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CAVES INVENTORY AND DATABASE IN GALICICA NATIONAL PARK

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ABSTRACT

More than 40 speleological objects were registered on the territory of the Galicica National Park. The majority of them are caves, however, there are also precipices, and along the coast of the Ohrid and Prespa Lake there are several rock shelters. Fourteen species of troglobites, twenty species of troglaphiles, about ten species of troglonexes and accidental troglonexes were recorded in the caves. Nine species of bats use these caves as their habitat. Galicica National Park is the first protected area in North Macedonia for which a database of caves has been created. The database includes 39 caves, with a total of 22 features for each cave, separately.

Keywords: cave, cave fauna, database, Galicica National Park

INTRODUCTION

Galicica mountain is located in the southwestern part of North Macedonia, between the Ohrid and Prespa Lakes. It stretches in a meridian direction. The Triassic massive limestones with a thickness of 500-550 m (Думурџанов & Ивановски, 1978) enabled a strong karstification which is represented by surface (poljes) and underground (caves, pits) relief forms. Data on the underground karst relief forms were presented by Точковски (1970) and Андоновски & Колчаковски

(1990). The new research aimed to explore new caves, to determine the morphological characteristics of known caves and to start measuring some microclimatic elements in the cave ecosystem.

In terms of biospeleological research, Galicica National Park has received more attention compared to other Macedonian mountains. The first ever described troglobyte from Macedonian caves - *Ceuthophyes karamani* Jeannel, 1924 (Fig. 1) was discovered in Mečkina Dupka cave (Jeannel, 1924). Another endemic leiodid species (*Bathyscidius rambouseki* Knirsch, 1931) was described from an unknown cave in the vicinity of the village of Trpjeca (Knirsch, 1931). There are also published data for spiders, pseudoscorpions and orthopterans from caves on Galicica mountain (Ćurčić, 1984; Ćurčić et al., 1997; Karaman et al., 2011; Deltchev et al., 2013).



Figure 1. *Ceuthophyes karamani* (Jeannel, 1924), **autor:** S. Hristovski.

One of the goals was to study the diversity of cave species of invertebrates and analyze them from the aspect of their ecological adaptations (troglobites, troglaphiles, troglloxenes and accidental troglloxenes).

The development of a cave database is very important in the process in promoting multisectoral approach in investigation and protection of cave ecosystems. This type of document does not exist in any protected area in North Macedonia as well as on national level (national cave database).

DATA AND METHODS

Various groups of methods were applied for investigating caves in Galicica National Park.

GPS Garmin Montana 680 was used for cave location (coordinates). Published cave maps made by different authors (Точковски, 1970; Андоновски & Колчаковски, 1990) were revised and added with new data. Cave surveying was done using Leica laser distance meter (DISTO D 330i), and Suunto compass and clinometer (SU-51-TANDEM). The preparation of the cave maps was done using the software CorelDraw as well as draft attempts to develop 3D maps of selected caves and testing them in the program Therion.

Air temperature and air humidity in the caves were measured *in-situ* using field-type instrument PeakTech 5090. In the caves Samotska Dupka and Leskoečka Peštera continuous measurements of air temperature and humidity were done by data loggers HOBO MX 2303 ONSET from 25.3.2023.

Cave invertebrates were collected manually or by pitfall traps during the period April-November 2023. The research of the caves Samotska Dupka, Leskoečka Peštera was carried out in March, May, August and September of 2023. Other caves were visited once or twice. Pitfall traps were placed in the caves of Samotska Dupka, Leskoečka Peštera, Svinska Strna and Krstova Peštera. Pitfall traps consisted of 0.5 L plastic containers filled with cca 200 ml of propylene glycol.

The monitoring of bats was done using the method of roost inspection. We identified the bats species, counted the number of individuals and took photos of the specimens and the colonies in each of the visited caves. In some cases, for proper identification of the species, we captured individuals inside the caves and recorded bat call using Pettersson D240x and BatLogger M bat detectors. The analysis of the recorded calls was done using the computer software BatSound v.4.0.

