Important Caves in Turkish Thrace for Bats: Dupnisa Cave System and Koyunbaba Cave

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Abstract

Today, caves and some bat populations are declining worldwide because of anthropogenic pressures such as habitat use, tourism, quarrying, and guano mining. The protection of caves is very essential for bat conservation programs because some caves are indispensable and specific living areas for many bat populations. In this chapter, the species composition, colony structure, seasonal population dynamics, roosting habits, and roosting requirements of the bats in Dupnisa Cave System and Koyunbaba Cave in Turkish Thrace are discussed. Dupnisa Cave System and Koyunbaba Cave, which have different roost characteristics and microclimates, are alternative to each other in terms of the season. Therefore, they are inhabited by different bat species for different purposes at different levels according to weather conditions changing throughout the year. Dupnisa Cave System is mainly used by 18 bat species for hibernating, whereas Koyunbaba Cave is mainly used by 11 bat species for breeding and nursing. Due to different roost characteristics and microclimatic conditions, Dupnisa Cave System and Koyunbaba Cave are the most important underground habitats for bat populations in Turkish Thrace. Therefore, the protection of these caves is very important for the future of bat populations in the region.

Keywords: bats, caves, conservation, Dupnisa Cave System, Koyunbaba Cave, Turkish Thrace

1. Introduction

This chapter summarizes general information about cave ecosystems and bats. In the first part, the characteristics and importance of caves and bats will be elaborated for interested readers who are not experts in these subjects. In the following sections, geomorphology and biogeography of Turkey and Turkish Thrace are discussed in detail, and the characteristics that make the region important are also underlined. In conclusion of the chapter, more detailed data about Dupnisa Cave System and Koyunbaba Cave in Turkish Thrace will be presented, and the importance of these caves for the future of the bats in the region will be revealed. This chapter presents a summary of related previous studies. The aim is to raise awareness about the protection of bats and caves rather than be a reference for similar topics.

1.1. Cave ecosystems and their characteristics

In simple terms, cave is defined as an underground hollow that is large enough for a person to enter; however, cave has various definitions in terminology. Caves are formed as a result of the dissolution of carbonated and sulfated rocks with a series of physiochemical processes by underground waters. Caves contain the past and current data of the geological, geomorphological, hydrological, and ecological characteristics of the region where they are located [1]. Caves are not only the underground hollows formed in the rocks but also the unique habitats that host many organisms and natural values. Caves are important ecosystems in terms of both cave-dwelling species, and geological, historical, anthropological, archaeological, ecological, and cultural values.

Caves are very specific and susceptible ecosystems, because they have some extreme features that force life such as darkness, low temperature, high humidity, and limited nutrients [2–4]. Because of their darkness, caves are devoid of plants, which are the main producers of the food chain. For this reason, all the organic materials are brought from the outside into the cave in various ways. The main factors that provide nutrient entry into the caves are the air flows and the water currents in the caves. Besides these, guano, the main energy source in the growth of many organisms, is the most important nutrient in caves [5]. Lack of light, low temperature, high humidity, and the restriction of nutrients can be seen as important limiting factors in many caves [3, 4]. In the caves, living organisms are resistant or adapted to the scarcity of nutrients and other limiting factors. The essential condition for organisms to survive in the cave is energy saving. For this reason, the cave organisms are as small as possible and they move as little as possible.

The most important difference between underground and terrestrial habitats is the stable environmental conditions of caves. Unlike terrestrial conditions, caves have an almost constant temperature and humidity throughout the year. All these differences and characteristics make cave habitats unique and very sensitive. Any changes in the conditions of the cave ecosystems threaten the lives of the cave inhabitants. Despite challenging living conditions such as darkness and limited nutrient sources, caves accommodate many species [3, 4]. Because of these negative conditions in the cave, the cave dwellers have developed various ways of adaptations to survive. For example, the sense of sight of organisms adapted to life in caves has either weakened or completely disappeared in the evolutionary process. On the other hand, most of these species have developed their antennas longer than their relatives outside. Similarly, some species that adapted to the cave life usually appear white or transparent because they lack pigment.

Caves are initially creepy, but the mystery of the darkness and the past in caves is the most important features that attract people into caves. And also, in the caves formed as a result of a very slow and long process, stalactites, stalagmites, and travertines come in various formations, which attract people visually. In addition, underground waters, rivers, and lakes within caves are another beauty. So, it is possible to see that cave tourism, which is called as alternative tourism, has improved all over the world. The visual, sportive, religious, historical, and cultural characteristics of the caves provide a potential for tourism. However, it is also known that caves are used for different purposes such as shelter, barn, and storage. For this reason, it is inevitable that underground habitats, which are natural habitats of organisms, are damaged by human pressures over time.

Underground habitats around the world are under constant threat due to human pressures such as cave tourism, treasure hunting, guano mining, stone quarries, and water dams. The use of caves by humans can cause significant harmful effects on caves [6–8]. It should not be forgotten that these natural values, gradually formed in millions of years, will not come back again in a short time. For this reason, the identification and investigation of important cave habitats are essential for the future of these habitats and organisms living there.

1.2. Bats and their characteristics

Bats (Chiroptera) are among the most diverse and widely distributed groups of mammals and can be found in most continents. Bats consist of greater than 1300 species worldwide and comprise approximately one quarter of mammalian species richness [9–11]. The order Chiroptera is subdivided into the Megachiroptera and the Microchiroptera. The Megachiroptera is represented by only one family, whereas the Microchiroptera comprise 17 families. Megabats are also called as fruit bats. Fruit bats mostly roost in trees and shrubs. Megabats are frugivorous and nectarivorous, and they eat fruit or lick nectar from flowers. Microbats are called as insectivorous, and they mostly feed on insects, and use echolocation. Insectivorous bats use a wide variety of roosts such as caves, trees, and manmade structures.

