological characteristic (Dietz and von Helversen, 2004). To reduce disturbance, identification was performed quickly and bats were released after measurement.

To determine cave preferences of bats, 12 variables were measured: coordinates and altitude (A) of caves using a GPS, distance to the nearest settlement (DNS), distance to the nearest paved road (DNR), distance to the nearest water body (DNW), distance to the nearest agricultural area (DNAG) using Google Earth maps, height (H), width (W) and orientation of cave entrance (O) and length of cave (L); these measurements were compared with data from Eskişehir's cave report (MTA, 2001). If cave had a running stream, it was assessed as active cave (AC). Temperature and humidity were recorded using a digital thermo hygrometer at each point where bats were detected. To identify cave preferences of bats caves with (15) and without (11) bat species were compared for all variables, except for temperature and humidity. Caves without any bat were selected according to earlier studies in the region (Nazik *et al*., 2001).

To obtain information about species diversity, richness and evenness, Simpson index of diversity (1 - D), Shannon diversity index, Margalef richness index and Pielou's evenness index were calculated for each season.

Simpson index of diversity; $1 - \sum (n (n - 1)) / N (N - 1)$

Where, n is number of individuals of one species and N is the total number of individuals of all species.

Shannon diversty; $- \sum (n / N. \log (n) / N)$

Where, n is number of individuals of one species and N is the total number of all individuals in the sample.

Margalef richness; $S - 1 / \log N$

Where, S is number of species and N is the total number of individuals in the sample.

Pielou's evenness; Shannon diversity / In S

Where, S is the total number of species in the sample.

Normality was tested via Shapiro Wilk's test. Since data did not satisfy the assumptions of normality, non-parametric tests were performed. To investigate the differences between caves hosting vs not hosting bats chi-square (χ^2) tests were used for categorical variables. Otherwise we used Mann-Whitney U tests. Differences were considered significant at the threshold of 0.05 and data were presented as mean±standard deviation (SD), minimum (min.) and maximum (max.) values. Data were analyzed using Statistica 8.0 for Windows (StatSoft Inc. 2007).

RESULTS

A total of 10 bat species were recorded in the study area: *Myotis myotis* (Borkhausen, 1797), *M. blythii* (Tomes, 1857), *M. capaccinii* (Bonaparte, 1837), *M. emarginatus* (Geoffroy, 1806), *Rhinolophus hipposideros*

(Bechstein, 1800), *R. ferrumequinum* (Schreber, 1774), *R. blasii* (Peters, 1867), *R. euryale* (Blasius, 1853), *R. mehelyi* (Matschie, 1901) and *Miniopterus schreibersii* (Kuhl, 1817). Bat species richness ranged from 1 to 6 in the 15 occupied caves (Fig. 2). The mean number of species was 3.06 ± 1.57.

Table I.- Diversity, richness and evenness index of bat species according to seasons in the study area.

	Seasons		
	Spring	**Summer**	**Winter**
Richness	10	5	6
Number of individuals	2283	1262	1503
Simpson index of diversity	0.53	0.70	0.69
Shannon diversity	1.26	1.32	1.34
Margalef richness	1.16	0.56	0.68
Pielou's evenness	0.54	0.82	0.74

The highest species richness value (1.16) was recorded in the spring (Table I). According to diversity and evenness index, dominance of the species was higher in the summer and the winter than in the spring.

The most common species was *M. capaccinii* in the spring (990 individuals) and the summer (500 individuals), *R. blasii* in the winter (598 individuals). On the other hand, only one *M. emarginatus* specimen was detected in spring (Supplementary Table I).

The mean temperature at each point where bat species were located ranged between 11.0-18.0°C, 12.5-18.6°C and 10.0-13.3 °C in the spring, the summer and the winter, respectively. The mean humidity ranged from 59.6- 87.0%, 57.0- 91.0% and 62.5- 82.3% accordingly (Table II).

