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Distribution and conservation status of cave-dwelling bats in the Romanian Western Carpathians

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Abstract. The limestone regions of the Pădurea Craiului, Bihor and Trascău Mountains are home to the largest and most important bat aggregations in Romania. In the last few decades only sporadic information on cave-dwelling bat fauna of the regions was published, with no large-scale studies undertaken. The present study is meant to fill this information gap. Between 2010 and 2012 we visited 60 caves, located in the territory or in the close proximity of six Natura 2000 sites. Data collection was done during the summer and winter periods, with the identification of resident bat species, and estimation or counting of large aggregations. In the study area we found two thirds of the 31 species of the Romanian bat fauna. The largest winter aggregations are formed by *Miniopterus schreibersii*, large *Myotis*, and *Pipistrellus pipistrellus*, the former two having also the largest maternity colonies. The cave with by far the largest winter aggregation is Huda lui Papară, with nearly 100,000 bats hibernating. Here, the largest colonies are formed by *M. schreibersii* (≈60,000 bats), and *P. pipistrellus* (≈25,000 bats). Similarly important are the winter aggregations from Peştera cu Apă din Valea Leşului and Peştera Meziad, the former being also the cave with the greatest diversity (14 species present). The largest maternity colonies (>5,000 bats) are found in Peştera de la Aştileu, Peştera Ţiclului and Avenul de la Betfia. The main threats identified in relation to caves are uncontrolled tourism, vandalism, unsuitable cave closings, deforestation (or in general, habitat modification), water pollution and illegal waste depositing. In order to ensure long-term protection of resident bats, a series of concrete conservation actions will be undertaken in the most important 40 caves of the region.

Cave-dwelling bats, distribution, Bihor, Pădurea Craiului, Trascău, conservation actions

Introduction

The extensive limestone areas of Romania include more than 12,000 caves (Bleahu et al. 1976), many of which offer temporal or permanent roosting possibilities for bats. The presence of these caves is enhanced with a great diversity of natural and semi-natural habitats, contributing in turn to the presence of one of the most important bat populations in Europe. The bat species identified in these areas, but also all over Romania's limestone regions, had a major contribution in the designation of Natura 2000 sites. In the western part of Romania, there are three large (>350 km^2) and several smaller (<20 km^2) Natura 2000 sites, located in the territories or in the close proximity of three mountain ranges: the Pădurea Craiului, Bihor and Trascău Mountains (Fig. 1). These three mountain ranges include the most important limestone areas of the country, and are also home to the largest and most important cave-dwelling bat aggregations in Romania. These areas are also characterized by high bat diversity.

The first data regarding the cave-dwelling bat fauna of the area was published by Petényi (1854), already indicating the presence of three species: *Rhinolophus hipposideros*, *Myotis myotis*

and *Miniopterus schreibersii*. Dumitrescu et al. (1963) published the first large database of the Romanian bat fauna, which included 30 caves from Western Romania, with current and fossil distribution of 13 bat species in these caves. Systemic research started with the study of Dobrosi & Gulyás (1997), which surveyed 47 roosts in the Pădurea Craiului and Bihor Mountains and demonstrated the relationship between summer roosts in Hungary and hibernation roosts in Romania by ringing of *Rhinolophus ferrumequinum* individuals. Also in this period the Romanian Bat Protection Association started several large inventory and long-term monitoring projects in the area, with more than 60 important cave roosts regularly visited. However, the only publication that included partial results of these surveys was that of Nagy et al. (2003), offering details about less than ten caves.

Considering the observed (but so far not published) population sizes and species richness in the region, and also the sudden and sometimes dramatic changes occurring in caves and their surrounding habitats, it is certain that the lack of published data greatly hinders the adequate protection of bats and the long-term management of caves and Natura 2000 sites. The current study is meant to fill this information gap by presenting data collected in the territory of six Natura 2000 sites, located in the area or in the close proximity of the Pădurea Craiului, Bihor, and Trascău Mountains. The data set will also contribute to the proper management of the Natura 2000 sites in question, as well as to the monitoring and conservation process of bat species.

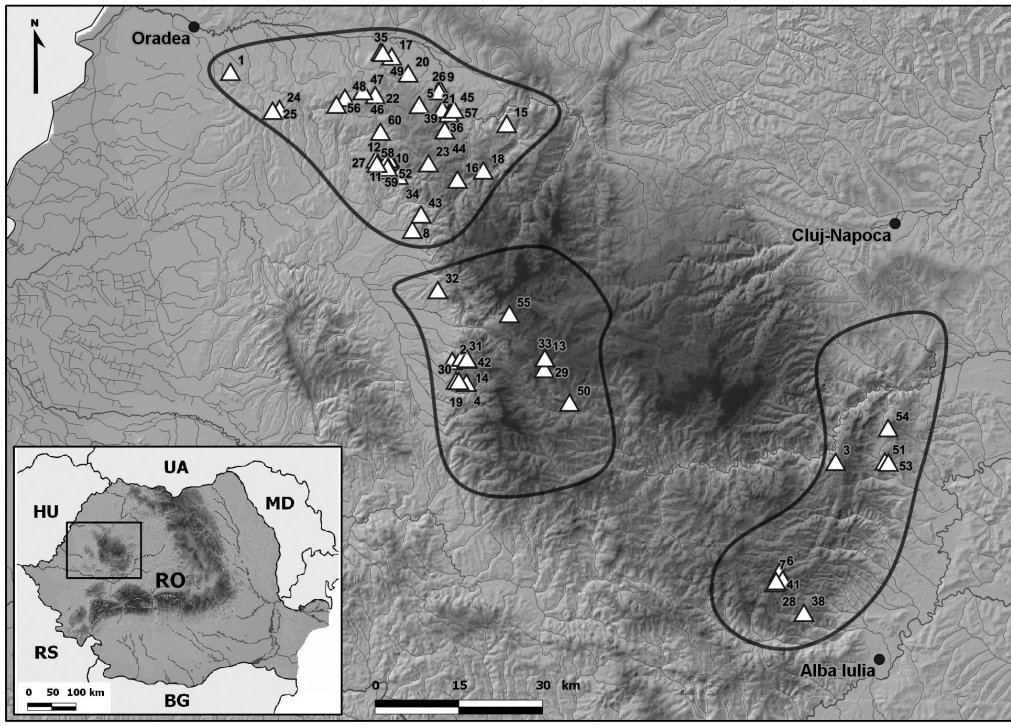

Fig. 1. Geographical position of the 60 caves investigated in the Romanian Western Carpathians in the period 2010–2012. Encircled areas (from left to right) correspond to the Pădurea Craiului, Bihor and Trascău Mountains. Numbers correspond to those in Tables 1 and 3.

Material and Methods

The study was conducted in the Romanian Western Carpathians, in the Pădurea Craiului, Bihor and Trascău Mountains (Fig. 1). These mountain ranges are characterized by extensive limestone areas rich in caves (0.79 caves per km^2, Bleahu et al. 1976), temperate moderate climate, diverse landscape and a maximum altitude of 1,849 m a. s. l. Habitat composition includes coniferous, deciduous and mixed forests, bushes, grasslands, agricultural areas, wetlands and/or other water bodies, as well as rural habitats.