Bats are the only flying mammals and they have a wide range of feeding and roosting habits, social behaviors, and reproductive strategies. Flying ability made bats become one of the most common groups of mammals [6]. Most of bat species use echolocation to navigate and forage. Echolocation allowing bats to see their surroundings by sound is actually an adaptation. Bats emit calls out to the environment through their nostrils and mouth, and then they find their direction by listening to the echoes of the calls returning from the objects around them. Thus, bats get information about the location, position, and shape of objects in the surroundings by processing these echoes [12, 13]. When food quantity decreases, bats have to make a choice: to hibernate or to migrate. Hibernation involves a reduction in metabolic rate that allows bats to survive for a long time without food [14]. Many species of bats migrate between summer and winter roosts. Some migrations are made to reach for more abundant food sources in warmer locations, while others are made to obtain roosts that have optimal microclimate for hibernating in winter or raising offspring in summer [14, 15].

Bats have acquired a wide variety of characteristics in parallel with the lifestyle they are adapted. Although the patterns of feeding, roosting, and reproduction of the bats differ between species, some basic adaptations are similar. Most bat species are nocturnal, and they forage during the nights. Bats feed with a wide variety of foods such as insect, fruit, flower nectar, small vertebrate, and blood [12, 15]. In the daylight, bats pass into torpor in roosts such as foliage, caves, hollows of trees, rock crevices, and various manmade structures. The most prominent predators of bats are owls, hawks, snakes, raccoons, and martens [15]. Female bats have some strategies that they can control the timing of their pregnancy to give birth at an appropriate time [13]. Females generally give birth to one offspring every year, and they nurse their young until they get mature to feed on their own [15].

Bats that play a key role in many ecosystems are an important group of mammals with species diversity, abundance, and distribution all over the world. Bats have important ecological roles that are critical for human and ecosystem health, including the pollination and dispersal of many plants, and the control of insects [16, 17]. Bats are primary predators of insects that are harmful for human health and agriculture. Thus, bats play an important role in human health and biological pest control by balancing harmful insect and microorganism populations [15]. Guano mined from caves is provided by bats and used as a natural fertilizer on agricultural crops. Guano is a primary source of nutrition that allows the development of a great diversity of organisms such as arthropod, fungi, bacteria, and lichen.

Bats are one of the most sensitive mammal groups to varying weather conditions with their peculiarities in physiology, thermoregulation, and life cycle. Bats prefer different roosts depending on the season and spend more than half of their lives in roost. Most species of bats have specific requirements in terms of roost conditions such as microclimate and environmental stability [18]. Roosts protect bats from bad weather conditions and their predators, so roost selection is essential to sustain the life of the bats [13]. Therefore, the presence of suitable roost is an important factor affecting the social structure and the distribution of bats [18–20]. The identification of these roosts is essential for the protection of bats. Bats have been known as cave dwellers for a long time, because caves that provide stable environmental conditions and protection throughout the year are pretty suitable roosts for bats. All over the world, caves and mines are used as shelter by large bat populations, but particularly sensitive species are highly dependent on only a few of these underground shelters [9, 18, 21]. However, most caves are used only by a small number of bats. Only a few caves provide convenient conditions to host thousands of bats, especially during hibernating and breeding periods. These caves are vital to bat populations [9, 18, 20, 22].

Microclimatic conditions are often particularly important for habitat quality of bats [23]. Therefore, the seasonal use of roosts by bats is profoundly associated with its microclimatic conditions and these conditions form the assembling patterns of bats. The particular roost requirements of bat species restrict the permanent shelters that are used by bats. Thus, the environmental stability and protection provided by caves make them highly suitable roost for bats throughout the year. Most bat species make use of caves as roost for various purposes during some phases of their annual cycle [22].

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Microclimatic requirements of bats show seasonal variations according to their annual life cycle. Therefore, the availability of a cave by bats is increased by providing alternative microclimatic conditions compared to season. Caves may serve as one of the most adequate roosting sites for bats because of the relatively stable microclimatic characteristics. Therefore, natural caves and artificial underground sites are widely used as roosting sites by bats and may be occupied by large breeding and/or hibernating populations [9]. The distribution and availability of suitable roosting sites is a limited resource for some cave-dwelling bat species [20]. Besides, cave-dwelling bats are mostly threatened by visitors and human activities.

The distribution areas of animals depend on their biological requirements and environmental conditions. Because of the variety of such conditions, the caves, which are potential roosts for bats, can serve as a good model for studying the relationship between the regional settlement and the structure of the environment [24]. Bats have to find special periodic roosts according to the requirements of hibernation or breeding, so knowing the roosting requirements of bats is vital for conservation and management works. Identifying and surveying these sites will help to understand the habitat requirements of species [25].

Bats form the largest mammalian assemblages on earth, and one place may be a shelter for a significant portion of the total populations of some species [26]. Such places have a great importance for bats and may be limiting for their population size and distribution. Most bat species rely on underground shelters to maintain their lives. Cave disturbance and destruction is one of the biggest problems that cause the decline of bat populations all over the world, so the identification and protection of such important sites has vital importance for the future of bats [8].

1.3. Biogeography and geomorphology of Turkey

When compared to the regional countries, Turkey has a special biogeography due to its large surface area, different geomorphologic structure, different climatic conditions, and transition position between the continents [27]. As a result of these features, Turkey has a rich biodiversity and a variety of ecosystems that almost a continent can have. The geomorphological structure of Turkey is one of the main factors in having various biogeographic areas [27].

The soluble karstic rocks such as limestone, gypsum, and dolomite, which are suitable for cave formation, constitute approximately 40% of Turkey's surface area [28]. One of the most important formations in the karstic areas of Turkey is caves. Because of the insufficiency of cave explorations, not all of the caves in Turkey have yet been examined; it is not possible to give a definite figure about the number of caves in our country. However, it is estimated that more than 20,000 caves can be found in Turkey according to the size of the area covered by the soluble rocks and the ratio of the number of caves detected in these areas [28]. However, many of the caves in Turkey are still not identified. In parallel, research on caves in Turkey is extremely inadequate. The research carried out until now is mostly focused on the caves in the touristic areas. Approximately 3000 of these caves were surveyed by caving associations, clubs, communities, and organizations. Until today, 31 caves in Turkey have been opened as tourist attractions [29].