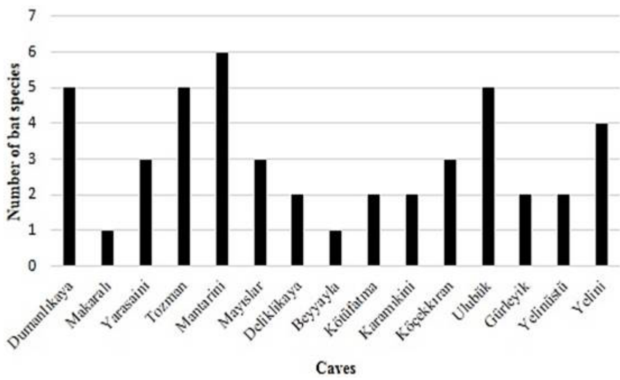

Fig. 2. Bat species number according to undergrounds in the study area.

Table II.- Temperature (ºC) and humidity (%) values of caves according to species and season.

Species	n	Season	Temperature (ºC)			Humidity (%)		
			Mean±SD	**Min.**	**Max.**	**Mean±SD**	**Min.**	**Max.**
Myotis myotis	4	Spring	14.7±3.4	12.0	19.0	80.5±10.5	65.0	88.0
	6	Summer	16.5±4.3	12.0	22.0	78.3±19.7	53.0	93.0
	2	Winter	12.5±3.5	10.0	15.0	75.0±25.4	57.0	93.0
M. blythii	3	Spring	17.6±1.5	16.0	19.0	85.6±2.5	83.0	88.0
	3	Summer	18.6±5.7	12.0	22.0	91.0±3.4	87.0	93.0
M. capaccinii	4	Spring	15.5±3.0	12.0	18.0	72.5±17.5	53.0	88.0
	1	Summer	16.0	16.0	16.0	57.0	57.0	57.0
M. emarginatus	1	Spring	11.0	11.0	11.0	87.0	87.0	87.0
Rhinolophus hipposideros	4	Spring	14.5±1.9	12.0	16.0	76.7±14.7	57.0	88.0
	14	Winter	12.7±3.0	8.0	18.0	68.1±12.7	52.0	93.0
R. ferrimequinum	12	Spring	14.5±2.0	11.0	18.0	73.0±13.9	50.0	88.0
	7	Summer	16.0±2.5	12.0	18.0	59.1±6.6	51.0	67.0
	17	Winter	12.1±2.9	9.0	17.0	65.2±13.6	48.0	93.0
R. blasii	2	Spring	15.5±0.7	15.0	16.0	83.0±7.0	78.0	88.0
	3	Winter	13.3±3.2	11.0	17.0	82.3±15.04	65.0	92.0
R. euryale	1	Spring	18.0	18.0	18.0	78.0	78.0	78.0
	1	Winter	10.0	10.0	10.0	69.0	69.0	69.0
R. mehelyi	3	Spring	16.3±2.8	13.0	18.0	74.3±21.12	50.0	88.0
Miniopterus schreibersii	3	Spring	12.6±1.5	11.0	14.0	59.6±11.2	50.0	72.0
	2	Summer	12.5±0.7	12.0	13.0	79.5±10.6	72.0	87.0
	2	Winter	10.5±0.7	10.0	11.0	62.5±4.9	59.0	66.0

Table III.- Characteristics for caves with and without bats. To compare differences between caves the nonparametric Mann Whitney U test was performed.

Characteristics	Caves with bat species				Caves without bat species				Z	p
	n	Mean±SD	Min.	Max.	n	Mean±SD	Min.	Max.		
A (m)	15	932.0±351.1	199	1241	11	1177.7±194.4	844	1565	2.205	*
DNS (m)	15	2533.3±1814.0	400	7000	11	2539.0±1861.2	10	5600	-0.181	ns
DNR (m)	15	1807.0±1064.7	5	3500	11	767.2±697.0	10	2000	-2.439	*
DNW (m)	15	2506.6±2342.9	0	7000	11	5632.7±3464.1	700	11000	2.309	*
DNAG (m)	15	775.3±1011.4	30	4100	11	1427.2±1481.7	0	4400	1.167	ns
H (m)	15	3.5±2.3	1	8	11	4.8±4.5	1	16	-0.752	ns
W (m)	15	3.3±1.5	1	7	11	5.0±4.8	1	18	0.467	ns
L (m)	15	265.4±200.0	45	770	11	115.2±108.9	26	390	2.309	*

* Significantly different ($p<0.05$). ns, not significantly different.