We investigated 60 caves in the study area (Fig. 1, see also Table 3), that were selected based on previous knowledge of bat presence (ex. Dumitrescu et al. 1963, Nagy et al. 2003), and in some cases added with new caves, based on recommendations from custodians and/or caver associations. Geographic position (latitude, longitude, altitude) was recorded using a Garmin 60CSx GPS. Cave parameters (entrance size, length, max. height, min. height) and characters (presence of water surfaces, chambers, multiple levels, etc.) were noted in standard survey forms. The studied caves are located between 230 and 1,316 m a.s.l. (altitudinal range: 1,086 m), with the following groups: 34 caves below 500 m, 18 caves between 500 and 1,000 m, and eight caves above 1,000 m. We also investigated possible disturbance factors in relation to caves and their bat fauna, and also natural or human induced changes inside caves (e.g. unsuitable cave closings) and the surrounding habitats (e.g. extensive deforestation). Cave locations, altitude and major disturbance factors are summarized in Table 3. We refer to caves using their full Romanian official name, with "Peştera" meaning "cave" and "Aven" meaning "pothole".

Identification of the cave-dwelling bat fauna was done between February 2010 and March 2012, during the summer (May–August) and winter (November–March) periods, yielding a total of 146 site visits. The duration of observations was reduced to minimum by counting large colonies (>100 bats) based on photographs and subsequent PC work. Species identification was done using morphological traits based on Dietz et al. (2009), and Jére et al. (2010). In some cases or in large aggregations it was not possible to distinguish between cryptic species. In such cases (e.g. *Myotis myotis*, *M. oxygnathus*, *M. mystacinus*, *M. brandtii*, *Plecotus* sp.), we indicated their presence by grouping them as large *Myotis*, *M. mystacinus* group (Benda & Tsytsulina 2000) and *Plecotus* sp. respectively, while retaining species level where identification was possible. We calculated species frequencies based on 25 caves (summer site visits) and 60 caves (winter site visits), respectively. Species abbreviations in figures and tables are as follows: *Rfer – Rhinolophus ferrumequinum*, *Rhip – Rhinolophus hipposideros*, *Reur – Rhinolophus euryale*, *Mdau – Myotis daubentonii*, *Mdas – Myotis dasycneme*, *Mmys – Myotis mystacinus*, *Mmys* group – *Myotis mystacinus* or *Myotis brandtii*, *Mnat – Myotis nattereri*, *Mema – Myotis emarginatus*, *Mbec – Myotis bechsteinii*, large *Myotis* – *Myotis myotis* and *Myotis oxygnathus*, *Nnoc – Nyctalus noctula*, *Eser – Eptesicus serotinus*, *Enil – Eptesicus nilssonii*, *Vmur – Vespertilio murinus*, *Ppip – Pipistrellus pipistrellus*, *Paur – Plecotus auritus*, *Paus – Plecotus austriacus*, *Plec* sp. – unidentified *Plecotus* bat, *Bbar – Barbastella barbastellus*, *Msch – Miniopterus schreibersii*.

Results

During the investigation of 60 caves in the Romanian Western Carpathians, we identified with certainty 20 of the Romanian 31 bat species, representing all three bat families, and nine genera. Also, we observed species that could only be categorized into *M. mystacinus* group, or *Myotis* sp. Eight caves had no bat presence, with the remaining 52 being occupied seasonally or all year long. 27 caves had five or more bat species present, and three caves had a bat fauna of 10 or more species, the most diverse being Peştera cu Apă din Valea Leşului, in the Pădurea Craiului Mountains, with 14 species present (see a separate section for caves). A full list of caves and data on bat presence are given in Table 1. Bat species found during the study include typical cave-dwellers (e.g. *Rhinolophus* species, large *Myotis* and *M. schreibersii*), but also species that were identified only in winter (e.g. *M. bechsteinii*, *P. pipistrellus*, *B. barbastellus*, Table 2). Overall, the most frequent bat species and species groups are: *R. hipposideros* (0.68), *R. ferrumequinum* (0.65), large *Myotis* (0.55), *B. barbastellus* (0.27) and *M. schreibersii* (0.27). However, when considering different periods of the year, the frequencies are altered, in accordance with specific ecological traits of bats. In this way, bat species that do not entirely leave the cave environment after hibernation (large *Myotis*, *M. schreibersii*), or species that are less frequent in the area during hibernation, but gather in caves to form maternity colonies (e.g. *R. euryale*), make up a large part of the summer bat fauna. Other species, even if they are typical cave-dwellers during

Table 1. Distribution of bat species between 2010 and 2012, in the 60 caves investigated in the Romanian Western Carpathians. Numbers in the first column correspond to those in Fig. 1 and Fig. 3. In case of the two roosts named “Peştera Calului”, 1 refers to a cave in the Trascău Mountains (Ciumerna Plateau), and 2 refers to a cave in the Pădurea Craiului Mountains (Meziad Valley). Species abbreviations are given in Materials and methods. Presence is indicated with an asterisk (*). The large *Myotis* column refers to both species being present, with the total species number receiving a +1 in such cases. Total number of species present in each cave is also indicated, with eight caves having no bat fauna

no.	roost	*Rfer*	*Rhip*	*Reur*	*Mdau*	*Mdas*	*Mnat*	large *Myotis*	*Nnoc*	*Ppip*	*Paur*	*Paus*	*Bbar*	*Msch*	other	total spp.
1	Avenul de la Betfia	*	*					*						*		5
2	Gaura Fetii															–
3	Huda lui Papară	*	*		*		*	*	*	*			*	*		10
4	Peştera Băiţa		*													1
5	Peştera Bătrânului	*	*		*			*							*Mema*, *Mbec*	7
6	Peştera Bisericuţa	*	*					*				*				5
7	Peştera Calului[1]															–
8	Peştera Calului[2]	*	*	*				*		*	*	*		*		9
9	Peştera Caprei						*									1
10	Peştera care Cântă															–
11	Peştera Ciur Izbuc	*	*													2
12	Peştera Ciur Ponor	*	*										*			3
13	Peştera Coiba Mare	*						*								3
14	Peştera Coliboaia	*	*					*						*		5
15	Peştera cu Apă de la Bulz	*	*					*						*		5
16	Peştera cu Apă din Valea Leşului	*	*	*	*	*		*	*		*		*	*	*Mema*, *Enil* *Vmur*	14
17	Peştera de la Aştileu	*	*		*			*						*		6
18	Peştera de la Faţa Apei	*	*					*								4
19	Peştera de la Fânaţe	*	*	*				*						*		6
20	Peştera de la Gălăşeni	*	*	*			*									4
21	Peştera de la Izvor	*	*										*			3
22	Peştera de la Izvorul lui Gábor						*						*		*Plec* sp.	3
23	Peştera de la Întorsuri	*	*					*					*			5
24	Peştera de la Stracoş	*	*	*				*								5
25	Peştera de la Tăşad			*				*								3
26	Peştera de la Vadu Crişului	*	*					*								4
27	Peştera de la Valău							*								2