1.4. Biogeography and geomorphology of Turkish Thrace

Thrace is a geographic region located in southeastern Europe within the territories of Greece, Bulgaria, and Turkey. Thrace lies in the northeastern Greece, the southeastern Bulgaria, and the European part of Turkey (**Figure 1**). Turkish Thrace, which constitutes about 3% of Turkey's surface, is not very high (average altitude of 180 m) and only 15% of the region is covered by forest in north and south. When evaluated in terms of geological, geographical, and tectonic features, it is seen that the Thrace region is different from the other regions of Turkey. Karst formation in Turkish Thrace is characterized by Eocene limestone, but a few caves developed within the marbles of the Paleozoic metamorphic basement, which is limited in the region [30].

Thrace is one of the major biogeographic zones in Turkey and, due to its karst formation, more than 50 caves have been formed in the region. Most of these caves, which form horizontally, are fossil-typed caves that have completed development. The caves in Turkish Thrace are concentrated at elevations between 150 and 200 m in Yıldız Mountains. The two longest caves explored were İkigöz Cave (4816 m) and Dupnisa Cave System (2720 m) in length with altitudes of 70 and 345 m, respectively [30, 31].

Despite the presence of thousands of caves in Turkey, there are few studies of the cave fauna, and most are old and based on the limited sampling. However, in recent years, the caves in Turkish Thrace have been slightly more surveyed in terms of the bats. Bilgin [32] has examined some of the caves in the region and provided information on the summer population sizes and habitat preferences of the bat species. Furman and Özgül [33, 34] have investigated the population sizes of bat species in many caves in the region and also stated that they should be protected by identifying important underground shelters in the region. In particular, two caves in the region, Dupnisa Cave System and Koyunbaba Cave, have been investigated in

Figure 1. The location map of Thrace, and the positions of Dupnisa Cave System and Koyunbaba Cave in Turkish Thrace.

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detail by the author based on regular and long-term monitoring (**Figure 1**) [35–38]. In recent years, many studies have been conducted throughout Turkey to determine other underground habitats that are important for bat populations. These studies provide important contributions to the identification and conservation of the bat populations and roosts in Turkey [39, 40].

Due to its location and different climatic zones, Turkey has become a homeland and shelter for many species affected by geological and climatic changes in the past. For this reason, Turkey, which has a rich biodiversity, is also very rich in terms of bat species. Turkey is the country with the highest bat diversity in the region with 39 species identified so far. In Turkish Thrace, 27 of these species have been recorded. Dupnisa Cave System, Koyunbaba Cave, and Kocakuyu Cave are the most important shelters for bats in the Thrace region of Turkey [32–38].

Besides the lack of suitable shelters, today's rapidly growing urbanization, population growth, and the increased interest of humans intended for nature are causing damage and gradual decline of natural habitats of bats, and thus bat populations are at risk of extinction. Cave-dwelling bats are mostly threatened by visitors and human activities. Treasure hunting, quarrying, and cave tourism are the main threats to caves in Turkish Thrace. Knowing and protecting of roosts are essential to bat conservation. The use of caves by bats is shaped by microclimatic, morphological, and ecological conditions provided by the caves, because species have specific requirements for roosts in terms of shelter. Roost selection of bats differs in particular parts of caves and changes according to their annual life cycle. Therefore, knowledge about roost requirements and roost switching of the bat species in Turkish Thrace is required to any plan of the protection of the bats.

2. Methodology and study area

In this study, Dupnisa Cave System and Koyunbaba Cave in Turkish Thrace were investigated based on a long-term monitoring. The data given in this chapter belong to the years 2002–2010 for Dupnisa Cave System and 2007–2008 for Koyunbaba Cave. The roosts used by bats in both the caves were determined. In each survey, the species composition, colony structure, seasonal population numbers, and roosting habits of the bats were recorded. Roost temperature and humidity were regularly measured in each survey. Collected data were evaluated in two periods as winter/hibernation (November–March) and summer/nursery (April–October). Species identifications were done by following the identification keys [41]. Small colonies were counted directly and large colonies were counted using photographs. Also, some of these data have been previously presented by the author at congresses and articles [36, 38, 42].

2.1. Dupnisa Cave System

Dupnisa Cave System is located south of Sarpdere Village (Kırklareli) in Thrace, the European part of Turkey (**Figure 1**). The cave system lies in the forested Yıldız (Strandja) Mountains. Dupnisa Cave System is the second largest cave in Thrace region with a total length of 2720 m long. This cave system, which developed as a result of the disintegration of the Pliocene relief system in the upper part of the Yıldız Mountains with the Quaternary rivers, has the polycyclic development feature [31]. The cave system, which has four entrances, has developed horizontally and its formation process still continues. Dupnisa Cave System is regarded as a cave system because it is formed by two floors and three interconnected caves. These caves have different features. In this system, the active main gallery through which an underground stream flows is called Sulu Cave, while the totally fossilized ones above are called Kuru Cave and Kız Cave (**Figure 2**) [31].

Sulu Cave has the longest gallery of these caves with a length of 1977 m, and has only one entrance and one corridor. The height and width of this corridor are up to 40 and 15 m, respectively, and there is a very large hall of 125 m long, 80 m high and 35 m wide in this corridor. Kuru Cave, with a total length of 480 m, has two entrances and two corridors. In addition, a large hall was formed at the junction of these two corridors. Kuru Cave is connected with Sulu Cave by a narrow corridor. Kız Cave, 263 m in length, has one entrance and a small hall after the entrance. Kız Cave, which is covered with a thick fossil layer mixed with large blocks, gravel, and sand, is connected to Sulu Cave below at two points (**Figure 2**) [31].