To prepare and standardize the first database of caves in Galicica National Park, the process included conducting extensive literature review (Speleološko društvo Velebit, Hrvatski planinarski savez & Hrvatska gorska služba spašavanja, 2019; Mudrak & Budaj, 1999/2021; QGIS Project, 2023) to gather existing data and knowledge about existing cave data bases in country and region (active and passive), identifying key areas (fields) for the attribute table (coordinates, length etc.), incorporating the database on free to use software's (Google Platform, Microsoft Excel and QGIS), validating, verifying and manual data entry of the collected data and capacity building for the users of the database.

RESULTS

Caves inventory

More than 40 speleological objects were registered on the territory of the Galicica National Park (Fig. 2). Majority of them are caves, the number of precipices is lower, and along the coast of the Ohrid and Prespa Lake there are several rock shelters. For the first time 8 caves (Fig. 3,4,5,6,7,8), 4 precipices (Fig. 9,10,11), and 5 rock shelters (Fig. 12) were observed. Around the top of Tomoros (1675 m), several natural depressions were widened by man and turned into ditches (Fig. 13).

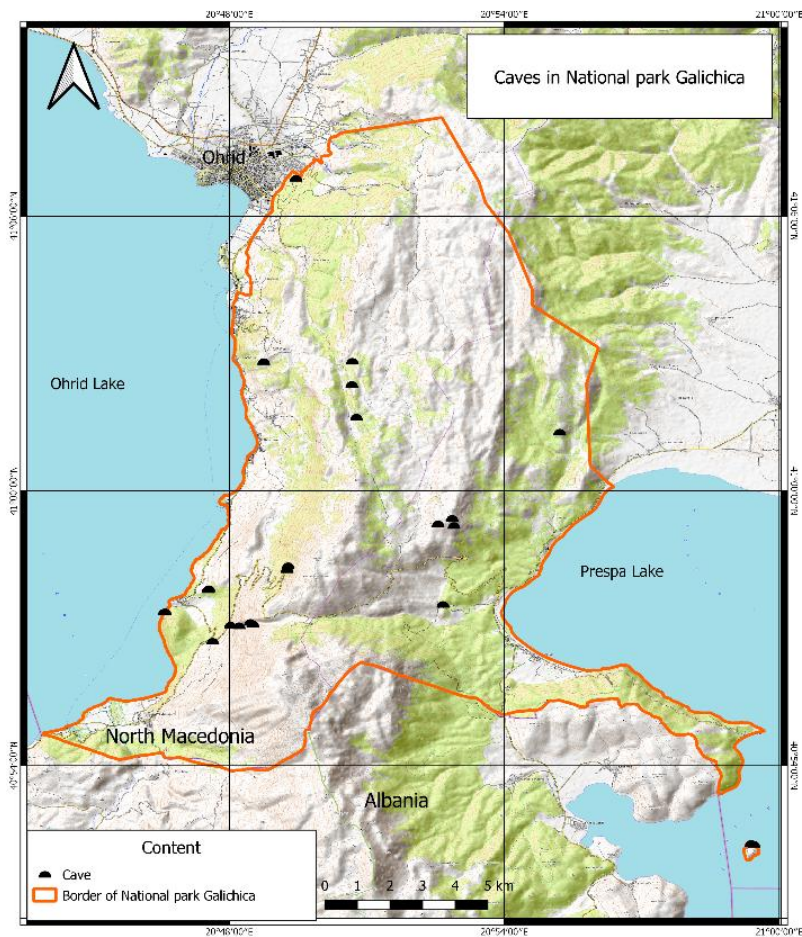


Figure 2. Map of caves in Galicica National Park.

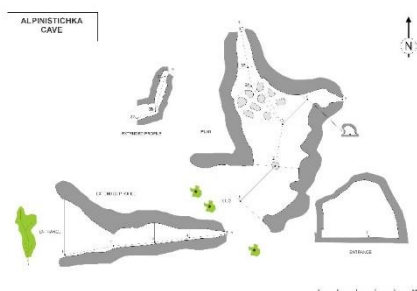


Figure 3. Map of cave Alpinistička Peštera.

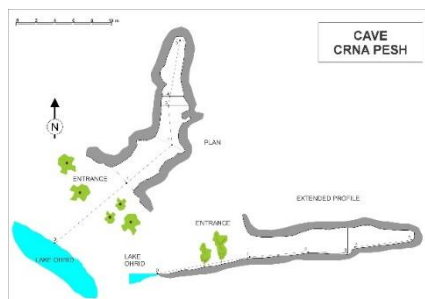


Figure 4. Map of cave Crna Peš.