no.	roost	*Rfer*	*Rhip*	*Reur*	*Mdau*	*Mdas*	*Mnat*	large *Myotis*	*Nnoc*	*Ppip*	*Paur*	*Paus*	*Bbar*	*Msch*	other	total spp.
28	Peştera Diaclază din Hăldăhaia		*													1
29	Peştera din pârâul Hodobanei		*					*			*				*Mmys*, *Mmys* group	6
30	Peştera din Secătura	*	*					*			*					5
31	Peştera Drăcoaia	*	*										*	*		4
32	Peştera Ferice	*	*											*		3
33	Peştera Gârdişoara															–
34	Peştera Gruieţului	*	*					*					*			5
35	Peştera Igriţa	*	*				*	*								5
36	Peştera Izbândiş	*	*					*					*			5
37	Peştera Liliacului										*					1
38	Peştera Liliecilor din Cheile Ampoiţei	*		*				*					*	*	*Eser*, *Plec* sp.	8
39	Peştera lui Cotuna	*	*					*			*		*			6
40	Peştera lui Doboş	*	*													2
41	Peştera Mare din Hăldăhaia		*													1
42	Peştera Măgura	*	*	*				*						*		6
43	Peştera Meziad	*	*	*				*	*	*	*		*	*	*Mmys* group, *Mbec*, *Plec* sp.	13
44	Peştera Moanei	*			*			*					*		*Eser*	6
45	Peştera Napiştileu	*	*					*					*			5
46	Peştera Osoi	*														1
47	Peştera Osoi nr. 2					*	*									2
48	Peştera Peşteraşul															–
49	Peştera Pişniţa															–
50	Peştera Poarta lui Ionele		*													1
51	Peştera Puculea		*												*Eser*	2
52	Peştera Rece															–
53	Peştera Sandului		*		*											2
54	Peştera Ştudenţilor															–
55	Peştera Şura Boghii	*	*					*								4
56	Peştera Ţiclului	*	*	*			*	*						*	*Mbec*	8
57	Peştera Ungurului	*	*					*	*			*	*	*		8
58	Peştera Vacii	*	*					*				*	*		*Mmys* group	7
59	Peştera Vacii din Cheile Albioara	*														1
60	Peştera Viduţa nr. 2	*	*					*						*		5

hibernation, leave the cave environment to form nurseries in buildings (ex. *R. hipposideros*) or tree holes (ex. *B. barbastellus*), and in this way contribute in lesser or no extent to the summer diversity in caves (Table 2).

Distribution of bats indicates a preference towards low and medium altitudes, with 16 species observed below 500 m, 18 species between 500 and 1,000 m, and only seven species above 1,000 m. Altitudinal range for all species is indicated in Table 2. When viewed for separate periods of the year, this altitudinal separation becomes more obvious: even though during the winter there are several species hibernating above 1,000 m (Fig. 2), during the formation of nursery colonies in the summer, no typical cave-dweller bat is found above this altitude. The only record comes from a single individual of *R. hipposideros*, present during the summer period in Peştera Mare din Hăldăhaia, at 1,139 m. Preference of low altitudes is also indicated by the fact that all major nursery colonies (>1,000 bats) identified during the study are located below 600 m.

Summer bat fauna

The summer bat fauna of the studied limestone regions is composed mainly of those species that typically form nurseries in caves. In all, nine species were identified, four of which form important nurseries throughout the Romanian Western Carpathians: *R. euryale*, large *Myotis* and *M. schreibersii*. The size of nursery colonies ranges from a few hundred individuals (in case of *R. euryale*), to a maximum of 7,000 bats (in case of mixed colonies of large *Myotis* and *M. schreibersii*). The other five species identified in the summer period (*R. ferrumequinum*, *R. hipposideros*, *M. mystacinus* group, *N. noctula* and *E. serotinus*) were found only in small numbers, never exceeding ten individuals. In case of 12 caves we identified important nursery colonies (Fig. 3, see also Table 3).

R. euryale, first indicated in the region by Chappuis and Jeannel in 1924 (Barti 2005), is present on the margins and lowest parts of the Romanian Western Carpathians during the summer period

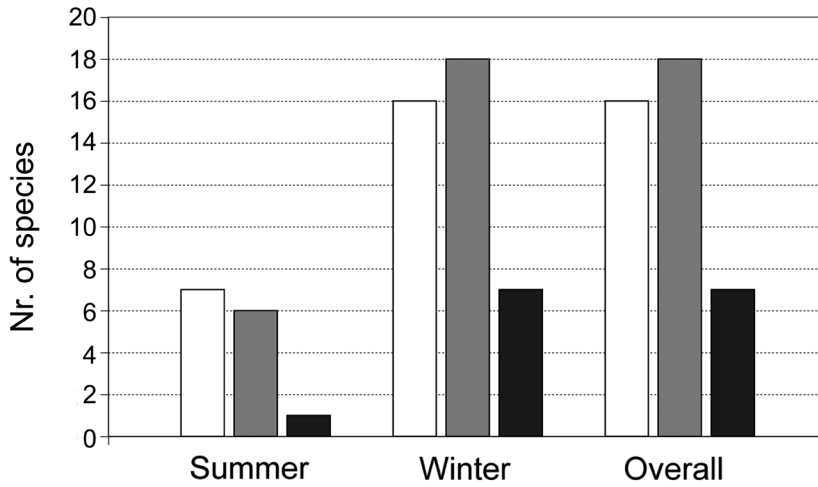

Fig. 2. Altitudinal distribution of bat species identified in the Romanian Western Carpathians in the period 2010–2012. Note the low presence of bat species above 1,000 m, as well as the lowest presence (1 species, 1 individual) during the summer period above 1,000 m. Legend: white – 230–500 m a. s. l.; pale grey – 500–1,000 m a. s. l.; dark grey – 1,000–1,316 m a. s. l.