Dupnisa Cave System is the first cave in the Thrace region that was opened to visitors in July 2003. This cave is also the first cave in Turkey to be opened to visitors with a program and gate construction according to the seasonal use of the cave by bats based on long-term-monitoring program [38]. Tourist circuits were constructed with the first 200 m of Sulu Cave and the first 230 m of Kuru Cave. However, Kız Cave is closed to visitors (**Figure 2**). The cave system has been visited by about 35,000 visitors each year after it was opened to visitors. The cave system has four entrances and two of these entrances, which are located on the tourist area, are closed to control human entry (**Figure 3**). Gates are constructed with a design of the horizontal angle iron bars that have 200-mm spacing between bars. The other entrances of the cave system, outside of the tourist area, where human entry is difficult, have been left to the natural state to minimize the negative effects of the two doors on the bats (**Figure 3**) [38].

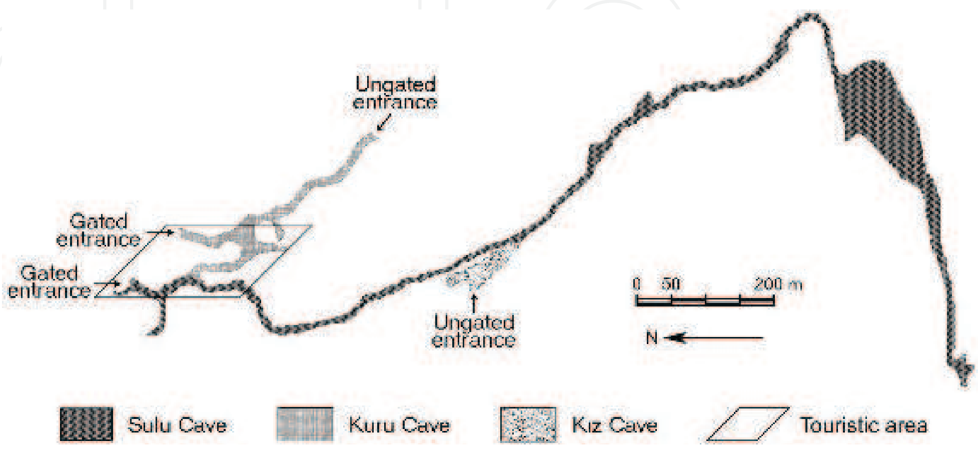

Figure 2. Dupnisa Cave System: the location of the three main caves, the areas open to tourists, and the gated and ungated entrances [38]. Adapted from Ref. [31].

Figure 3. The gated entrances of Sulu Cave (a) and Kuru Cave (b), used to control the entry of tourists. The ungated entrances of Kuru Cave (c) and Kız Cave (d), remained to minimize the negative effects of the gates on the bats.

2.2. Koyunbaba Cave

Koyunbaba Cave is located in the province of Kırklareli in Thrace of Turkey at 155 m altitude (**Figure 1**). Its length is 532 m, horizontally developed, and a fossil cave [31]. Depending on its development, the cave consists of different parts with various characteristics. There are seven stations used as roost by the bats in Koyunbaba Cave. These stations have different characteristics in terms of roost type, height, and microclimate (**Figure 4**).

Koyunbaba Cave developed on a prominent northwest-southeast direction fault line on the Eocene limestone. The fractured structure of the limestone resulted in the formation of many cavities and recess ledges in the cave. The cave initially developed in the northwest-southeast direction and takes the northeast-southwest direction from the middle section. At the intersection of these two sections, a large subsidence hall with a width of 50 × 60 m and a ceiling height of 30 m has developed (**Figure 4**). The formation of dripstone in Koyunbaba Cave, which has its base covered with a thick fossil layer consisting of soil, gravel, rubble block, and guano, is almost inexistent [31].

Koyunbaba Cave has three entrances, which are linked with different characteristics. The main entrance is the largest one. It is horizontally formed and its entry is very easy. Koyunbaba

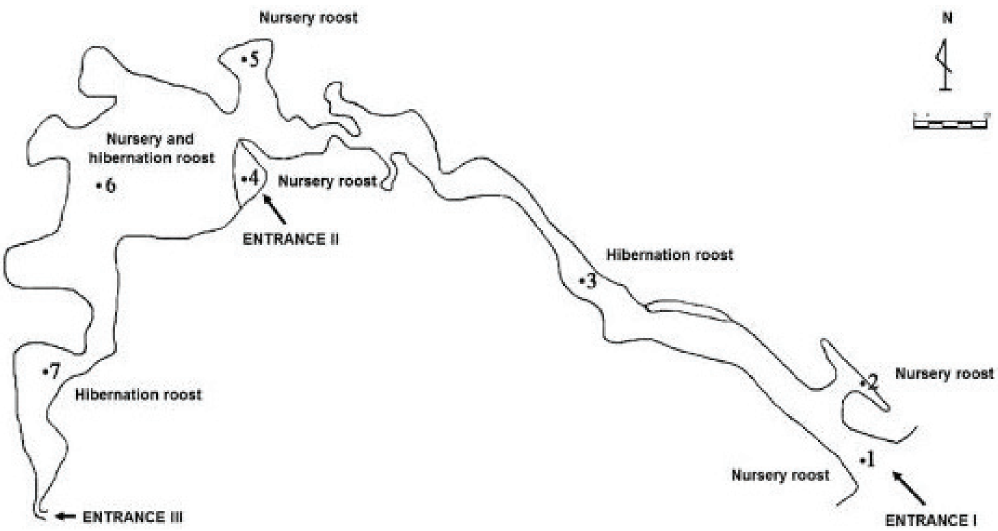

Figure 4. Koyunbaba Cave: the location of the seasonal roosts used by the bats, the three entrances of the cave. Adapted from Ref. [31].

Cave is closed to visitors, but this area of the cave is used by local people as an animal shelter during the summer. The second and third entrances of the cave are vertical. Because they are quite dangerous, these entrances cannot be used by local people (**Figure 5**). The cave is located in a relatively flat area consisting of farmland and pastures. This area is outside the Strandja Forest tree line. There are important water resources (Teke stream and Kayalı dam) around the cave.

