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Seasonal changes of cave-dwelling bat fauna, and their relationship with microclimate in Dupnisa Cave System (Turkish Thrace)

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Abstract. In the Dupnisa Cave System (Sulu, Kuru and Kız Caves in Turkey), between April 2002 and December 2005 34 surveys were conducted. The total number of species found there was 11. Five species of the Dupnisa Cave bat population constitute 99% of the fauna: *M. schreibersii* (78.0%), *M. myotis/blythii* (7.9%), *R. euryale* (6.9%), *R. ferrumequinum* (4.5%) and *M. capaccinii* (1.8%). During the winter months (November-March) the maximum number of bats recorded there amount to over 54 000, although in summer (April-October) the total was over 10 000 individuals. The different parts of the cave system are used differently according to the season (winter or summer): Sulu Cave is used almost solely by hibernating bats (70.6% vs 0.1%), Kuru Cave is used as a nursery (0.2% vs 10.6%), while Kız Cave is used both for hibernation and as a nursery (13.5% vs 5.0%). We found correlations between the species composition and the temperature recorded during the investigated season in particular parts of the system, although no influence of humidity was observed on *M.myotis*/*blythii*, *M. capaccinii*, *R. ferrumequinum* and *M. schreibersii*. Sulu Cave (the coldest in summer and in winter) is a hibernaculum, but Kuru Cave is used for breeding purposes as well as for hibernation by *R. mehelyi* and *R. euryale*. The Dupnisa Cave System is the most important shelter in theThrace region of Turkey.

Key words: Vespertilionidae, Rhinolophidae, cave-dwelling bats, Turkish Thrace, Dupnisa Cave System, hibernation, breeding, microclimate.

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I. INTRODUCTION

The most important shelters for bats in the Thrace region of Turkey are the Dupnisa Cave System, Koyunbaba Cave and Kocakuyu Cave (FURMAN & ÖZGÜL 2002, 2004). The Dupnisa Cave

System is also one of the largest winter and summer roosts in Southeast Europe and 16 bat species have been found there (ALBAYRAK 1993; BENDA & HORACEK 1998; FURMAN & ÖZGÜL 2004; PAKSUZ 2004). The system consist of 3 linked caves. These caves differs in size, number of entrances and the presence of underground streams (NAZIK et al. 1998). Microclimatic conditions in underground shelters determine the suitability as both breeding places (PLATCHER & PLATCHER 1988, RACEY et al. 1987) and hibernacula (KUNZ 1982, SPEAKMAN & THOMAS 2003). It is also important that many species have specific requirements for roosts in terms of shelter types, temperature, humidity and environmental stability (KUNZ 1982).

If a system is complex and there are several entrances present (like in Dupnisa Cave System), we can expect significant differences in microclimatic conditions both in winter and summer. This will result in bat fauna differences according to season.

The main aim of this study is to investigate the influence of microclimate (temperature and humidity) on hibernaculum and beeding place selection by bats occuring in particular parts of the Dupnisa Cave System (Sulu, Kuru and Kız cave). An additional aim is the study of the diversity of the cave system's bat fauna.

II. MATERIALS AND METHODS

The field study location, Dupnisa Cave System, is located to the south of Kırklareli-Sarpdere Village. This village is situated on the north-western flanks of Mount Mahya (1031 m) which is the highest peak of the Istranca (Yıldız) Mountains on the Turkish-Bulgarian border in the Turkish Thrace region (Fig. 1).

The Dupnisa Cave System is the second largest cave of Thrace (2720 m). There is a combination of two levels and three caves connected together (NAZIK et al. 1998):

– Sulu Cave (41°50'29" N; 27°33'25" E): 1977 m in length, 346 m above sea level, lower level with an underground stream. Sulu Cave has one corridor and one entry. The height and width of this

Fig. 1. Map of Turkish Thrace. ■ – location of Dupnisa Cave System.

corridor are up to 40 m and 15 m, respectively. There is a big hall at the end of the corridor: 125 m long, 80 m high and 35 m wide. Bats mostly hibernate near the connection with Kuru Cave between 50-500 m from the entrance. They do not roost in the big hall or the last part of the corridor.