Table 2. Species frequencies in different periods of the year, as well as overall, observed between 2010 and 2012, in the 60 caves of the Romanian Western Carpathians. Summer and winter frequencies were calculated for 25, respectively 60 caves. Highest frequencies are marked with an asterisk (*). Altitudinal range is also indicated. Most important bat aggregations of each species and their location are specified. Species abbreviations are given in Materials and Methods

species	frequency (summer)	frequency (winter)	frequency (overall)	altitudinal range (m)	most important summer aggregations	most important winter aggregations
Rfer	0.20*	0.62*	0.65*	230–1,316	14 bats, Peştera de la Fânaţe	775 bats, Huda lui Papară
Rhip	0.20*	0.65*	0.68*	230–1,316	10 bats, Peştera Puculea	168 bats, Huda lui Papară
Reur	0.32*	0.08	0.17*	230–1,000	>250 juveniles, Peştera de laTăşad	130 bats, Peştera de la Gălăşeni
Mdau	–	0.10	0.10	230–1,000	–	–
Mdas	–	0.03	0.03	230–1,000	–	–
Mmys	–	0.02	0.02	1,000–1,316	–	–
Mmys group	0.04	0.03	0.05	230–1,316	–	–
Mnat	–	0.12	0.12	230–1,000	–	–
Mema	–	0.03	0.03	500–1,000	–	–
Mbec	–	0.05	0.05	230–1,000	–	–
large *Myotis*	0.36*	0.53*	0.55*	230–1,316	≈5,000 bats, Huda lui Papară	4,419 bats, Huda lui Papară
Nnoc	0.04	0.07	0.07	230–1,000	–	2,500 bats, Peştera Ungurului
Eser	0.08	0.03	0.05	500–1,000	–	–
Enil	–	0.02	0.02	500–1,000	–	–
Vmur	–	0.02	0.02	500–1,000	–	–
Ppip	–	0.05	0.05	230–1,000	–	33,800 bats, Huda lui Papară
Paur	–	0.12	0.12	230–1,316	–	–
Paus	–	0.07	0.07	230–1,316	–	–
Plec sp.	–	0.05	0.05	230–1,000		
Bbar	–	0.27*	0.27*	230–1,000	–	36 bats, Huda lui Papară
Msch	0.48*	0.18*	0.27*	230–1,000	3,030 bats, Peştera Meziad	58,000 bats, Huda lui Papară

exclusively. Out of the eight caves inhabited, the most important are Peştera Calului (Meziad Valley), Peştera de la Gălăşeni and Peştera de la Tăşad, with the latter having the largest nursery colony in the region (>250 juveniles, July 2011). In case of the colony from Peştera de la Gălăşeni, it must be noted that recent mist nettings and finding of a dead specimen have demonstrated that *R. blasii* is also present (Mărginean et al. 2011, as well as unpublished data). In this way, the composition of all medium-sized *Rhinolophus* colonies in the region must be newly evaluated.

Since we cannot separate the two large *Myotis* species (*M. myotis* and *M. oxygnathus*) when they form mixed colonies, we discuss them together. Large *Myotis* species were first reported in the region by Frivaldszky (1865) from caves of the Pădurea Craiului and Bihor Mountains. During the summer periods of the current study, we identified the two species in nine caves, out of which eight were nursery colonies. Similarly as for *R. euryale*, these colonies are usually located on the margins of mountain ranges, at low altitudes. The two species form the largest nurseries identified throughout the study, numbering well over 1,000 individuals. In most cases, they cluster together with *M. schreibersii*, rarely with *R. euryale* (e.g. Peştera Meziad, Szodoray-Parádi 2011), to form colonies of more than 5,000 bats. The largest aggregation of these species is located in Peştera de la Aştileu, at the northern limit of the Pădurea Craiului Mountains, numbering over 7,000 bats (June 2010). The largest aggregation of solely large *Myotis* is found in Huda lui Papară (July 2011), numbering more than 5,000 bats (Table 2). Other notable nurseries are in Avenul de la Betfia (2,000 bats, June 2010), Peştera cu Apă din Bulz (2,000 bats, July 2011) and Peştera Ţiclului (3,500 bats, June 2010).

M. schreibersii, described from the region by Petényi (1854), is the most frequent species during the summer (0.48; Table 2), and is present in 12 caves, out of which eleven are nurseries. It clusters together with large *Myotis*, with the largest common colony of these species being in Peştera de la Aştileu, and numbering over 7,000 bats (June 2010). The largest aggregation of solely *M. schreibersii* is found in Peştera Meziad, numbering 3,030 bats (Table 2), being observed in June 2010. Other notable nurseries are in Avenul de la Betfia (1,000 bats, June 2010), Peştera Calului in the Meziad Valley (1,750 bats, July 2011), Peştera Coliboaia (1,800 bats, June 2010), Peştera Măgura (2,320 bats, June 2010) and Peştera Ţiclului (3,000 bats, July 2011).

Winter bat fauna

As expected, the winter bat fauna of the 60 caves investigated in the Romanian Western Carpathians is significantly more diverse in comparison to the summer bat fauna. Eleven caves had no winter bat presence, these being usually small-sized caves in remote regions (ex. Peştera Gârdişoara, Peştera Mare din Hăldăhaia), and/or located above 1,000 m (Peştera Calului at Ciumerna Plateau, 1,226 m). Also, some of the uninhabited caves have large entrances and small length (ex. Peştera Vacii din Cheile Albioara), meaning that microclimatic conditions are subject to sudden changes during winter for the entire length of the cave, making them unsuitable for most bat species.

In the 49 caves that do have a winter bat fauna, we identified 20 species with certainty, but also individuals belonging to *M. mystacinus* group and unidentified *Myotis* sp. The most frequent species include *R. ferrumequinum* (0.62), *R. hipposideros* (0.65), large *Myotis* (0.53), *B. barbastellus* (0.27) and *M. schreibersii* (0.18) (Table 2). In addition, *R. euryale*, *N. noctula* and *P. pipistrellus* are also present during the winter, with large colonies. The remaining eleven species are present with less than 20 individuals per species, for all caves combined. By far the largest hibernation colonies are found in Huda lui Papară, with nine resident bat species numbering a total of ≈100,000 individuals (see a separate section for caves). The most important 30 hibernacula (containing five or more bat species, and/or more than 50 individual bats), are presented in Fig. 3. See also Table 3 for details on these caves, and Table 1 showing bat species recorded.

R. ferrumequinum, first described from the region by Frivaldszky (1865), is present during the winter in 37 caves. Being a generalist species during hibernation, *R. ferrumequinum* inhabits almost the whole altitudinal range, from 252 m (Peştera de la Aştileu) to 1,316 m (Peştera Şura Boghii). It can be found in solitary hibernation, total numbers not exceeding ten individuals, but also in compact clusters of several hundreds of bats (ex. Peştera Meziad, Peştera cu Apă din Valea Leşului). The most important hibernaculum for *R. ferrumequinum* is Huda lui Papară, with a total of 775 bats, out of which more than 500 form a compact cluster (December 2010). *R. hipposideros* is the most frequent species in the Romanian Western Carpathians during the winter period (Table 2), being present in 39 caves. First described from the region by Petényi (1854), its altitudinal range is more than 1,000 m, exactly as for *R. ferrumequinum*, from 252 m (Peştera de la Aştileu) to 1,316 m (Peştera Şura Boghii). Throughout the study, we did not find any compact clusters of *R. hipposideros*, only individuals in solitary hibernation, with their total number per cave not exceeding ten individuals in most cases. In those cases, where *R. hipposideros* is present in greater numbers (ex. Peştera Măgura, Peştera Meziad, Peştera din Secătura), this value can rise above 50 individuals. The most numerous presence was noted in Huda lui Papară, with 168 bats hibernating in January 2012.