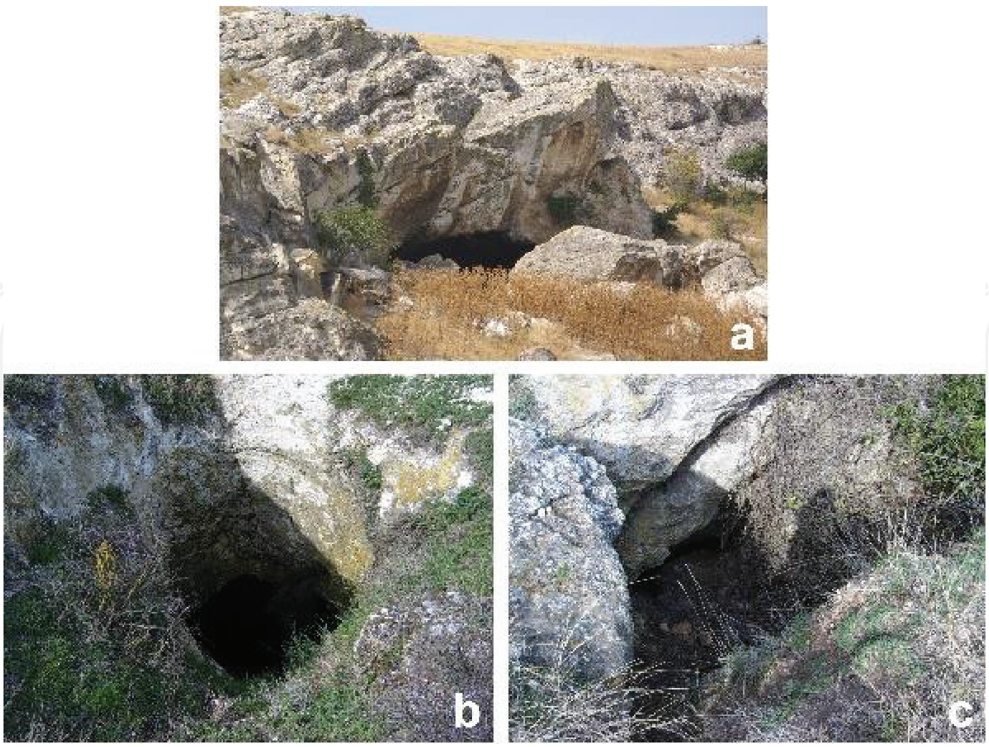

Figure 5. The three entrances of Koyunbaba Cave: the main entrance (a), the second entrance (b), and the third entrance (c).

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3. Results

3.1. Microclimate of Dunisa Cave System

Dupnisa Cave System, which has four entrances and three parts with different characteristics, provides seasonally different microclimatic conditions in the different parts (**Table 1**). Paksuz et al. [36] stated that the temperature varies between the different parts of the cave system, as well as by season. While the winter temperature ranges from −1 to 12°C in Sulu Cave, 8 to 14°C in Kuru Cave, and 10 to 14°C in Kız Cave, the summer temperature varies from 9 to 14°C in Sulu Cave, 13 to 22°C in Kuru Cave, and 13 to 18°C in Kız Cave. In winter, the mean temperature of Sulu Cave is significantly lower than from Kuru Cave and Kız Cave. During summer, the mean temperature in Kız Cave and Kuru Cave is significantly higher than in Sulu Cave. In Sulu Cave, the average temperature in winter is 7.4°C, in summer 10.7°C; in Kuru Cave in winter 11.4°C, in summer 16.3°C; in Kız Cave in winter 11.9°C, in summer 15.9°C. Humidity also varies depending on the caves and the seasons. The humidity in Dupnisa Cave System varies from 57 to 100%. The mean humidity in winter is similar and higher in Sulu Cave and Kız Cave, while it is lower in Kuru Cave. During summer, the humidity is similar in all three caves.

3.2. Bats of Dupnisa Cave System

Up to now, 17 species of bats have been recorded in Dupnisa Cave System, which is the most studied cave in Turkey in terms of bats. Five of these species belong to Rhinolophidae family (*Rhinolophus ferrumequinum, R. hipposideros, R. euryale, R. mehelyi*, and *R. blasii*) and 12 of them belong to Vespertilionidae family (*Myotis myotis, M. blythii, M. bechsteinii, M. emarginatus, M. nattereri, M. mystacinus, M. capaccinii, M. daubentonii, Miniopterus schreibersii, Barbastella barbastellus, Plecotus austriacus*, and *P. auritus*) [34–36, 38]. *M. alcathoe*, recorded in this study, has been newly registered for Dupnisa Cave System. The maximum number of bats recorded in Dupnisa Cave System is 54,600 in hibernation, while 11,000 in nursery. Dupnisa Cave System is used for hibernating by the majority (83%) of the total number of bats recorded, while it is used for breeding and nursing by the minority (17%). The three parts of the cave system were used by different species to varying degrees according to the season. Sulu Cave is used only for hibernating, while Kız Cave and Kuru Cave are used for both hibernating and nursery (**Figure 6**) [36, 38].

In Dupnisa Cave System, 99% of bat colonies are composed of six species, *M. schreibersii* (78%), *M. myotis/blythii* (8%), *R. euryale* (6%), *R. ferrumequinum* (4%), and *M. capaccinii* (3%).

Caves	Length (m)	Summer temp. (°C)	Winter temp. (°C)	Summer hum. (%)	Winter hum. (%)
Sulu Cave	1977	10.7	7.4	84.6	91.5
Kuru Cave	480	16.3	11.4	77.3	80.9
Kız Cave	263	15.9	11.9	80.7	87.6

Table 1. The length measurements and mean microclimate data of Dunisa Cave System.