Distance to the nearest paved road (1807.0 ± 1064.7 m vs 767.2 ± 697.0, -2.439, $p < 0.05$), distance to the nearest water body (2506.6 ± 2342.9 m vs 5632.7 ± 3464.1, 2.309, $p < 0.05$) and length of the cave (265.4 ± 200.0 m vs 115.2 ± 108.9 m, 2.309, $p < 0.05$) had significant effect on selection of caves by bats (Table III). There was also a significant preference for caves situated at lower altitude (932.0 ± 351.1 vs 1177.7 ± 194.4 m, 2.205, $p < 0.05$). Most of the cave entrances were oriented to northwest and southeast ($\chi^2 = 28.1$, df = 12, $p < 0.05$) (Fig. 3). Caves which are entrance toward sky were excluded from analysis. No significant preference was detected for cave activity ($\chi^2 = 0.7$, df = 1, p = 0.3).

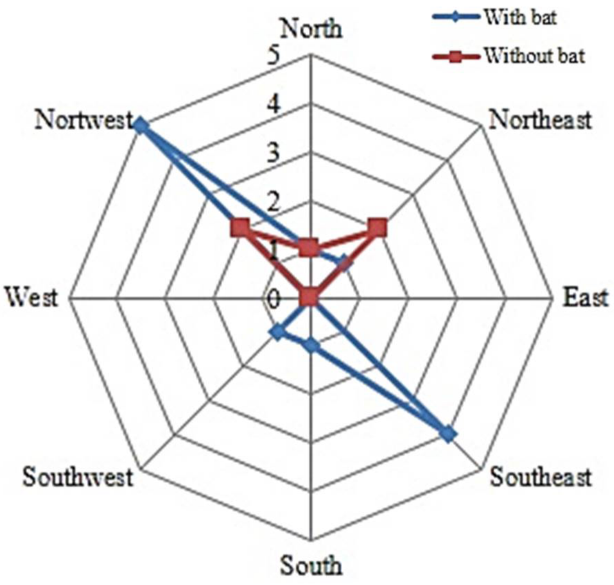

Fig. 3. Orientation of caves with and without bat species.

DISCUSSION

In this study, we found 10 of the 24 Turkish cave-dwelling bat species (Eurobats, 2018) in the Northwest of Central Anatolia. According to previous studies, *Myotis myotis* and *M. blythii* (Benda and Horáček, 1998; Aşan and Albayrak, 2011), *Eptesicus serotinus*, *Hypsugo savii*, *Pipistrellus pipistrellus* (Benda and Horáček, 1998) and *Rhinolophus ferrumequinum* (Baydemir Aşan and Albayrak, 2006) were detected in the study area. Although *Eptesicus serotinus*, *Hypsugo savii* and *Pipistrellus pipistrellus* have been reported in the region, they were not recorded in this study. In spite of the fact that these species also occupy in caves, they commonly roost in wall and roof crevices of buildings, crevices of cliff and holes of tree (Eurobats, 2018; Dietz *et al*., 2009). Thus, they may have not detected in this study, which was performed in the caves.

M. capaccinii, *M. emarginatus*, *R. hipposideros*, *R. blasii*, *R. euryale*, *R. mehelyi* and *Miniopterus schreibersii* were recorded for the first time. Detailed studies on the cave dwelling bat species have not been conducted previously in the study area. Thus, occurance of species have not been determined exactly, although there are some records near the study area on the species such as *R. hipposideros* (Benda and Horacek, 1998). Also, it is thought that, insufficient former studies have made it impossible to identify species with a small number of individuals in the region. For example, only one *M. emarginatus* specimen was recorded in this study. Besides, previous studies which were conducted in limited time may led to undetect of species which are found only one season in the region (because of differences of species existence according to season). For example, the maximum number of individuals of *R. blasii* were recorded in winter season in Yelini cave. Also, most of the data for *R. hipposideros* were recorded in winter seasons (Supplementary Table I).