– Kuru Cave (41°50'20"N; 27°33'26" E): 480 m in length, 400 m above sea level, upper level without a stream. Kuru Cave has two corridors and two entries. The height and width of the corridors are up to 25 m and 15 m, respectively. There is a large hall at the connection of the two corridors. Kuru Cave is connected with Sulu Cave by a narrow corridor. The altitude difference between Kuru and Sulu Cave is 40 m. Bats roost mostly in the hall and near the entry.

– Kız Cave (41°50'07" N; 27°33'28" E): 263 m in length, 412 m above sea level, upper level without stream. Kız Cave has one entry. There is a small hall after the entrance. Kız Cave is connected the Sulu Cave at two points. The height and width of Kız Cave are up to10 m and 5 m, respectively. Bats roost mostly near the entrance.

The field work was conducted by visiting the Dupnisa Cave System periodically (once every 40 days) between April 2002 and December 2005. The total number of visits was 34. Surveys were conducted when bats were at their roosts. During these visits we collected data on bat abundance and their use of the roosts in the caves throughout the year. Bats were counted in two periods: hibernation – from November to March, and nursery – from April to October. Colonies with fewer than 100 individuals were counted directly. Larger colonies were divided into small areas (quadrates), and were counted using a torch. The total number of bats in the colony was calculated using the quadrate counts and the colony area, and the margin of error was estimated as 10%.

Bats were counted and identified visually without disturbance when they were resting in the daytime. When it was difficult, they were collected by hand, nets and pliers and identified. Determination of species was carried out with reference to SCHOBER & GRIMMBERGER (1997) and DIETZ & VON HELVERSEN (2004). A pair of species, *Myotis myotis* and *M. blythii*, were treated as one species because they are difficult to identify. Similarly, *M. mystacinus* was combined into the category *M. mystacinus* group.

Temperature and humidity were measured for each cave using a digital thermometer (accurate to 0.1°C) and a hygrometer (accurate to 1%), respectively. These measurements were taken at a height of 1.5 m below the roosting site.

III. STATISTICAL ANALYSES

Two-way ANOVA tests were used to establish differences of temperature and humidity between season (winter/summer) and cave systems (Kız, Sulu and Kuru Cave).

For every ANOVA test Tukey's *post-hoc* tests were conducted, and the results were given separately for winter and summer (for both caves). To describe the relationship between frequency of species and cave systems, Correspondence Analysis (CA) was used. Frequency were log-transformed prior running statistical analysis. Hypotheses were tested at p=0.05. Statistical analysis was performed using Statistica 6.0 (StatSoft Inc.).

IV. RESULTS

Microclimate

The temperatures differ between cave systems (two-way ANOVA: $F_{2,167}=120.45$, $p<0.0001$) as well as by season ($F_{1,167}=165.75$, $p<0.0001$). In Sulu Cave during winter the mean temperature was significantly lower than that from Kuru Cave (mean±SD: 7.5±2.69°C vs 11.8±1.81°C, p=0.0002) and Kız Cave (7.5±2.69°C vs 12.1±0.92°C, p=0.0002). During summer Sulu Cave mean temperature was significantly lower than that from Kuru Cave (10.8±1.10°C vs 16.3±2.37°C, p=0.0002) and that from Kız Cave (10.8±1.10°C vs 16.0±1.54°C, p=0.0002). Humidity also differs between systems (two-way ANOVA: $F_{2,203}=3.95$, p=0.021) and seasons ($F_{1,203}=35.63$, p<0.0001). The mean humidity during winter is similar within all three systems: Sulu Cave and Kuru Cave (88.3±7.54% vs 83.9±8.02%, p=0.31), Sulu Cave and Kız Cave (88.3±2.69% vs 89.0±8.16%, p=0.9996), and Kuru and Kız (83.9±8.02% vs 89.0±8.16%, p=0.22). Mean humidity during summer is similar within all three systems: Sulu Cave and Kuru Cave (82.6±8.11% vs 79.3±10.11%, p=0.50), Sulu Cave and Kız Cave (82.6±8.11% vs 78.4±5.59%, p=0.34), and Kuru and Kız (79.3±10.11% vs 78.4±5.59%, p=0.997). (Tukey's pairwise comparision).