Large *Myotis* species are frequent throughout the hibernation season, too (0.53; Table 2), in many cases being present with colonies of several hundreds of bats. As a generalist, highly adaptable species (Dietz et al. 2009), they occupy the whole altitudinal range of the study, from 230 m (Peştera de la Tăşad) to 1,316 m (Peştera Şura Boghii), and are also found in the most isolated caves (ex. Peştera Bisericuţa at Ciumerna Plateau). Large *Myotis* species hibernate in isolation, or form clusters of tens of bats that tend to merge or disperse, according to changing microclimatic conditions, or disturbance. Notably sized colonies during the winter are located in Peştera Bătrânului, Peştera cu Apă din Valea Leşului, Avenul de la Betfia, Peştera Meziad and Peştera Vacii. The most important winter aggregation is found in Huda lui Papară, numbering a maximum of 4,419 bats (January 2012).

Even though missing from the cave environment during the summer period, and in spite of the fact that even during winter the species has a low frequency (0.05; Table 2), *P. pipistrellus* forms the second largest aggregations of all bat species in hibernation. First described in the region by Dumitrescu et al. (1963), *P. pipistrellus* was found only in three caves during our study, all being caves of a complex structure (e.g. large corridors, halls, with secondary levels, water surfaces and sometimes, artificial elements). The main part of the *P. pipistrellus* colony is usually found resting on walls of small secondary corridors, with isolated individuals using crevices of natural or artificial inner walls. We identified two large colonies of *P. pipistrellus*, in Peştera Meziad (1,029 bats, January 2011), and Huda lui Papară. The latter is the largest known hibernation colony of *P. pipistrellus* in the whole region, reaching a maximum of 33,800 bats in December 2010. Typically a woodland species, *B. barbastellus* moves to caves during hibernation (Dietz et al. 2009). Indicated from the region by Dobrosi & Gulyás (1997), the species was present in 16 caves during our study. Even though individual numbers in caves are usually less than five, its presence is still notable, the species occupying a large variety of cave types. The greatest numbers were recorded in Huda lui Papară, with 36 individuals hibernating in January 2012.

Being present in the cave environment all year long, *M. schreibersii* was found in 16 caves during the winter period of our study. It forms hibernating colonies of several hundreds of individuals, notable caves being Peştera de la Fânaţe (1,838 bats, November 2011), Peştera Liliecilor din Cheile Ampoiţei (454 bats, March 2011), Peştera Meziad (1,694 bats, January 2011) and Peştera Ungurului (2,045 bats, January 2011). The largest aggregation by far, important at the regional and continental level, is the colony from Huda lui Papară, numbering a maximum of 58,000 bats

in December 2010. Even though not present in great numbers or in many caves, several other bat species recorded in the Romanian Western Carpathians should be mentioned (Table 1). *M. daubentonii* was identified only during the winter period, being present in six caves. Similarly, *M. nattereri* was found only in hibernation, in seven caves. *N. noctula* was observed all year long, however, important colonies were formed only during hibernation, the species being a typical woodland- and city-dweller during the summer (Dietz et al. 2009). The largest colony observed in the region is in Peştera Ungurului, the size of which increased dramatically from year to year (from 740 bats in 2011 to 2,500 bats in 2012), because of the relocation of a building-dwelling colony from Cluj-Napoca. *P. auritus* is present only during the winter period, and was observed in seven caves, in each case a single individual. It must be mentioned that in case of these "rare" species, the observed numbers must be considered a minimum, and the real population size is probably much larger. This is due to the fact that caves usually have complex structures, containing multiple levels and deep fissures, as well as inaccessible sections, where identification of bats is impossible. Also, several of these species use buildings during the summer period, partially explaining their absence from caves. All caves and bat species present are summarized in Table 1.

Most important caves

During the study, we identified a series of threats in relation to caves, their surroundings, and the local bat fauna (Table 3). Threats from within the caves, affecting the bat fauna directly, are uncontrolled and excessive cave tourism, vandalism, unsuitable cave closings, unsuitable artificial illumination in tourist caves, illegal waste depositing and water pollution. These threats were observed mostly in those caves that are easily accessible and/or have a great influx of tourists, for example Peştera Meziad, Peştera Ungurului, and Peştera de la Vadu Crişului. Unsuitable cave closings were identified, and probably have a significant negative effect on the nursery colonies at Peştera Coliboaia, and the hibernation colony of *R. ferrumequinum* in Peştera de la Vadu Crişului. Threats regarding the habitats around caves include deforestation, clearcutting, cutting of hollow trees, water pollution, and illegal waste depositing. The most affected area regarding deforestation and clearcutting is at Peştera cu Apă din Valea Leşului. Large illegal waste deposits are degrading the underground environment of Avenul de la Betfia.

By far the most important cave in the study area, regarding colony size, is Huda lui Papară in the Trascău Mountains. With ten species hibernating on a regular basis (Table 1), its diversity is also notable. However, its main importance lies in the presence of the largest hibernation colonies of *M. schreibersii* and *P. pipistrellus* in Romania, numbering a maximum of 58,000 and 33,800 bats, respectively, in December 2010. We observed large fluctuations in the size of these colonies during the winter period, a fact already indicated by Coroiu et al. (2006), but also a gradual increase of the *M. schreibersii* colony. Szodoray-Parádi (2011) observed 24,600 bats in 2001 and 45,100 bats in 2009, whereas the current numbers reach almost or even exceed 60,000 individuals of *M. schreibersii* (Coroiu & David 2008, and current study). Similarly, *R. hipposideros* has been growing in numbers, with 65 bats in 2009 (Szodoray-Parádi 2011), and 168 bats currently. On the contrary, the colony size of *R. ferrumequinum* seems to be in a slight decline, with 1,050 bats in 2002 (Coroiu & David 2008), but only 751 bats currently. At the beginning of 2012, Huda lui Papară was used as a hibernaculum by approximately 1,000 individuals of the large *Myotis* less than in 2005 (Coroiu & David 2008) or the years after (Szodoray-Parádi 2011). Currently, the colony size of large *Myotis* fluctuates between 3,200 and 4,400 individuals. It must be noted