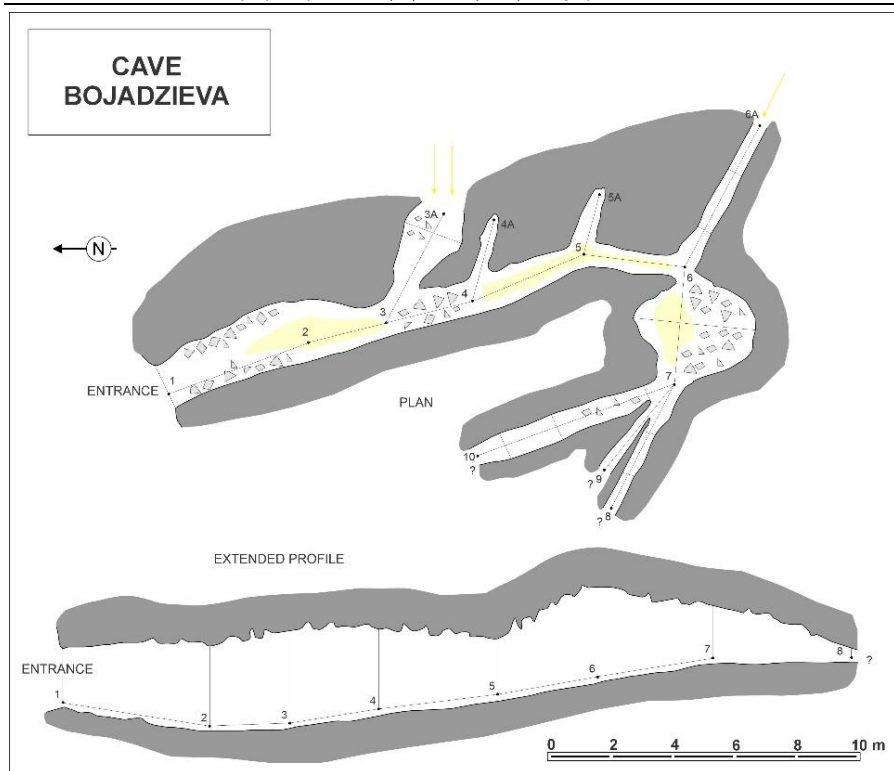


Figure 5. Map of cave Bojadžieva Peštera.

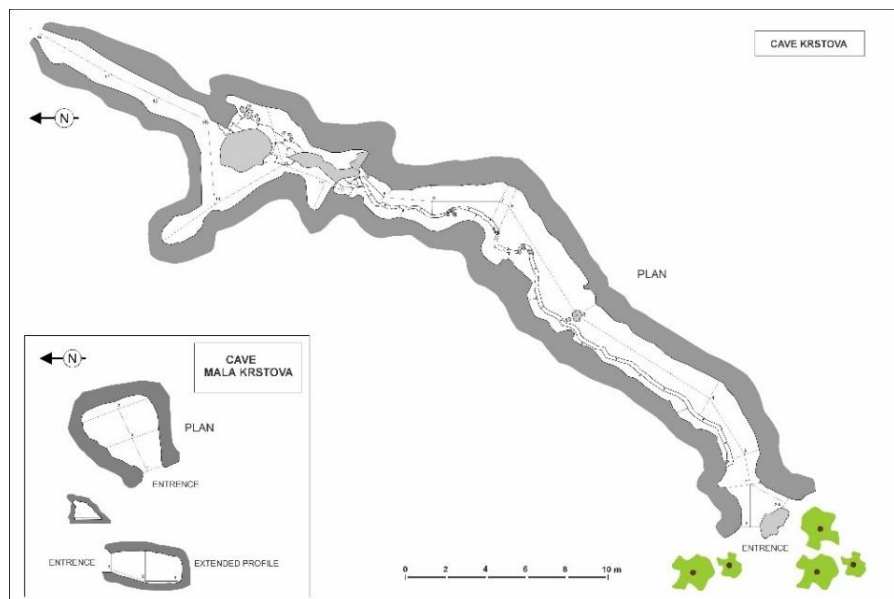


Figure 6. Map of Krstova cave.