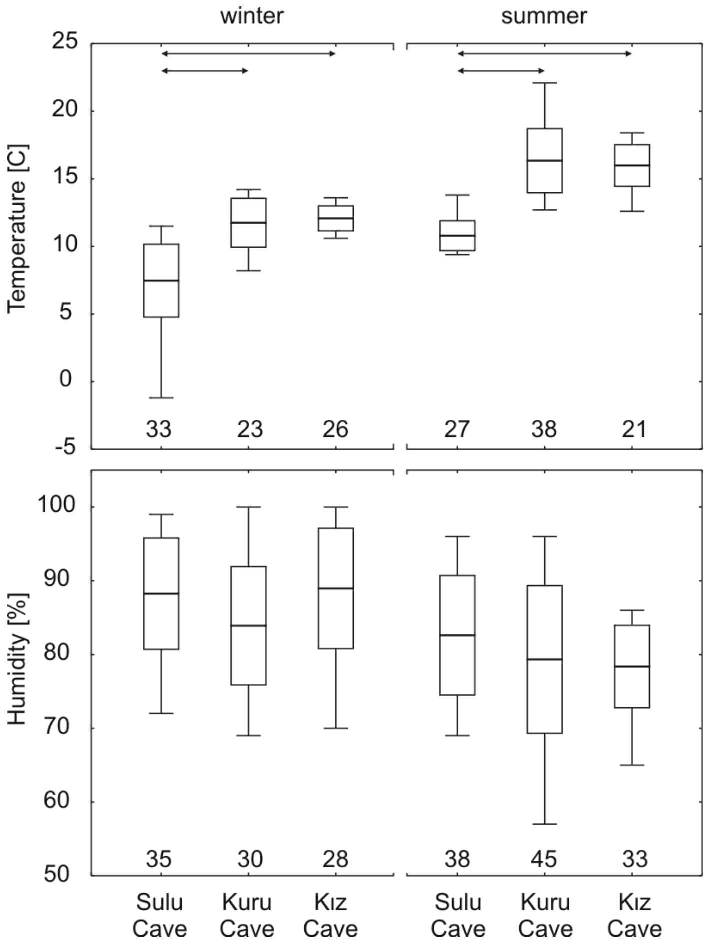

Fig. 2. Box plots of temperature and humidity in three caves: Sulu, Kuru and Kız, colected during 2002-2005. Box: Standard Deviation, horizontal line: mean, whiskers: min. – max., horizontal arrow: statistically significant differences (p-values in text).

Bats

In the Dupnisa Cave System, a total 189 843 individuals of 11 bat species were detected: *Rhinolophus ferrumequinum* (SCHREBER, 1774), *R. hipposideros* (BECHSTEIN, 1800), *R. euryale* (BLASIUS, 1853), *R. mehelyi* (MATSCHIE, 1901), *Myotis myotis* (BORKHAUSEN, 1797), *M. blythii* (THOMES, 1857), *M. emarginatus* (GEOFFROY, 1806), *M. mystacinus* (KUHL, 1817), *M. capaccinii*

(BONAPARTE, 1837)*, Miniopterus schreibersii* (KUHL, 1817) *and Plecotus auritus* (LINNAEUS, 1758). The Dupnisa Cave System is used by 84% (54 660) of the total bat population for hibernation (December-February) and by a minority 16% (10 443) of the bat population as a shelter for breeding and nursery (July-August) (Fig. 3).