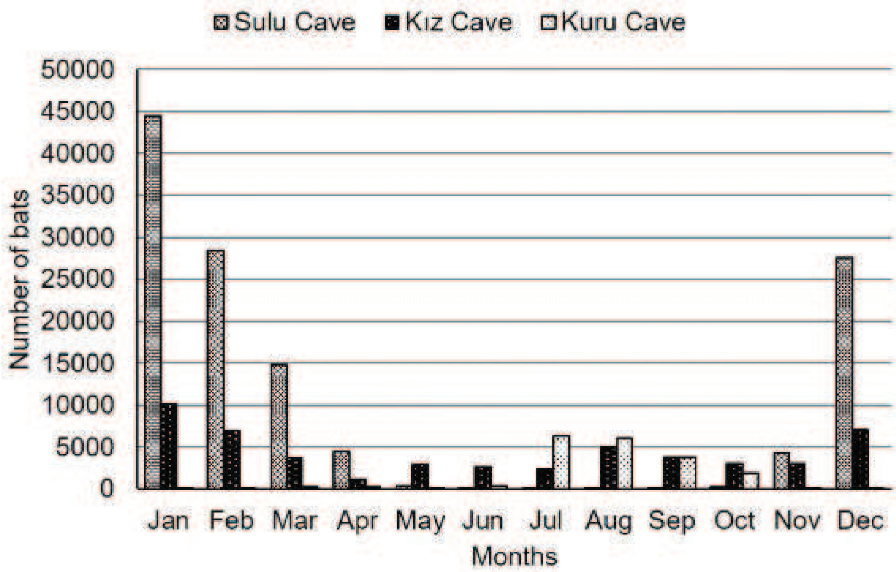

Figure 6. The maximum monthly number of bats recorded in a single survey in the three parts of Dupnisa Cave System. The data were collected from 2002 to 2010.

The biggest aggregations of the species recorded in a single survey in Dupnisa Cave System are *M. schreibersii* (45,600) in hibernation, *M. myotis/blythii* (4300) in hibernation, *R. euryale* (3600) in nursery, *R. ferrumequinum* (2200) in hibernation, *M. capaccinii* (1800) in hibernation, *R. mehelyi* (300) in nursery, *R. blasii* (200) in nursery, *M. emarginatus* (93) in hibernation, *R. hipposideros* (73) in hibernation, *M. daubentonii* (56) in hibernation, *M. mystacinus* (19) in hibernation, *M. bechsteinii* (six) in hibernation, *M. alcathoe* (five) in hibernation, *M. nattereri* (three) in hibernation, and *P. auritus* (one) in hibernation [36, 38].

While *Myotis* species mainly use Sulu Cave for hibernating, *Rhinolophus* species use both Sulu Cave and Kız Cave. On the other hand, *Myotis* species only use Kuru Cave for breeding and nursing, while *Rhinolophus* species use both Kuru Cave and Kız Cave. Although *M. schreibersii* is the most numerous species in Dupnisa Cave System, it does not use the cave system for breeding and nursing. However, unbred females and males of the species use Kuru Cave and Kız Cave only to spend the summer. Instead, *M. schreibersii* migrates to other suitable underground habitats in the area such as Koyunbaba Cave for breeding and nursing. In winter roosts, bat colonies are usually formed by one species. However, *M. myotis/M. blythii* and more rarely in smaller colonies *M. schreibersii/R. ferrumequinum* and *R. euryale/R. mehelyi/R. blasii* can be seen together in the same roosts (**Figure 7**). On the other hand, summer colonies are of multi-species. Only *R. hipposideros* does not mix in with other species. In winter roosts, the two sexes are found together, whereas in summer roosts the two sexes are rarely found together.

The observation that the bats in the cave system always formed colonies at the same points depending on the seasons led to the belief that the rock characteristics, temperature, and humidity are the factors affecting roost selection. Paksuz et al. [36] emphasize that the main factor shaping the use of the cave system by the bats at various degrees is the microclimate. The temperature of Sulu Cave is low for breeding while the temperature of Kuru Cave is

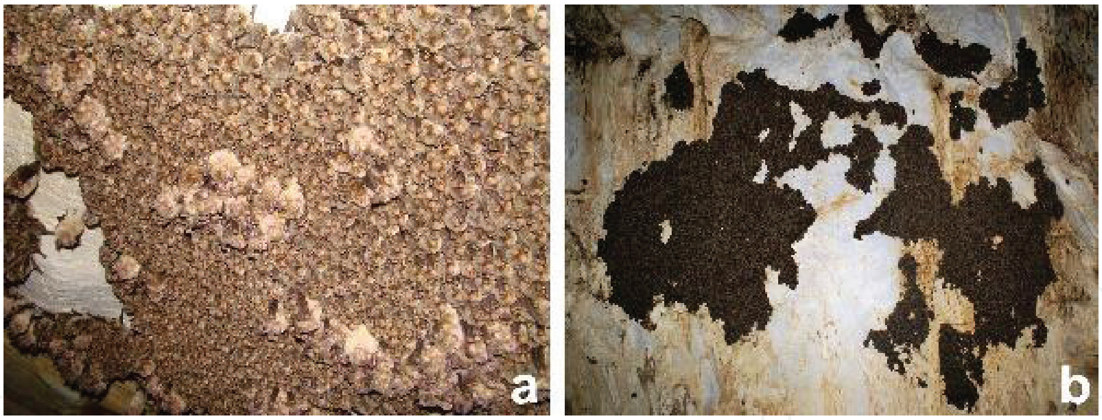

Figure 7. The hibernation colonies of the bats in Dupnisa Cave System: a mixed colony of species *M. schreibersii* and *R. ferrumequinum* (a), a large colony of *M. schreibersii* (b).

high for wintering. Although the winter temperature is higher in Kız Cave than in Kuru Cave, Kız Cave is used for hibernating by the bats. The two entrances of Kuru Cave and its connection with Sulu Cave indicate that it may be more affected by temperature fluctuations and airflows, which may be the reason why the cave is preferred less than the other caves for hibernating. The humidity in winter is variable in all the three caves, while it is similar in summer. The specific roost requirements of bat species limit the use of many caves by bats. Thus, providing alternative conditions makes caves pretty appropriate roost for bats throughout the year. Therefore, Dupnisa Cave System, which offers alternative microclimatic conditions in the different parts, may be an important opportunity for many bats because the appropriate roosts will be more limited in the future, as global warming will become increasingly prevalent.