Except for *M. myotis* and *M. emarginatus* all of bat species which were detected in this study are in decline all over the world (IUCN, 2018). *M.capaccinii* and *R. mehelyi* are listed "Vulnerable", *R. euryale* and *M. schreibersii* are "Near Threatened" (IUCN, 2018). For this reason, bat species should be considered in regional conservation strategies and management plans. Especially, studies on the negative human impact on habitat of species should be a priority.

Some authors have been reported that undergrounds have more bat species and individuals in winter than other seasons in Europe and Turkey. (Paksuz and Ozkan, 2012, Torrent Alsina, 2014). Temperature, altitude, vegetation, etc. may affect wintering area preferences of species (Nagy and Postawa, 2010, Piksa *et al*., 2013). Explanation for the low bat species number could be unsuitable ecological conditions of cave for hibernation to species in this study. On the other hand, there are plenty of studies indicated that not only species number, but also population size is higher in spring time (Jarzembowski, 2003; Georgiakakis *et al*., 2010, Barclay, 2014; Paksuz, 2009). According to this study species number is higher in spring than summer and winter seasons. The entire bat species found in the study area was recorded in spring season. Species richness in spring can be related to food supply. As a result of the spring rainfall and water availability, insects which are consumed by bats can be abundant. It is known that the insect species number and population size increase in spring after rainfall (Cumming and Bernard, 1997; Hristov *et al*., 2010). It is indicated that bat species richness and activities has been increased close to water bodies (Salsamendi *et al*., 2012, Amorim *et al*., 2018, Salvarina *et al*., 2018). Especially, occcurence of bat species which is fed on aquatic insect such as *M. capaccini* is associated with aquatic resources (Almenar *et al*., 2006). Also, insufficient water availability due to dry summer season in Mediterranean region can lead to reduce insect population. Bondarenco (2009) reported that bat species can move to available area to food resources.

The highest number of bat species was recorded in Mantarini cave with 6 species. Because of the species richness, this area should be primarily considered for conservation plans on bats in the region. As a matter of fact, loss of available roosting sites is a significant threatened factor. Using of cave and cave's surrounding for different purposes such as tourism, mining, *etc*. leads to not only being abandoned of caves by species but also decreasing of species number or population size (Ladle *et al*. 2012; Kasso and Balakrishnan, 2013; Sedlock *et al*., 2014).

The evenness index was the highest in the summer when the species richness and the number of bats are the lowest. The most common bat genus was Rhinolophus in winter time. *R. blasii* which is the widespread species between Palearctic and Afrotropic area had the largest number in winter. This species is listed "Least Concern" category (IUCN, 2018), even if population is decreasing (Jacobs *et al*., 2008). Also species was recorded in spring season. It is known that R. blasii is not a migratory species, travelling only short distances between summer and winter roosts (maximum distance is 6.4 km according to Hutterer *et al*., 2005). A colony included 176 individuals in summer season was reported in Koyunbaba cave in Thrace, northwestern of Turkey (Paksuz, 2009). In this study, 598 individuals belonging to *R. blasii* were recorded in Yelini cave in winter. According to our results, study area is important for winter roosting of this species as *R. hipposideros* and *R. ferrumequinum.*

Paksuz (2009) recorded more *R. hipposideros* individuals in winter season in Koyunbaba cave which is confirmed with our results. Although species prefer buildings for summer roosts, the individuals hibernate in caves (Hutterer *et al*., 2005). Because of decreasing trends of population, caves which were recorded species in the study area should be taken into account for conservation.

Although *R. ferrumequinum* was found all of the seasons in the study area, wintering individuals' number was higher. In Dupnisa cave 2200 specimens were recorded in winter season (Paksuz, 2004). Although the number of individuals of this species was not as much as Dupnisa cave, conservation plans should be conducted in the study area, because of population decreasing according to IUCN.