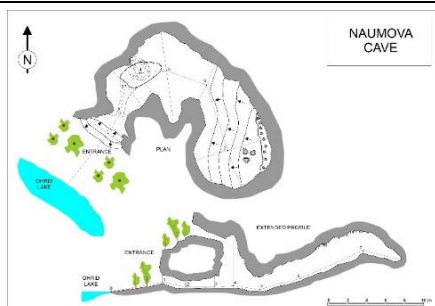


Figure 7. Map of Naumova cave.

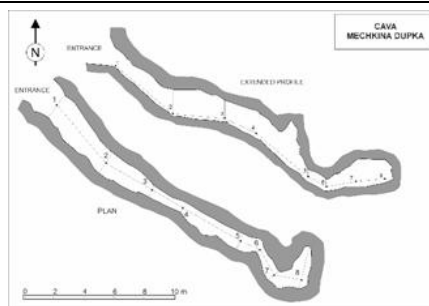


Figure 8. Map of Mečkina Dupka cave.

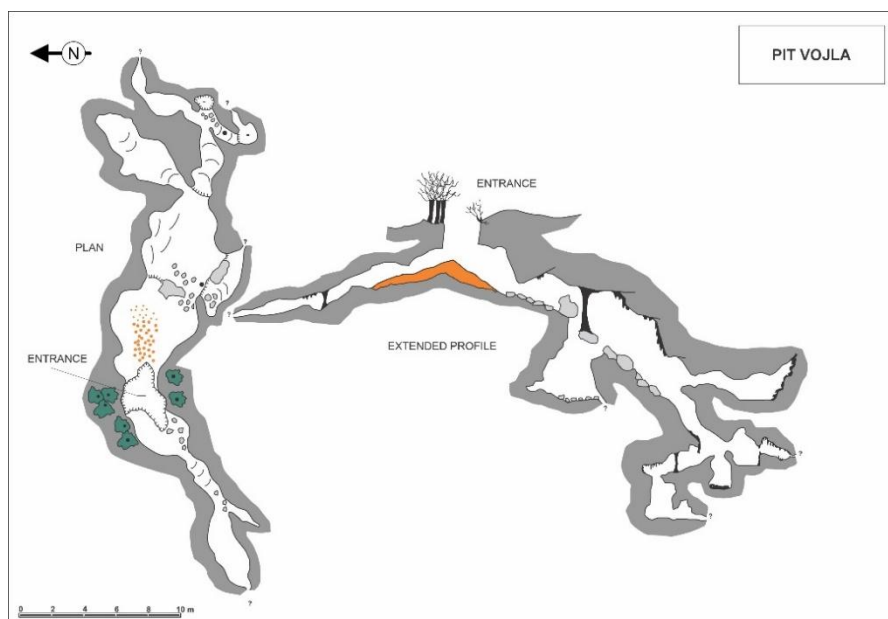


Figure 9. Map of Vojla pit.

The explored caves represent epigene caves. In hydrological point of view, all caves registered are dry and located in the vadose zone. Only, in the cave Bimbilova Peštera there was a cave lake which is connected with Prespa Lake. In some caves (Samotska Dupka, Leskoečka Peštera), one can clearly see traces of ground rivers that have flown through the cave passages and have modelled them, while others have been filled with breccia material (Krstova Peštera, Mečkina Dupka). Speleothems, depending on the environment in which they have formed, belong to three groups: speleothems formed by flowing and dripping water, basin sediments and evaporative formations.

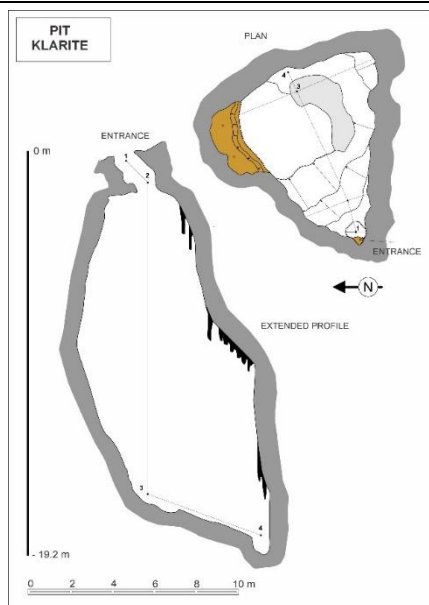


Figure 10. Map of pit Klarite.