In Dupnisa Cave System, a conservation plan is applied for the protection of the bats and the cave system according to the seasonal use of the cave system by bats. This protection plan includes an appropriate visitor schedule and gate construction. The visitor schedule was arranged according to the seasonal use of Dupnisa Cave System by bats. The entrances of cave system where tourist circuits placed in were closed with horizontal angle iron gates to control the human disturbance. The other entrances of the cave system, outside of the tourist area, have been left to the natural state to minimize the negative effects of the two doors that can disturb the bats. In addition to these, some arrangements have been made for visitors and the use of lighting system. The protection of the caves and the bats will be possible only if the precautions that are taken and the suggestion that have been made are applied carefully [38].

Paksuz and Özkan [38] stated that the seasonal usage patterns of the parts in Dupnisa Cave System by the bats are completely preserved in periods of before and after tourist mobility (**Figure 8**). The authors also emphasized that there is no decrease in the total number of the bats in Dupnisa Cave System following the opening period tourist mobility. Moreover, they found a statistically significant increase after the tourist mobility only in Kız Cave, which is closed to tourism and ungated. This increase may indicate that the bats prefer to use the caves which are not visited by humans and tourist mobility. It seems as if Kız Cave, which is

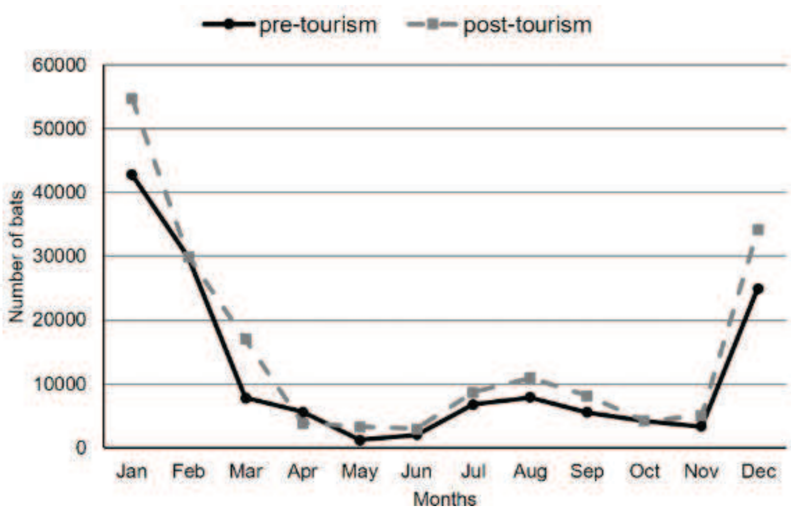

Figure 8. The monthly population sizes of the bats in the periods before and after tourist mobility in Dupnisa Cave System.

closed to tourism and ungated in Dupnisa Cave System, is a good opportunity to minimize the potential negative effects of the tourism activities in Sulu Cave and Kuru Cave on the bats. These results show that the protection program prepared for the protection of Dupnisa Cave System and bats is sustainable and must be applied meticulously.

3.3. Microclimate of Koyunbaba Cave

Koyunbaba Cave has different microclimatic conditions according to stations and seasons (**Table 2**) [37]. While the summer temperature in Koyunbaba Cave varies from 10 to 24°C, the winter temperature varies from 5 to 16°C. In summer, while the highest mean temperature is in station 4 (17.1°C), the lowest mean temperature is in station 7 (12.3°C). The highest (15.2°C) and lowest (5.2°C) mean temperatures in winter are in station 1. The humidity in Koyunbaba Cave varies from 58 to 98% depending on seasons and stations.

Stations	Roost location	Summer temp. (°C)	Winter temp. (°C)	Summer hum. (%)	Winter hum. (%)
1	Hall	17.0	9.3	66.7	68.6
2	Room	15.1	12.8	83.7	89.6
3	Corridor	12.6	8.1	75.9	86.0
4	Hall	17.1	9.4	68.9	76.2
5	Room	13.7	11.4	88.4	95.0
6	Hall	13.8	9.5	91.6	89.6
7	Corridor	12.3	7.9	75.7	80.4

Table 2. The mean microclimate data and location of the roosts in Koyunbaba Cave.

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3.4. Bats of Koyunbaba Cave

In the studies conducted until now, 11 species of bats have been recorded in Koyunbaba Cave. Five of these species belong to Rhinolophidae family (*R. ferrumequinum, R. hipposideros, R. euryale, R. mehelyi*, and *R. blasii*) and six of them belong to Vespertilionidae family (*M. myotis, M. blythii, M. emarginatus, M. capaccinii, M. schreibersii*, and *P. austriacus*) [34, 37]. The maximum number of bats recorded in a single survey in Koyunbaba Cave is 29,500 in summer, while 600 in winter. Koyunbaba Cave is used by the majority (92%) of the total bat numbers for breeding and nursing, while it is used by the minority (8%) for hibernating (**Figure 9**) [37].

Seven species constitute 98% of the bat colonies in Koyunbaba Cave, *M. schreibersii* (55%), *M. myotis/blythii* (25%), *M. capaccinii* (7%), *R. mehelyi* (6%), *R. euryale* (3%), and *R. ferrumequinum* (2%). The largest aggregations of the species recorded in a single survey in Koyunbaba Cave are *M. schreibersii* (17,710), *M. myotis/blythii* (7840), *M. capaccinii* (2230), *R. mehelyi* (1850), *R. euryale* (859), *R. ferrumequinum* (788), *M. emarginatus* (356), *R. blasii* (176), *R. hipposideros* (10), and *P. austriacus* (one) [37].

The cave is used by species of *R. ferrumequinum, R. mehelyi*, and *R. hipposideros* for both breeding/nursing and hibernating throughout the year, while it is used by species of *R. blasii, R. euryale, M. myotis/blythii, M. capaccinii, M. emarginatus*, and *M. schreibersii* for breeding/nursing in the summer (**Figure 10**).

The roosts in Koyunbaba Cave are used by bats for various degrees and purposes according to species. The rooms and halls of Koyunbaba Cave are used as summer roost, while the corridors are used as winter roost. The selection of roost location in the cave by bats differed according to the species. *R. ferrumequinum, R. hipposideros, R. euryale, R. mehelyi*, and *M. emarginatus* use all roost types, while *R. blasii, M. myotis/blythii, M. capaccinii*, and *M. schreibersii* mainly use halls [37].