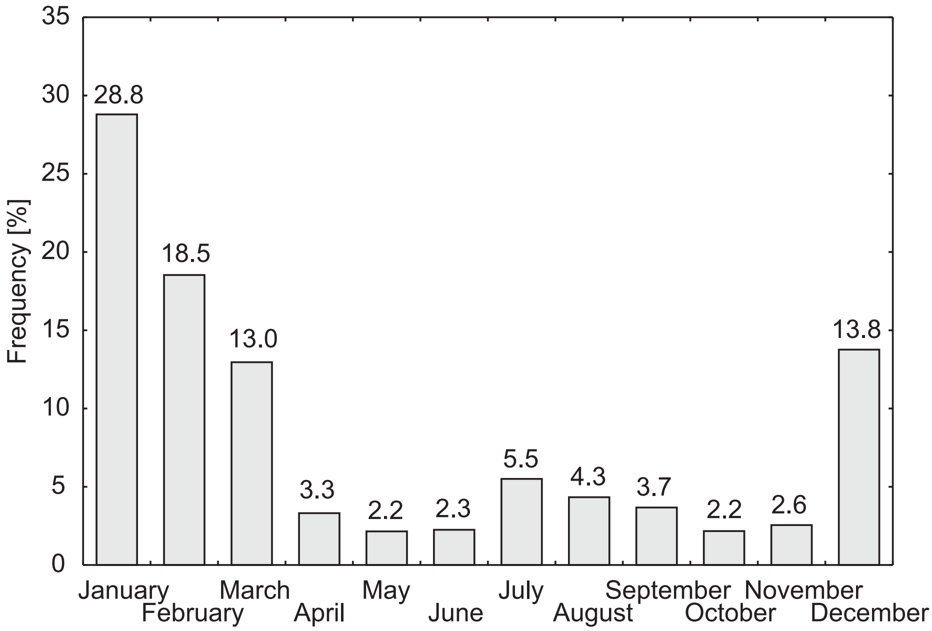

Fig. 3. Frequency of bat population using Dupnisa Cave System. Data from 2002 to 2005 year were combined, N=189 843.

Five species constitute 99% of the total bat population in Dupnisa Cave System: *M. schreibersii* (78.0%), *M. myotis/M. blythii* (7.9%), *R. euryale* (6.9%), *R. ferrumequinum* (4.5%) and *M. capaccinii* (1.8%). Five species constitute less than 1%: *R. mehelyi*, *R. hipposideros*, *M. emarginatus*, *M. mystacinus group*, *P. auritus*.

The biggest winter aggregations are formed by *M. schreibersii* – 36 000 individuals, *M. myotis/blythii* – 4 300 ind., *R. ferrumequinum* – 2 200 ind., *M. capaccinii* – 1 800 ind., and less numerous *R. euryale* – 800 ind., and *R. mehelyi* – 300 ind. During the breeding period the most numerous are *R. euryale* – 2 500 ind., *M. schreibersii* – 2 400 ind., *M. myotis/blythii* – 1 300 ind., *R. ferrumequinum* – 1 000 ind., and rarely *M. capaccinii* – 500 ind., and *R. mehelyi* – 300 individuals (Table I)

Different parts of the Dupnisa Cave System are used by bats to various degrees: Sulu Cave was used only during the winter, Kuru Cave only in the breeding/nursery period, and Kız Cave was used both during the winter and summer.

The total inertia of the CA was equal to 0.379 (χ^2= 69.94; df=30; $p<0.0001$), and the first two axes summarize 88.8% of the inertia. Axes F1 and F2 were responsible for 65.9% and 22.9% of the total inertia, respectively. F1 distinguished between Sulu Cave (winter) and Kız Cave (winter and summer), these contributed the most to the axis: 0.856, 0.857 and 0.834, respectively. Furthermore, species such as *R. mehelyi* (0.978) and *R. euryale* (0.884) differ from *M. capaccinii* (0.964) and *M. myotis/blythii* (0.876).

F2 distinguished between Kuru Cave (winter and summer) and Sulu Cave (summer), these contributed the most to the axis: 0.950, 0.338 and 0.210, respectively. *R. hipposideros* (0.850) also differ from *M. schreibersii* (0.756).

Table I

Maximum species numbers recorded in the Dupnisa Cave System; hib – hibernation period (November-March); nur – nursery period (April-October)