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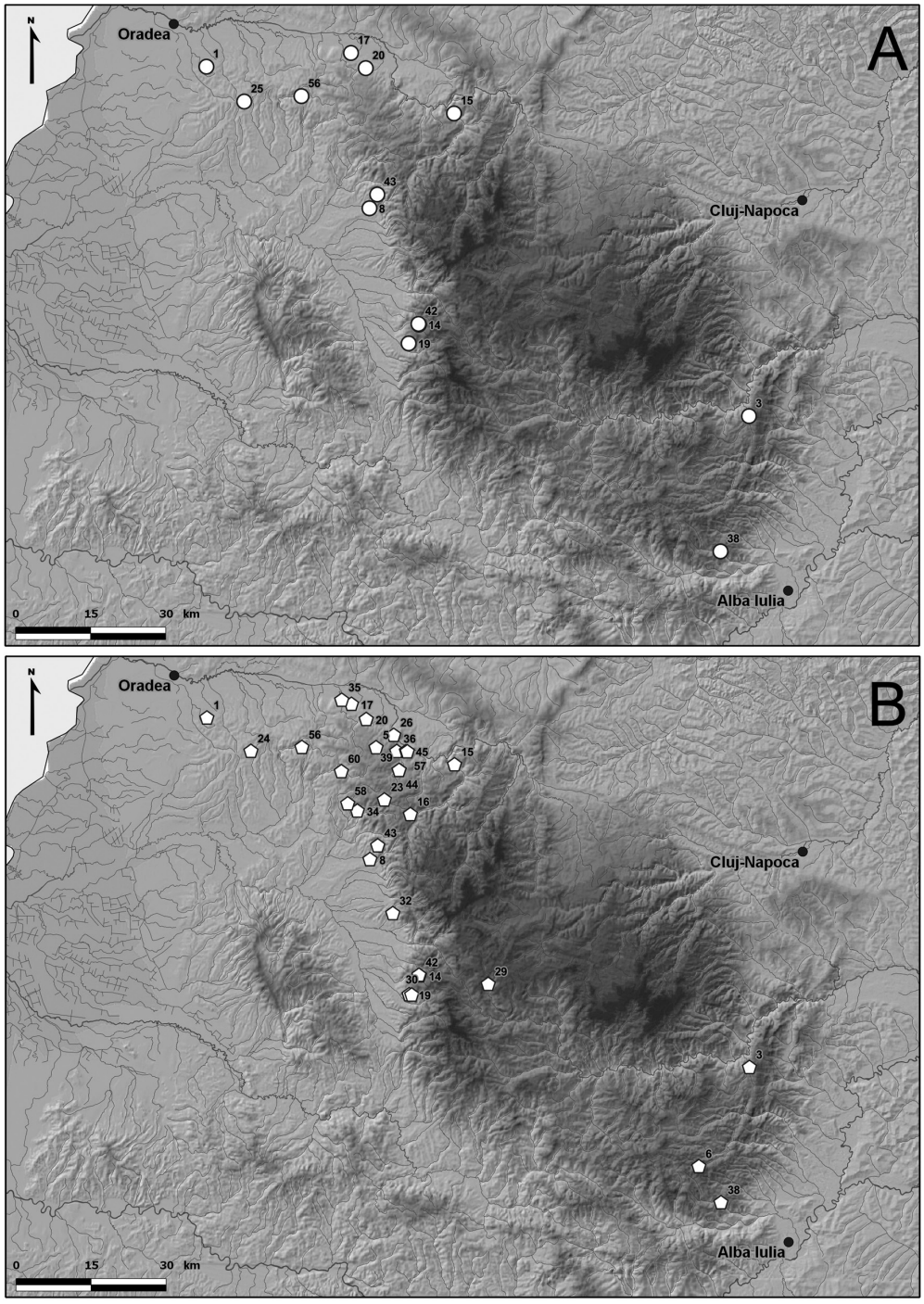
Fig. 3. Location of the most important caves and colonies identified in the Romanian Western Carpathians in the period 2010–2012. A – caves with important nursery colonies. B – caves with important hibernation colonies. In both cases, numbers correspond to those in Tables 1 and 3.


A
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1
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Cluj-Napoca
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Alba Iulia
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23
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16
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43
8
Cluj-Napoca
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3
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Alba Iulia
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15
30 km

that colony sizes and individual numbers reported from Huda lui Papară should be considered a minimum, since the complex morphology of the cave galleries impedes identification of every individual bat in certain sections.

The cave with the highest species diversity in the study region is Peştera cu Apă din Valea Leşului, with a total of 14 species present (Table 1). The dominating species are large *Myotis*, with a maximum of 2,820 bats in February 2011, and *R. ferrumequinum*, with a maximum of 774 bats in January 2012. However, these numbers are in fluctuation, a fact already indicated by Szodoray-Parádi (2011). Individual numbers of large *Myotis* change between a few hundred and 5,200 bats, while the *R. ferrumequinum* colony fluctuates between a minimum of 394 (Szodoray-Parádi 2011) and a maximum of 795 bats (Szodoray-Parádi & Szántó 1998). A non-numerous, but constant presence is observed in case of *R. hipposideros*, *M. daubentonii*, and *M. dasycneme*. The status of the most diverse cave is achieved through the sighting of several rare bat species that were identified only in this cave, such as *M. emarginatus*, *E. nilssonii*, and *V. murinus*. The cave is also regarded as an important swarming site (unpublished data).

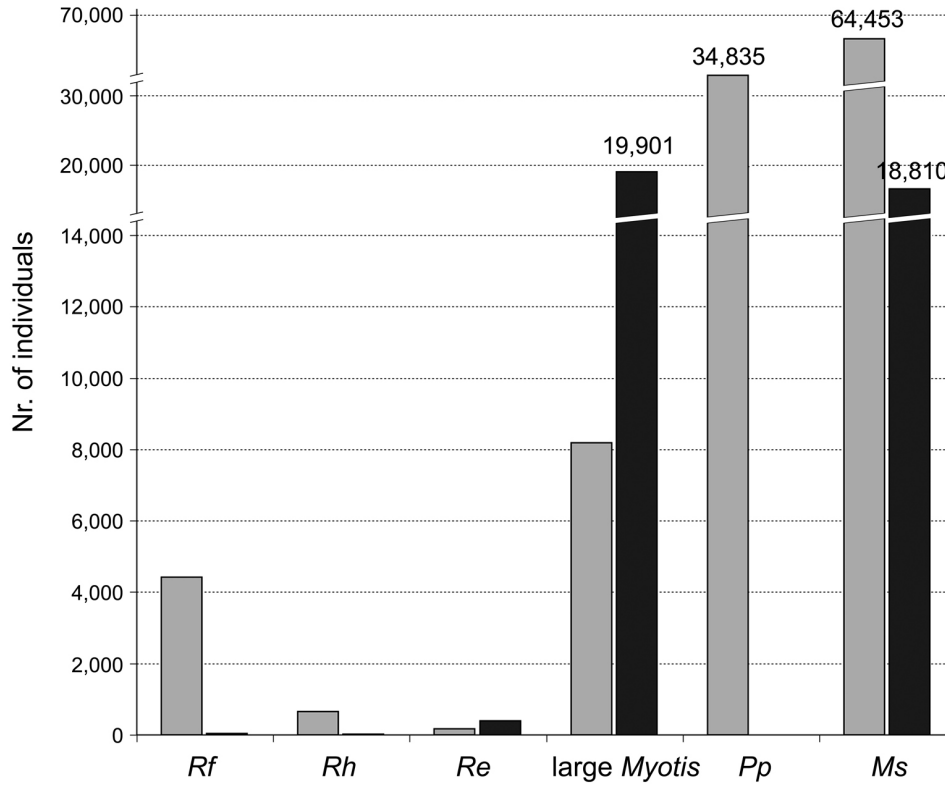

Fig 4. Observed total numbers of the six most abundant bat species in the Romanian Western Carpathians, in different periods of the year. The vertical axis is modified, in order to accommodate individual numbers of *Pipistrellus pipistrellus* (*Pp*) and *Miniopterus schreibersii* (*Ms*). Legend: pale grey – winter; dark grey – summer, *Rf – Rhinolophus ferrumequinum*, *Rh – Rhinolophus hipposideos*, *Re – Rhinolophus euryale*.