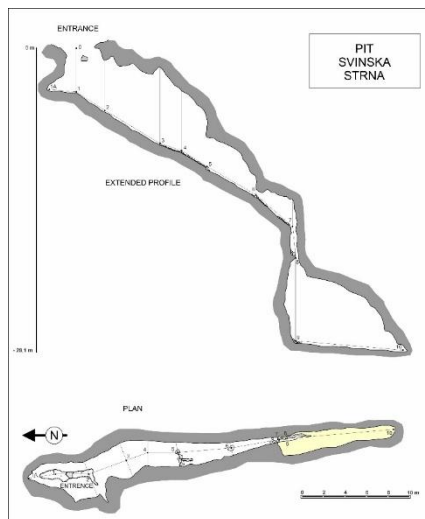


Figure 11. Map of pit Svinska Strna.

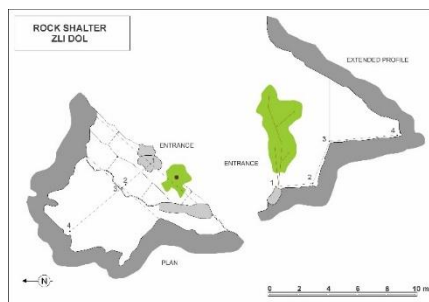


Figure 12. Map of rock shalter Zli Dol.

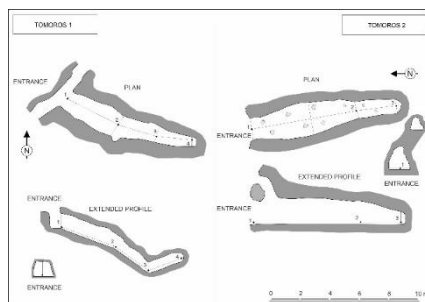


Figure 13. Map of ditches Tomoros 1 and Tomoros 2.

Air temperature in the caves at Galicica was different and ranges from 6°C to 16°C, while the air humidity in the cave environment varied from 55 to 99.98%. Average temperature of the air in the cave Samotska Dupka was 6.12°C and the average air humidity was high and amounted to 99.96%, whereas average temperature of the air in Leskoečka Peštera was 11.09°C, and the average air humidity amounted to 99.98%.

Diversity of invertebrates

The following species are known from the literature concerning the caves of Galicica National Park:

- *Ceuthophyes karamani* Jeannel, 1924, *Cyphophthalmus ohridanus* Hadži, 1973 and *Neobisium ohridanum* Hadži, 1940 from Mečkina Dupka (Jeannel, 1924; Hadži, 1940, 1973);
- *Chthonius ohridanus* Čurčić, 1997, *Chthonius lychnidis* Čurčić, 1997 and *Roncus lychnidis* Čurčić, 1984 from Orevče cave while *Roncus kikimora* Čurčić, 1984 from the habitat in front of Orevče cave (Čurčić et al., 1997; Čurčić & Dimitrijević, 2004);
- *Acanthopetalum carinatum* (Brandt, 1840) from Leskoečka Peštera (Makarov et al., 2004);
- *Troglophilus cavicola* (Kollar, 1833) from Vojla cave (Karaman et al., 2011) and
- 11 species of spiders (Araneae): *Centromerus acutidentatus* Deltsh, 2002, *Nesticus cellulanus* (Clerck, 1758), *Lepthyphantes centromeroides* Kulczyński, 1914, *Lepthyphantes leprosus* (Ohlert, 1865), *Palliduphantes byzantinus* (Fage, 1931), *Palliduphantes trnovensis* (Drensky, 1931), *Meta menardi* (Latreille, 1804), *Gibbaranea bituberculata* (Walck., 1802), *Oxyopes heterophthalmus* (Latreille, 1804), *Tegenaria domestica* (Clerck, 1757), *Tegenaria paragamiani* Deltsh, 2008 from caves Vojla, Leskoečka Peštera, Mečkina Dupka, Samotska Dupka, and Trpejca (Deltsh et al., 2013).

In total, more than 40 species of invertebrates were recorded during the field surveys in the caves in Galicica National Park. All of these species belong to different taxonomic groups, out of which spiders (Araneae) and beetles (Coleoptera) were the most numerous with 16 and 10 taxa, respectively.

Table 1. List of recorded species of invertebrates during the field surveys of caves in Galicica National Park.