	2002		2003		2004		2005	
	Hib	Nur	Hib	Nur	Hib	Nur	Hib	Nur
Sulu Cave								
R. ferrumequinum	947	–	1 770	–	2246	–	530	–
R. hipposideros	–	–	17	–	11	–	5	–
R. euryale	–	–	–	–	–	–	1	–
R. mehelyi	–	–	–	–	–	–	–	–
M. myotis/blythii	1 575	67	3 075	–	4 305	1	1 863	–
M. emarginatus	–	–	–	–	93	–	72	–
M. mystacinus	2	–	–	–	12	–	19	–
M. capaccinii	196	21	298	–	1 764	–	144	–
M. schreibersii	21 402	15	28 000	–	36 128	1	27 220	39
	24 122	103	33 160	–	44 559	2	29 854	74
Kuru Cave								
R. ferrumequinum	–	659	1	928	8	1	3	489
R. hipposideros	20	35	56	13	68	7	69	31
R. euryale	–	900	44	2 456	46	2 030	54	520
R. mehelyi	–	–	–	28	14	–	2	–
M. myotis/blythii	10	896	2	1 319	12	1 340	–	277
M. emarginatus	–	–	–	–	–	–	–	–
M. mystacinus	–	–	–	–	–	–	–	–
M. capaccinii	6	50	–	360	1	500	–	17
M. schreibersii	17	1 520	–	2 365	–	1 538	–	1 553
	54	4 060	103	7 469	149	5 416	128	2 887
Kız Cave								
R. ferrumequinum	28	200	–	261	–	20	7	310
R. hipposideros	–	–	–	–	–	–	–	–
R. euryale	720	920	680	1 164	397	1 600	167	1 170
R. mehelyi	232	38	40	272	45	290	25	48
M. myotis/blythii	–	16	–	9	–	–	–	20
M. emarginatus	–	–	–	–	–	–	–	–
M. mystacinus	–	–	–	–	–	–	–	–
M. capaccinii	–	–	–	–	–	–	–	–
M. schreibersii	6 342	190	4 200	1 250	9 510	20	2 830	1 480
	7 322	1 364	4 920	2 956	9 952	1 930	3 029	3 028

Correspondence analysis of the caves and bats gave three groups (Fig. 4):

– Kız Cave (winter and summer period) determined by *R. euryale* and *R. mehelyi*;

– Sulu Cave (winter period) and Kuru Cave (summer period) determined by *M. myotis/M. blythii*, *M. cappacinii*, *R. ferrumequinum* and *M. schreibersii*;

– Kuru Cave (winter period) determined by *R. hipposideros*.

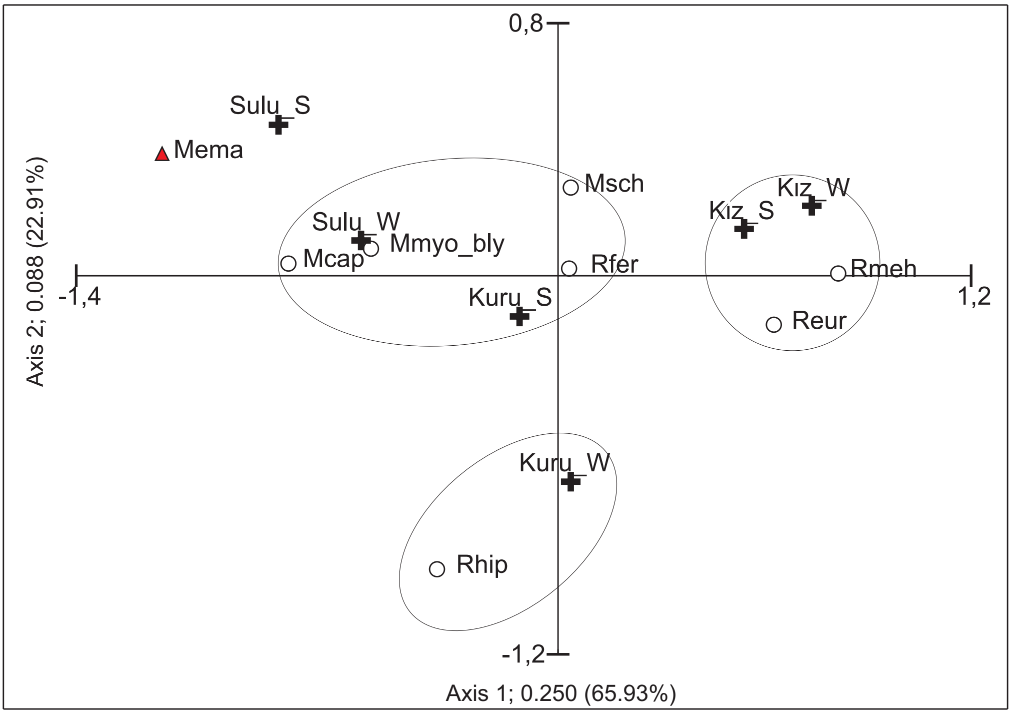

Fig. 4. Biplot of CA: projection of species (open circle) and cave during particular periods (cross). The frequency of *M. emarginatus* occurrences was added as an additional point (triangle). Mcap – *M. capaccinii*, Mema – *M. emarginatus*, Mmyo_bly – *M. myotis/M. blythii*, Msch – *M. schreibersii*, Reur – *R. euryale*, Rfer – *R. ferrumequinum*, Rhip – *R. hipposideros*, Rmeh – *R. mehelyi*, W – winter period, S – summer period.