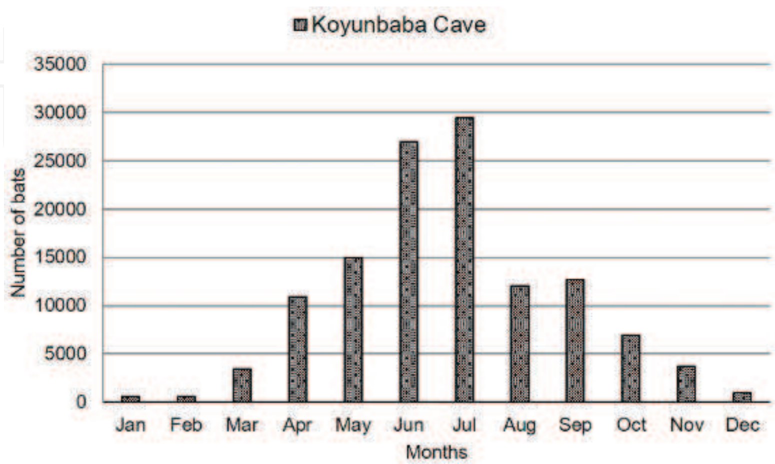

Figure 9. The maximum monthly number of bats recorded in a single survey in Koyunbaba Cave. The data were collected from 2007 to 2008.

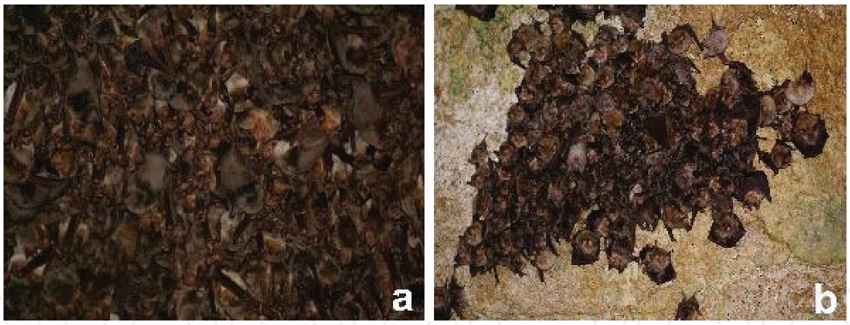

Figure 10. The breeding/nursing colonies of the bats in Koyunbaba Cave: a mixed colony of species *M. schreibersii, M. myotis, M. blythii*, and *M. capaccinii* (a), a nursery colony of Rhinolophidae family: grey(light)-colored bats are juveniles, brown(dark)-colored bats are adults (b).

These data show that Koyunbaba Cave is an important nursery roost for large populations of many bat species in the summer, as it has appropriate microclimatic conditions, large roosts, and entrances.

4. Conclusion

Turkish Thrace, located in the north-west of Turkey, served as a bridge between the Balkans, Anatolia, and Mediterranean. Thrace is one of the major biogeographic zones in Turkey and, due to its karst formation, there are many caves with different characteristics in the region. Due to these features, Thrace region, which has been an important glacial refuge for bats in the past, still provides a pretty opportunity to be hosted particularly for obligatory cave-dwelling bats. Turkish Thrace hosts large populations of many bat species [32–38].

Roost selection is essential for bats that spend more than half of their lives in roost [13]. Caves may serve as one of the most adequate roosting sites for bats because of the relatively stable microclimatic characteristics. Dupnisa Cave System and Koyunbaba Cave are the most important underground habitats for bat populations in southeastern Europe [34–38]. The hosting of large populations (56,600 hibernating bats and 11,000 breeding/nursing bats) of many bat species (18 species) is an indicator that Dupnisa Cave System is the most important shelter in the region. In addition to this, Koyunbaba Cave, which is used by a large breeding/nursing population (29,500) consisting of 11 bat species, is the most important summer roost in the region. Some bat species are listed as Near Threatened in the IUCN Red List, because of their declining populations in most of the European countries [43]. However, the populations of these species in Balkans and Turkey are stable [43], because Turkish Thrace provides many appropriate shelters to use by bats such as Dupnisa Cave System and Koyunbaba Cave.

Many species have very specific microclimatic requirements for roosts [18]. Microclimatic requirements of bats show seasonal variations according to their annual life cycle. Microclimatic conditions of roost and microclimatic requirements of species may contribute to patterns of association of bats [18, 23, 44]. Therefore, cave availability for bats is increased by providing alternative microclimatic conditions according to seasons. Most of the caves in

Turkish Thrace are appropriate shelters for winter colonies of bats and also for their nurseries. When there are alternative roosts, bats prefer the most appropriate ones to others. Therefore, Dupnisa Cave System is mainly used as a winter roost by bats, whereas Koyunbaba Cave is mainly used as a summer roost. Dupnisa Cave System and Koyunbaba Cave have different roost characteristics and microclimates and are used by different bat species for different purposes at different levels according to seasons. Therefore, they are alternative roosts to each other for bat population throughout the year. These caves, which complement each other in terms of seasonal use, are a chance for bats that have limited roosts. This makes these caves more important for the future of the bats in the region.

Growing urbanization across the world is resulting in negative impacts on bats and their key roosting habitats. Disturbance and destruction at caves is a widespread and major threat for cave-dwelling bats. Populations of some bat species are threatened globally due to human disturbance and roost lost caused by the increase in human population and land use. The protection of caves should be the most effective of bat conservation programs because a single cave can shelter thousands of bats from various species. Our findings related to these caves give some important clues for the population status and roost ecology of the bat species in Turkish Thrace. Also, it is very important for the implementation of any plans contributing to the protection of the roosts. The conservation of the caves, primarily Dupnisa Cave System and Koyunbaba Cave, whose importance for bats and other cave inhabitants was scientifically proven, is very important for the future of endangered species. Such preservation actions are made obligatory by international agreements including Turkey.

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