Species	Ecological group	Bimilova Peštera	Bojadžieva Peštera	Vojla	Dobroja	Klarite	Krstova Peštera	Leskoečka Peštera	Mečkina Dupka	Naumova Peštera	Samotska Dupka	Svinska Strna	Crna Peš
Araneae													
<i>Centromerus acutidentatus</i> Deltsh+ev, 2002	f							o					
<i>Centromerus</i> sp.	t			o							o		
Gen et sp? (Dysderidae)	t						o						
<i>Harpactea</i> sp.	x								o		o		
<i>Lepthyphantes leprosus</i> (Ohlert, 1865)	f							o					
<i>Meta menardi</i> (Latreille, 1804)	f						o						
<i>Metellina merianae</i> (Scopoli, 1763)	f	o	o							o			
<i>Nesticus cellulanus</i> (Clerck, 1757)	f	o					o	o					
<i>Palliduphantes byzantinus</i> (Fage, 1931)	f							o	o				
<i>Palliduphantes trnovensis</i> (Drensky, 1931)	f					o						o	
<i>Tegenaria domestica</i> (Clerck, 1757)	f	o					o			o			
<i>Tegenaria faniapollinis</i> Brignoli, 1978	f								o				
<i>Tegenaria ferruginea</i> (Panzer, 1804)	f		o										
<i>Tenuiphantes tenuis</i> (Blackwall, 1852)	f					o							
<i>Troglohyphantes</i> sp.	t					o	o						
<i>Zygiella keyserlingi</i> (Ausserer, 1871)	x	o											
Coleoptera													
<i>Bathyscidius rambouseki</i> Knirsch 1931	t						o						

Species	Ecological group	Bimilova Peštera	Bojadžieva Peštera	Vojla	Dobroja	Klarite	Krstova Peštera	Leskoečka Peštera	Mečkina Dupka	Naumova Peštera	Samotška Dupka	Svinska Strma	Crna Peš
<i>Blaps mucronata</i> Latreille, 1804	x	o	o						o				
<i>Ceuthophyes karamani</i> Jeannel, 1924	f					o					o		
<i>Cychnus semigranosus albanicus</i> Hopp, 1929	a			o							o		
<i>Duvalius</i> cf. <i>vignai</i> Casale, 1983	f			o							o	o	
<i>Enoplopus dentipes</i> (Rossi, 1790)	x										o		
<i>Helops</i> sp.	x										o		
<i>Laemostenus (Antisphodrus) cavicola</i> sp.	f						o						
<i>Laemostenus terricola punctatus</i> (Dejean, 1828)	f			o				o					
Crustacea													
<i>Niphargus</i> sp.	f	o											
Diptera													
<i>Limonia nubeculosa</i> Meigen, 1804	f			o			o	o		o	o		o
Gastropoda													
<i>Gyalina mirabilis</i> Pintér & Riedel, 1973	f						o						
<i>Helix lucorum</i> Linnaeus, 1758	x						o			o			o
<i>Helix schlaeflii</i> Mousson, 1859	x										o		
<i>Oxychilus</i> sp.	f						o				o		
<i>Zebrina detrita</i> (O.F.Müller, 1774)	x										o		
Isopoda													
? <i>Alpioniscus</i> sp.	f			o				o	o		o		
Lepidoptera													
<i>Autographa</i> sp.	x							o					
<i>Scoliopteryx libatrix</i> (Linnaeus, 1758)	f										o		
<i>Triphosa</i> sp.	f										o		
Orthoptera													
<i>Troglophilus cavicola</i> (Kollar, 1833)	f			o	o		o	o			o		
Pseudoscorpiones													
<i>Allochernes</i> sp.	f									o			
<i>Neobisium</i> sp.	x					o	o				o		
<i>Roncus</i> sp.	x									o			

Ecological group: f - troglobite, f- troglophile, x - troglaxene and a - accidental troglaxene

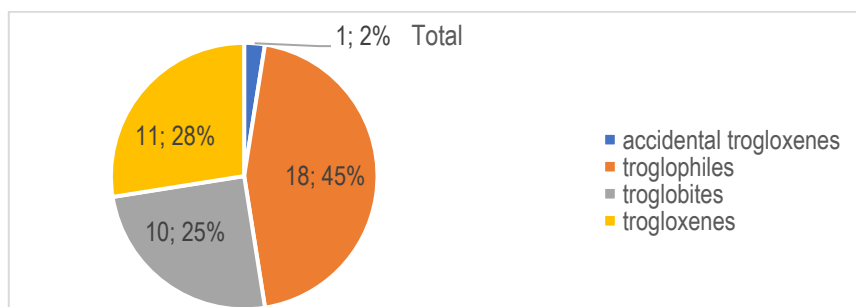


Figure 14. Number and percentual participation of ecological groups of invertebrates in caves of Galicica National Park.