IV. DISCUSSION

Ten species (or species pairs) of bats has been recorded within Dupnisa Cave System: *R. hipposideros*, *R. ferrumequinum*, *R. euryale*, *R. mehelyi*, *M. myotis*/*M. blythii*, *M. capaccinii*, *M. emarginatus*, *M. mystacinus*, *M. schreibersii*, and also *P. auritus*.

We did not find any of the species mentioned in earlier articles such as: *M. daubentonii* and *P. austriacus* (Furman & Özgül 2004), and *M. nattereri, M. bechsteinii* and *B. barbastellus* (Albayrak 1993; Benda and Horaček 1998).

Untill now, 24 (in the literature) bat species have been found in the Turkish Thrace, and 16 of these are associated with caves. All of which have been recorded within Dupnisa Cave.

Bats use the Dupnisa Cave System to various degrees, depending on the season (winter/summer). Each part of the system differs from the other in size and volume of corridors and chambers, number of exits, and as a result, in microclimatic conditions. These charactersitsitcs determine the winter fauna (KUNZ 1982; SPEAKMAN & THOMAS 2003) as well as the presence of nursery colonies (PLACHTER & PLACHTER 1988; RACEY et al. 1987). Sulu Cave is used only as a hibernaculum, Kuru Cave mainly as a breeding location, although Kız Cave is used as both a hibernaculum and a breeding place. The humidity was variable although the mean values do not differ significantly between the investigated caves and seem to have no influence on the bat faunas. Correspondence analysis has differentiated groups described by the temperature preferences of each bat species. Sulu Cave is only used as a hibernaculum, and 4 of the most numerous species with wide thermal preferences hibernate there: *M. schreibersii* hibernate at 4-10°C (ALCALDE & ESCALA 2000), *M. myotis/blythii*: 0-12°C (GÜTTINGER et al. 2001), *M. capaccinii*: 6-10°C (SPITZENBERGER & VON HELVERSEN 2001), *R. ferrumequinum*: 5-12°C (GAISLER 2001a).

The absence of nursery colonies within this part of the cave system can be explained by temperatures too low to breed (PLACHTER & PLACHTER 1988; RACEY et al. 1987, RODRIGUES et al. 2003). Numerous colonies of *M. myotis*/*blythii* are not known from caves with low temperatures (PANDURSKA 1998; GAS & POSTAWA 2001). Kuru Cave is used by small numbers of bats as a hibernaculum, with *R. hipposideros* as the dominant species whose optimum temperature oscilates from 2°C to 14°C (ROER & SCHOBER 2001). This cave is significantly warmer compared to Sulu Cave and temperature amplitudes are larger than recorded in Kız Cave. This could explain the lack of species in Kuru Cave demanding higher temperatures and stable conditions. On the other hand Kız Cave is used to the same degree in summer and winter by *R. euryale* and *R. mehelyi*, species that prefer high temperatures both during hibernation (10-12.5°C GAISLER 2001b; 15-16°C – GAISLER 2001c), and breeding (12-26°C GAISLER 2001b; GAISLER 2001c). Kuru Cave is also used as a breeding location by *R. euryale,* and at present by very low numbers of individuals of *R. mehelyi,* and a large colony of *R. ferrumequinum.* Kız Cave and Kuru Cave differ from each other only in the maximum temperature values, respectively 18°C and 22°C. This may be enough to differentiate their bat faunas. The Dupnisa Cave System is the largest hibernaculum in the Turkish Thrace – 54 000 animals hibernate here.

The most numerous species hibernating there is *M. schreibersii,* whose number exceeds 45 000 individuals. In other caves from this region such large numbers have not been recorded – this is the only one with such a large hibernaculum for this species (FURMAN & ÖZGÜL 2002, 2004). The nearest aggregations of this size are known from Bulgaria: Djavolskoto Gărlo cave > 40 000 ind., (Rodopes Mts.) and Parnicite cave > 60 000 ind. (Predbalkan) (BENDA et al. 2003).