While, *R. mehelyi* was recorded only in spring, *R. euryale* was found in winter and spring season in the study area. Higher individual numbers were recorded for these species in previous studies in different caves in Turkey (Furman and Özgül, 2004; Paksuz, 2004, 2009). According to IUCN criteria *R. euryale* and *R. mehelyi* are under threatened species. Therefore, it is crucial to protect of caves which inhabit of species in the region.

M. myotis and *M. blythii* were the most widespread bat species in the summer season. On the other hand, except two individuals belonging to *M. myotis* there were no observations in winter for these species. It is known that *M. myotis* makes trips between summer and winter areas as a regional migrant (Rogowska and Kokurewicz, 2007; Wojtaszyn *et al*., 2014). Also, short distance trips can be made by *M. blythii* although it is resident (EUROBATS, 2001). Thus, absence of these species in the region can be explained by leaving from the area for favourable sites for winter conditions. On the other hand, because of the winter seasons' unfavourable field conditions, studies could not be performed in 3 caves and knowledge about existence of *M. myotis* and *M. blythii* was not obtained. Thus, data deficiency may affect our results about the absence of these species. In spite of the fact that only *M. blythii* was found one of these 3 caves in the spring season, detailed studies should be carried out all over the years to evaluate the movement of species in the study area.

The largest bat assemblages belonged to *M. capaccinii* which was reported for the first time in the region. *M. capaccinii* found in Mediterranean and the Middle East (Spitzenberger and Von Helversen, 2001) occurs near the water bodies such as river, lake *etc*. (Almenar *et al*. 2006). It is cave-dwelling species not only in winter, but also in the summer season (Papadatou *et al*. 2008). European population of *M. capaccinii* has decreased and categorised as "vulnerable" (IUCN, 2018). Also population decline was reported for the species in Turkey and the colony which is included more than 100 individuals is seen occasionally (IUCN, 2018). For example, Yorulmaz (2010) recorded 150 individuals. Also, it was found a colony with 1000-4000 specimens (Furman and Özgül, 2004; Paksuz, 2009). Although the number of individuals of this species was not as much as another part of the country, study area seems important for *M. capaccinii*. Habitat loss is an important negative factor on the population (Almenar *et al*., 2006). Thus, it is essential to protect caves in the study area against to human disturbance for conservation of *M. capaccinii* which is likely to become endangered.

Only one *M. emarginatus* specimen was recorded in spring season, which was the first record for the study area. Although, species is recorded in northwestern, western and southern of Turkey (Paksuz, 2009; Benda and Horáček, 1998), it is thought that it will be able to obtain more data on species occurrence by the next studies in the region.

M. schreibersii which qualifies as "Near Threatened" according to IUCN criteria was recorded in all of the year in the study area. The highest individual number was detected as 70 specimens in Mantarini cave in winter season. The presence of the species in this cave was recorded in spring and summer seasons, also. Therefore, Mantarini cave should be taken into account for conservation of this species.

It is known that cave temperature is an important factor for roosting of bat species (Furey and Racey, 2016). Temperature preferences of bats can vary according to the species, region and seasons (Webb *et al*., 1996; Masing and Lutsar, 2007; Wermundsen and Siivonen, 2010, Piksa *et al*., 2013). Bats tend to hibernate in colder temperature to reduce energy expenditure (Boyles *et al*., 2007; Wermundsen and Siivonen, 2010). According to our study, the lowest mean temperature was 10.5°C for *M. schreibersii* in winter season. Our findings are similar to results of Paksuz (2009) which was indicated that the mean temperature in winter season was 10.36 for *M. schreibersii.*

Although it can be species-specific, bat species choose a higher temperature in spring and summer seasons for metabolic processes (Tuttle and Stevenson, 2011). The highest mean temperatures for summer and spring seasons were recorded as 18.6 and 18.0°C for *M. blythii* and *R. euryale*, respectively. These results are higher than the presented values for the same species in Koyunbaba cave. It can be concluded that temperature preferences can be changed as intra-specific.