The caves of Galicica National Park are inhabited by 10 species of troglolithes which consist 25% of the invertebrate cave fauna. However, the most numerous in

species were troglaphiles (18 species, 45 %). The troglaxenes and accidental troglaxenes were recorded with 12 species (Fig. 14). Presumably, the greatest attention during the field research was paid to troglabites and troglaphiles which lead to small number of species of troglaxenes and accidental troglaxenes.

Diversity of bats

Nine bat species were recorded to roost in the caves: greater horseshoe bat (*Rhinolophus ferrumequinum*), lesser horseshoe bat (*Rhinolophus hipposideros*), Blasius' horseshoe bat (*Rhinolophus blasii*), Mediterranean horseshoe bat (*Rhinolophus euryale*), greater mouse-eared bat (*Myotis myotis*), lesser mouse-eared bat (*Myotis blythii*), long-fingered bat (*Myotis capaccinii*), Geoffroy's bat (*Myotis emarginatus*) and Schreiber's bent-winged bat (*Miniopterus schreibersii*) (Table 2). The numbers and the species composition of bats differ in all caves and vary seasonally. The largest mixed bat colony was found in Bimbilova cave with more than 4000 individuals of long-fingered bat and Schreiber's bent-winged bat.

Table 2. List of recorded bat species during the field surveys of caves in Galicica National Park.

Species	Samotska Dupka	Bimbilova Peštera	Vojla	Klarite	Krstova Peštera	Leskoečka Peštera	Mečkina Dupka	Naumova Peštera	Svinska Strna	Crna Peš
<i>Rhinolophus ferrumequinum</i>	+	+			+	+		+		
<i>Rhinolophus hipposideros</i>	+			+	+	+	+	+	+	+
<i>Rhinolophus blasii</i>						+	+			
<i>Rhinolophus euryale</i>		+	+		+	+		+		+
<i>Myotis myotis</i>	+									
<i>Myotis blythii</i>	+									
<i>Myotis capaccinii</i>		+						+		
<i>Myotis emarginatus</i>								+		+
<i>Miniopterus schreibersii</i>		+						+		

Cave's database

The prepared database contains in total 39 speleological objects. The database has in total 21 caves (Table 3), 6 pits (Table 4) and 12 rock shelters (Table 5).

The master table of the database (excel table on google drive) consists of total of 22 main types of data fields - Cave/Pit name, Coordinates, Type of speleological object, Altitude of entrance (meters), Location, Type of rocks, Geological age of rocks, Total length (meters), Hydrographic function, Physical characteristics (air

temperature, water temperature, humidity, snow masses, etc.), Cave fauna – troglobites, Cave fauna – troglaphiles, Cave fauna – troglloxenes, Cave fauna – bats, Paleontology, Archaeology, Legends, Value, Protective category, Maps, Photographs, Literature and link to the literature).

Table 3. List of caves in Galicica National Park.

	Name	Location	Total Length (m)
1	Alpinistička Peštera	Dobroja (near via ferrata)	27.94
2	"B"	Prespa Lake, v. Evla	25
3	Bimbilova	Golem Grad	50
4	Bojadžieva	Golem Grad	50
5	Vojla (Sklana)	Asan Gjura	/
6	Gorno Studino	/	/
7	Duvalo-Trpejca	above the v. Trpejca	4-5 m
8	Dupkana	v. Konjsko	12
9	Dupka nad selo	v. Shipokno	25
10	Krstova Peštera	above the v. Trpejca	58.7
11	Leskoečka Peštera	v. Leskoeec	48
12	Mala Peštera (nad Krstova)	above the v. Trpejca	3.42
13	Mečkina Dupka	Ohrid, Bey Bunar	20.7
14	Naumova Peštera	v. Trpejca	31
15	Nevestulka	Zli Dol	/
16	Samotska Dupka	Asan Gjura	224
17	Svinska strna	Asan Gjura	-28.1
18	Tomoros 1	peak Tomoros	9.5
19	Tomoros 2	peak Tomoros	10
20	Tušena	/	/
21	Crna Pešt	v. Trpejca	17.6

Table 4. List of pits in Galicica National Park.