Even though slightly less diverse (13 species, Table 1), Peştera Meziad must be regarded as one of the most important roosts in the region. Inhabited all year long, it shelters large hibernation colonies of *R. ferrumequinum*, *M. schreibersii* and *P. pipistrellus*, and nurseries of large *Myotis* and *M. schreibersii*. Whilst the winter colony of *R. ferrumequinum* is nearly constant (≈ 300 bats), the numbers of *M. schreibersii* and *P. pipistrellus* show large fluctuations, from 924 to 1,694 bats, and from 10 to 1,029 bats, respectively. Even if we take into account natural fluctuations, the colony of *M. schreibersii* seems to be declining, with more than 2,000 bats identified on a regular basis before 2008 (max. 2,966 bats, Szodoray-Parádi 2011). Current size of the colony in the middle of the hibernation season is only 1,200 bats (January 2012). The extreme fluctuation of the *P. pipistrellus* colony is probably due to its location in the cave. It is located in an easily accesible secondary corridor, close to the main entrance of the cave, and in this way is exposed to sudden changes of outside climatic conditions, and/or to possible predatory activity of several species. The great winter diversity in the cave is achieved through the presence of *R. hipposideros*, *R. euryale*, *M. bechsteinii*, large *Myotis*, *N. noctula*, *Plecotus* species, and *B. barbastellus* (Table 1). The combined size of large *Myotis* and *M. schreibersii* nurseries is fairly constant, and is usually above 4,000 bats (max. 5,500, July 2011).

Caves that have a lower species diversity, but do have large colonies throughout the year are similarly important, at the regional or local level. Peştera de la Aştileu shelters large *Myotis* and *M. schreibersii* nurseries, of more than 5,000 bats. Peştera de la Fânaţe is occupied all year long, with a *M. schreibersii* nursery and hibernation colony of more than 1,000 ind., as well as over 200 *R. ferrumequinum* in hibernation. Peştera Bătrânului is an important hibernation site, with a *R. ferrumequinum* colony of several hundreds of bats (max. 401 bats, February 2011), and also large *Myotis* (max. 250 bats, February 2010). Peştera cu Apă din Bulz is occupied all year long, in the winter by *R. ferrumequinum* (max. 372 bats, February 2011), and in the summer by large *Myotis* and *M. schreibersii* (max. 3,000 bats, July 2011). Peştera Măgura and Peştera Coliboaia, situated close to each other, in the Sighiştel Valley, have significant nurseries of large *Myotis* and *M. schreibersii* (max. 3,026 bats, June 2010). The two caves with a major importance for *R. euryale* in the region are Peştera de la Gălăşeni and Peştera de la Tăşad. The latter is home to the largest maternity colony of the species known from the region, with min. 250 juveniles observed in July 2011.

Discussion and Conclusions

Diversity of the cave-dwelling bat fauna can be considered high in the Romanian Western Carpathians, throughout the year, but especially in the period of hibernation. Bats gather in these caves for hibernation from large areas, including the Hungarian Plain (Dobrosi & Gulyás 1997), occupying a large variety of cave types. Suitable hibernacula can be found across the whole altitudinal range (230–1,316 m), with bat species being present in large, complex tourist caves, but also in small, isolated caves. The six most abundant bat species are presented in Fig. 4. The numerous presence of *R. ferrumequinum*, *R. hipposideros*, and most notably *M. schreibersii* during the winter period clearly indicates that bats gather in these caves to hibernate from much larger territories than the Romanian Western Carpathians.

The fluctuations in colony sizes (e.g. *R. ferrumequinum*, large *Myotis*, and *M. schreibersii*) observed during the study, but also in comparison to the literature (ex. Szodoray-Parádi 2011) point to the assumption that several important hibernacula are still unidentified in the region. Another factor probably affecting bat presence is the increasing human pressure on underground roosts (e.g. excessive tourism, unsuitable infrastructure) and on the surrounding habitats (deforestation,

Table 3. General data of caves investigated between 2010 and 2012, in the Romanian Western Carpathians. Numbers in the first column correspond to those in Fig. 1 and Fig. 3. Natura 2000 site codes are, as follows: ROSCI0002 – Apuseni, ROSCI0008 – Betfia, ROSCI0062 – Defileul Crişului Repede Pădurea Craiului, ROSCI0084 – Ferice-Plai, ROSCI0240 – Tăşad, ROSCI0253 – Trascău. Altitude (m) is also indicated. The main function of caves based on bat presence is indicated by H (hibernation colonies) and/or N (nursery colonies). Swarming sites (unpublished data) are marked with S. We also indicated disturbance factors that have major impact on the environment of caves or their surroundings.

no.	roost	mountain range	Natura 2000 site	altitude (m)	used by	disturbance factors
1	Avenul de la Betfia	Pădurea Craiului Mts.	ROSCI0008	290	H, N	waste depositing
2	Gaura Fetii	Bihor Mts.	ROSCI0002	496	–	
3	Huda lui Papară	Trascău Mts.	ROSCI0253	575	H, N, S	
4	Peştera Băiţa	Bihor Mts.	ROSCI0002	583	H	
5	Peştera Bătrânului	Pădurea Craiului Mts.	ROSCI0062	581	H, S	
6	Peştera Bisericuţa	Trascău Mts.	ROSCI0253	1,209	H	
7	Peştera Calului	Trascău Mts.	ROSCI0253	1,226	–	
8	Peştera Calului	Pădurea Craiului Mts.	near ROSCI0062	277	H, N, S	
9	Peştera Caprei	Pădurea Craiului Mts.	ROSCI0062	318	H	
10	Peştera care Cântă	Pădurea Craiului Mts.	ROSCI0062	248	–	
11	Peştera Ciur Izbuc	Pădurea Craiului Mts.	ROSCI0062	528	H	
12	Peştera Ciur Ponor	Pădurea Craiului Mts.	ROSCI0062	510	H	
13	Peştera Coiba Mare	Bihor Mts.	ROSCI0002	1,043	H	
14	Peştera Coliboaia	Bihor Mts.	ROSCI0002	560	H, N	inadequate gates
15	Peştera cu Apă de la Bulz	Pădurea Craiului Mts.	near ROSCI0062	289	H, N	
16	Peştera cu Apă din Valea Leşului	Pădurea Craiului Mts.	ROSCI0062	652	H, S	deforestation, cutting hollow trees
17	Peştera de la Aştileu	Pădurea Craiului Mts.	near ROSCI0062	252	H, N	
18	Peştera de la Faţa Apei	Pădurea Craiului Mts.	ROSCI0062	485	H, S	large scale constructions
19	Peştera de la Fânaţe	Bihor Mts.	ROSCI0002	565	H, N, S	
20	Peştera de la Gălăşeni	Pădurea Craiului Mts.	near ROSCI0062	400	H, N, S	
21	Peştera de la Izvor	Pădurea Craiului Mts.	near ROSCI0062	313	H	
22	Peştera de la Izvorul lui Gábor	Pădurea Craiului Mts.	near ROSCI0062	440	H	
23	Peştera de la Întorsuri	Pădurea Craiului Mts.	ROSCI0062	560	H, S	
24	Peştera de la Stracoş	Pădurea Craiului Mts.	ROSCI0240	269	H	
25	Peştera de la Tăşad	Pădurea Craiului Mts.	ROSCI0240	230	H, N	excessive tourism, inadequate gates
26	Peştera de la Vadu Crişului	Pădurea Craiului Mts.	ROSCI0062	322	H, S	excessive tourism, inadequate gates, improper illumination