M. myotis/blythii is a considerably less numerous species hibernating in Dupnisa Cave System (about 4 300 ind.). FURMAN & ÖZGÜL (2004) provided an even higher number – about 6 000 ind. Apart from the aggregation at Kocakuyu Cave where in winter the number of bats reaches 3 300 ind. this species does not form larger hibernacula in this region (FURMAN & ÖZGÜL 2002). Aggregations of *R. ferrumequinum* and *M. capaccinii* recorded from the Dupnisa System are also the largest in the Turkish Thrace, respectively – 2 200 ind. and 1 700 ind. (FURMAN & ÖZGÜL 2002, 2004).

The winter aggregation of *R. euryale* at Dupnisa Cave includes about 700 ind.; and only larger ones are known from Koyunbaba Cave (about 1 300 ind.) and Bağlar (about 700 ind.) (FURMAN & ÖZGÜL 2004). Authors in earlier surveys have shown considerably higher numbers of bats of this species from the Kız part of the Dupnisa cave complex (4 600 ind.). Winter aggregations of *R. mehelyi* amount to 230 ind. and have not been recorded in such large numbers from this cave before. An interesting record concerns *M. emarginatus*, which has not been found in such a large aggregation until now (to 93 ind.) and the *M. mystacinus* group with about 19 ind./season. These species are found very rarely in the other caves of the Turkish Thrace (FURMAN and ÖZGÜL 2002, 2004).

The Dupnisa System is also used by large numbers of bats during the breeding season, but it is not to the same degree as during winter – over 10 000 individuals.

The largest aggregations recorded from the Turkish Trace come from Koyunbaba and amount to 23 000 ind., they are less numerous in Çilingoz Cave (about 4 800 ind.), Kıyıköy Cave (about 4 600 ind.); and several others exceeding 1000 ind. (FURMAN & ÖZGÜL 2002, 2004). In the Dupnisa System the most numerous during breeding season are *M. schreibersii* (to 3 600 ind.). The largest breeding aggregation of this species is in Koyunbaba Cave (about 6 000 ind.) (FURMAN & ÖZGÜL 2004), and in Gökçeali Cave, Yaylacık Cave and Çilingoz the number exceeds 1000 ind. (FURMAN & ÖZGÜL 2002). The Dupnisa System consists of the largest breeding aggregation of *R. euryale* (about 3 600 ind.). Smaller colonies are known from Kıyıköy Cave (3 500 ind.), Koyunbaba Cave (2 800 ind.) and Çilingoz (2 500 ind.). Within the Mermer Cave and Bağlar Cave the species does not exceed 2000, although in other places they are found in considerably smaller numbers and very rarely reach 500 ind. (FURMAN & ÖZGÜL 2002, 2004). *M. myotis/blythii* breeding aggregations reach 1 300 ind. and is the third largest in the region: in Koyunbaba Cave up to 10 000 ind. have been recorded, in Gökçeali Cave up to 2 200 ind., and the remaining sites have considerably smaller numbers and amount to several hundred individuals (FURMAN and ÖZGÜL 2004). The *R. ferrumequinum* aggregation from the Dupnisa System is the most impressive (1200 ind.), other than this location numbers rarely exceed 500 of individuals (FURMAN and ÖZGÜL 2004). Less numerous aggregations are formed by *M. capaccinii* (up to 500 ind.), and other than Koyunbaba Cave where the colony number is 4 000 ind. (FURMAN & ÖZGÜL 2004), and Çilingoz where it is up to 350 ind. (FURMAN & ÖZGÜL 2002), this species is generally considerably less numerous. The breeding aggregation of *R. mehelyi* (up to 300 ind.) was previously almost never recorded in the Turkish Thrace (BENDA & HORAČEK 1998; FURMAN & ÖZGÜL 2002, 2004). This makes the Dupnisa Cave System one of the most important shelters in the Balkans for endangered bat species living in caves, both as a hibernaculum and breeding location, and supports the data put forward by FURMAN & ÖZGÜL (2004). Considering that all the bat species in the Dupnisa Cave System belong to the red list of endangered species prepared by IUCN (International Union of Conservation of Nature and Natural Resources) any actions taken are of great importance. The conservation of the Dupnisa Cave System, is very important for the future of endangered species, whose preservation is made obligatory by international agreements such as the Eurobats Agreements. The preservation of the bats themselves and these caves, which are accessible to tourists only by appointment and by strict observation of the precautionary rules.

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