	Name	Location	Total Length (m)
1	Vetri Gumenja	Vetri Gumenja	/
2	Klarite	Ceremušana (Prespa valey)	-19.2
3	Kolkova Dupka (Kolkoa Dupka)	v. Ljubaništa (area Elenot)	/
4	Na Ploči	v. Konjsko	/
5	Rblok	v. Elšani	18.5
6	Tomoros 3	peak Tomoros	-4

Table 5. List of rock shelters in Galicica National Park.

	Name	Location	Total Length (m)
1	Brlj Kamen 1	Zli Dol	7.1
2	Brlj Kamen 2	Zli Dol	/
3	Brlj Kamen 3	Zli Dol	/
4	"V"	Prespa Lake, v. Evla	/
5	Gojarnik	v. Peštani	/
6	Gorna Temnica	v. Peštani	/
7	Dobroja	Dobroja (via ferrata)	11.2
8	Dolna Temnica	v. Peštani	/
9	Kaj Vodana ("A")	Prespa Lake, v. Evla	8
10	Kobličina Dupka	v. Peštani	10 - 15
11	Nad Trpejca	near v. Trpejca	/
12	Orevče	v. Peštani	10

The main component of the database is based on Google platform, with separate folders for each possible cave (containing subfolders for Map, Literature and Photo) – connected to the active master table (excel). For the database to have a multidisciplinary approach, the Google Drive and Excel file is connected to QGIS attribute table, so each user can have access to all the data.

DISCUSSION

Most of the investigated caves in Galicica National Park represent well preserved ecosystems. They are suitable for research of cave evolution, geodiversity significance and determination of their value and possible protective status.

The continuous monitoring of the microclimate in the caves Samotska Dupka and Leskoečka Peštera, can determine the impact of the external environment to the caves. Such research should continue in the future to determine the degree of vulnerability of cave ecosystems to climate change.

The presented list of cave species is the first attempt to present the speleodiversity Galicica National Park. So far, only Dona Duka cave as well as caves in Matka have received such an attention (Kolcakovski et al., 2009a, 2009b). However, we are aware that many species were not recorded of different taxonomic groups and ecological preferences. We hope that this effort will motivate many taxonomic specialists to conduct the research on various groups in order to fill-in the gaps. There are some open taxonomic questions which will presumably result in description of new taxa for sciences (Coleoptera – Carabidae, Arachnida – Araneae, Pseudoscorpiones). Nevertheless, the diversity of specialized species in the caves of Galicica National Park is impressive and deserves special attention for the protection of these valuable habitats.

Caves in the area of Galicica National Park proved to be important roosting site for 9 bat species throughout the year or in a certain season. Bimbilova cave hosts the largest colony with several thousand individuals of at least two bat species throughout the year. It is also an important hibernacula for bats in Prespa region, and most probably as maternity roost. The other caves in Galicica hosts smaller bat populations throughout the year.

To ensure sustainability and proper use of the database, Manual on Macedonian language has been prepared on how to use the database, with step-by-step explanatory process to foster a culture of knowledge sharing and collaboration among the database users to maximize its utility and impact. The prepared database of caves unites the speleological and biospeleological features of the speleological objects of Galicica National Park. It is a strategic document for the management of the National Park in order to enhance the protection of the cave ecosystems.

CONCLUSION

The database in future can be populated with new information about the explored caves or update it through utilizing advanced techniques such as 3D mapping to provide more detailed representations of cave structures. For proper use of the database, trainings, workshops, and support to users of the database must be provided on annual level, ensuring proficiency in data input, usage, and backup procedures. To build upon the achievements of the conducted activities and further enhance the usage and impact of the cave database, the developed database can be used as an example to other protected areas, institutions, civil society etc. of free to use/access data base, not requiring paid programs, easy to use and accessible for users without GIS background (the part of the Google platform access of the data base). The prepared database is a representative case study and can serve as an example for preparation of a National database of caves.

Acknowledgment

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