no.	roost	mountain range	Natura 2000 site	altitude (m)	used by	disturbance factors
27	Peştera de la Valău	Pădurea Craiului Mts.	near ROSCI0062	400	H	
28	Peştera Diaclază din Hăldăhaia	Trascău Mts.	ROSCI0253	1074	H	
29	Peştera din pârâul Hodobanei	Bihor Mts.	ROSCI0002	1011	H	
30	Peştera din Secătura	Bihor Mts.	ROSCI0002	608	H, S	
31	Peştera Drăcoaia	Bihor Mts.	ROSCI0002	470	H	
32	Peştera Ferice	Bihor Mts.	near ROSCI0084	378	H	
33	Peştera Gârdişoara	Bihor Mts.	ROSCI0002	1140	–	
34	Peştera Gruieţului	Pădurea Craiului Mts.	ROSCI0062	302	H	
35	Peştera Igriţa	Pădurea Craiului Mts.	ROSCI0062	336	H	excessive tourism
36	Peştera Izbândiş	Pădurea Craiului Mts.	ROSCI0062	420	H	
37	Peştera Liliaculuі	Pădurea Craiului Mts.	ROSCI0062	406	H	
38	Peştera Liliecilor din Cheile Ampoiţei	Trascău Mts.	ROSCI0253	608	H, N, S	excessive tourism
39	Peştera lui Cotuna	Pădurea Craiului Mts.	ROSCI0062	565	H	
40	Peştera lui Doboş	Pădurea Craiului Mts.	ROSCI0062	500	H	
41	Peştera Mare din Hăldăhaia	Trascău Mts.	ROSCI0253	1139	H	
42	Peştera Măgura	Bihor Mts.	ROSCI0002	526	H, N, S	excessive tourism
43	Peştera Meziad	Pădurea Craiului Mts.	ROSCI0062	463	H, N	excessive tourism
44	Peştera Moanei	Pădurea Craiului Mts.	ROSCI0062	540	H, S	
45	Peştera Napiştileu	Pădurea Craiului Mts.	near ROSCI0062	330	H	excessive tourism
46	Peştera Osoi	Pădurea Craiului Mts.	ROSCI0062	442	H	
47	Peştera Osoi nr. 2	Pădurea Craiului Mts.	ROSCI0062	448	H	
48	Peştera Peşteraşul	Pădurea Craiului Mts.	ROSCI0062	350	–	
49	Peştera Pişniţa	Pădurea Craiului Mts.	ROSCI0062	280	–	inadequate gates
50	Peştera Poarta lui Ionele	Bihor Mts.	ROSCI0002	848	H	
51	Peştera Puculea	Trascău Mts.	ROSCI0253	561	H	
52	Peştera Rece	Pădurea Craiului Mts.	ROSCI0062	390	–	
53	Peştera Sandului	Trascău Mts.	ROSCI0253	629	H	
54	Peştera Ştudenţilor	Trascău Mts.	ROSCI0253	819	–	
55	Peştera Şura Boghii	Bihor Mts.	ROSCI0002	1316	H	
56	Peştera Ţiclului	Pădurea Craiului Mts.	ROSCI0062	385	H, N, S	
57	Peştera Ungurului	Pădurea Craiului Mts.	near ROSCI0062	311	H	excessive tourism, improper illumination
58	Peştera Vacii	Pădurea Craiului Mts.	ROSCI0062	408	H	
59	Peştera Vacii din Cheile Albioara	Pădurea Craiului Mts.	near ROSCI0062	299	H	
60	Peştera Viduţa nr. 2	Pădurea Craiului Mts.	ROSCI0062	390	H, S	

clearcuttings). The complexity of cave structures (multiple levels, deep crevices, etc.) also influences the correct assessment of population sizes. For example, the colony size of large *Myotis* in Peştera cu Apă din Valea Leşului is always subject to fluctuations. The internal structure of the hibernaculum is surely responsible for underestimating bat presence, while the effects on colony sizes of large -scale deforestation in vicinity of the cave must be studied in the future. Taking into account the above mentioned assessment difficulties, we consider that the winter bat fauna of the Romanian Western Carpathians presented in this study (e.g. distribution and numbers) must be considered the minimum for the region, and highlights the importance of future investigations.

The summer bat fauna, even though less diverse (nine species), is equally important, mainly because of the presence of mixed nursery colonies numbering several thousands of individuals of *M. schreibersii* and large *Myotis*. The most abundant species are, with the exception of *P. pipistrellus*, the same as for the winter period (Fig. 4), but with a clear difference in overall numbers of individuals. The winter population of *R. ferrumequinum* and *R. hipposideros* numbers several thousands and several hundreds of bats, respectively, while the summer presence of these species in caves is negligible. This indicates that there are probably several important nurseries located in buildings at lower altitudes of the study area that are currently unknown. Identifying these roosts must be a priority for future bat research in the NW of Romania. Simultaneously, the long-term protection of all known nurseries is necessary in order to maintain a healthy bat population across the region. Presence and actual population size of *R. euryale* is a particular issue. Recent observations (including mist-netting) at Peştera de la Gălăşeni have identified a significant presence of *R. blasii* (Mărginean et al. 2011, as well as unpublished data). Since the species is present at the northern limit of the Pădurea Craiului Mountains, it means that all *R. euryale* colonies in the study region (ex. Peştera de la Tăşad, Peştera de la Ştracoş, Peştera Calului) must be revised, regarding species composition.

Overall, the conservation status of the bat fauna of the Romanian Western Carpathians is satisfactory, but if we take into account the continuous increase in human activities, the negative effects upon local bat populations will certainly grow. Since the begining of 2010, there has been a large-scale project underway, to ensure the long-term and efficient protection of the resident bat fauna. This will be achieved through the following conservation actions: (1) information and warning boards at the entrance of most caves, (2) modified visitor routes in tourist caves, (3) modified artificial illumination to avoid direct illumination of bat colonies, (4) waste cleaning in affected caves, (5) adequate cave closings in case of the most important caves. Constant monitoring of all roost types is also necessary to supply conservation efforts with current data.

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