Humidity is one of the other microclimatic factor which can affect the bat species preferences of roosting area. To reduce water loss via evaporation, bat species select area with high humidity (Speakman and Racey, 1989; Thomas and Cloutier, 1992). In this study, *R. blassi* and *M. blythii* were found in the caves which have the highest mean humidity area in winter and summer, respectively.

Our study indicated that most of the bats were found lower altitude in the region ($p<0.05$). It is well known that bat species can be affected by elevation (Ulrich *et al*., 2007; Schoeman *et al*., 2013). Although, there are findings on the high species richness at intermediate elevations in dry region (Mccain, 2007a), according to studies, species richness tends to decrease as elevation increases in a temperate climate (Bücs *et al*., 2012; Kaňuch and Krištín, 2006). There are two explanations about the bat species preferences for low altitude. First is weather conditions (Mccain, 2007b) and second is limited food supply in high altitude. For example, vegetation diversity which is related to food supply is decreased with altitude (Townsend *et al*., 2008).

It was found that roosting sites are away from the road significantly ($p<0.05$). It is well documented that roads have a negative influence on diversity (Berthinussen and Altringham, 2012), population size and activities of bats (Kerth and Melber, 2009; Siemers and Schaub, 2011; Medinas *et al*., 2013) because of the collision with vehicle, breeding or foraging area loss and noise pollution. Thus, Zurcher *et al*. (2010) indicated that bats exhibit road avoidance behaviour which also supports our findings.

According to our finding water source was important to roost selection by bat species ($p<0.05$). It is known that bats tend to roost near water sources, because of the prey availability (Krusic *et al*., 1996; Zahn and Maier, 1997). Also, Seibold *et al.* (2013) found that ponds are significant for species to supply drinking water.

According to previous studies longer caves include more bat species and larger colonies (Niu *et al*., 2007; Dixon, 2011; Bu *et al*., 2015). Long caves were determined as more preferable in the study area, also. Stable temperature, protection from human disturbance in deep sites and available roosting area for all individuals with a lot of microhabitats can be ensured by longer caves (Briggler and Prather, 2003; Fernández-Cortéz *et al*., 2006; Glover and Altringham, 2008, Tuttle and Stevenson, 2011; Furey and Racey, 2016).

Significant difference was detected in the aspect of the cave entrance with the preferences of northwest and southeast facing ($p<0.05$). Although Bu *et al*. (2015) did not find preferences of cave entrance orientation, some bat species can roost east facing cave in winter season (Briggler and Prather, 2003) and some species can prefer vertical entrance cave (Glover and Altringham, 2008). Cave orientation can provide an available microclimate for bats. On the other hand, requirements of the species can be changed in winter and summer time. Thus, cave entrance orientation preferences should be evaluated according to seasons. But it was not analysed differences between seasons for cave entrance aspect in this study and detailed studies should be carried out.

As a consequence, this study reveals importance of Northwest of Central Anatolia for bat species. All bat species determined in the area are in Supplementary Table I of Bern Convention, which include the species under strict protection. Because of the threatened 8 species are found in the region, conservation plans should be performed urgently. Due to lack of knowledge about the population trends of species and foraging area detailed monitoring programs and studies should be conducted. Particularly in underground sites to avoid disturbance of bats, studies should be carried out by experienced researchers. Also collaboration between caving clubs which are keen to protect of cave fauna and bat researchers will provide more effective conservation efforts.

All caves inhabit bat species in the study area should be checked regularly for physical changes which can affect to the ecological conditions of caves. In addition, human activities should be restricted near and in roosting caves. Also, in case of excessive disturbance, a grille which permits the passage of bats, but not people can be implemented entrances of caves. Finally, obtained data should be generalised from a limited area to country for conservation management of bat species.

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Supplementary material

There is supplementary material associated with this article. Access the material online at: http://dx.doi.org/10.17582/journal.pjz/2019.51.6.2141.2151

Statement of conflict of interest

The authors declare no conflict of interest.

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