CAVE LIFE

Ľubomír Kováč

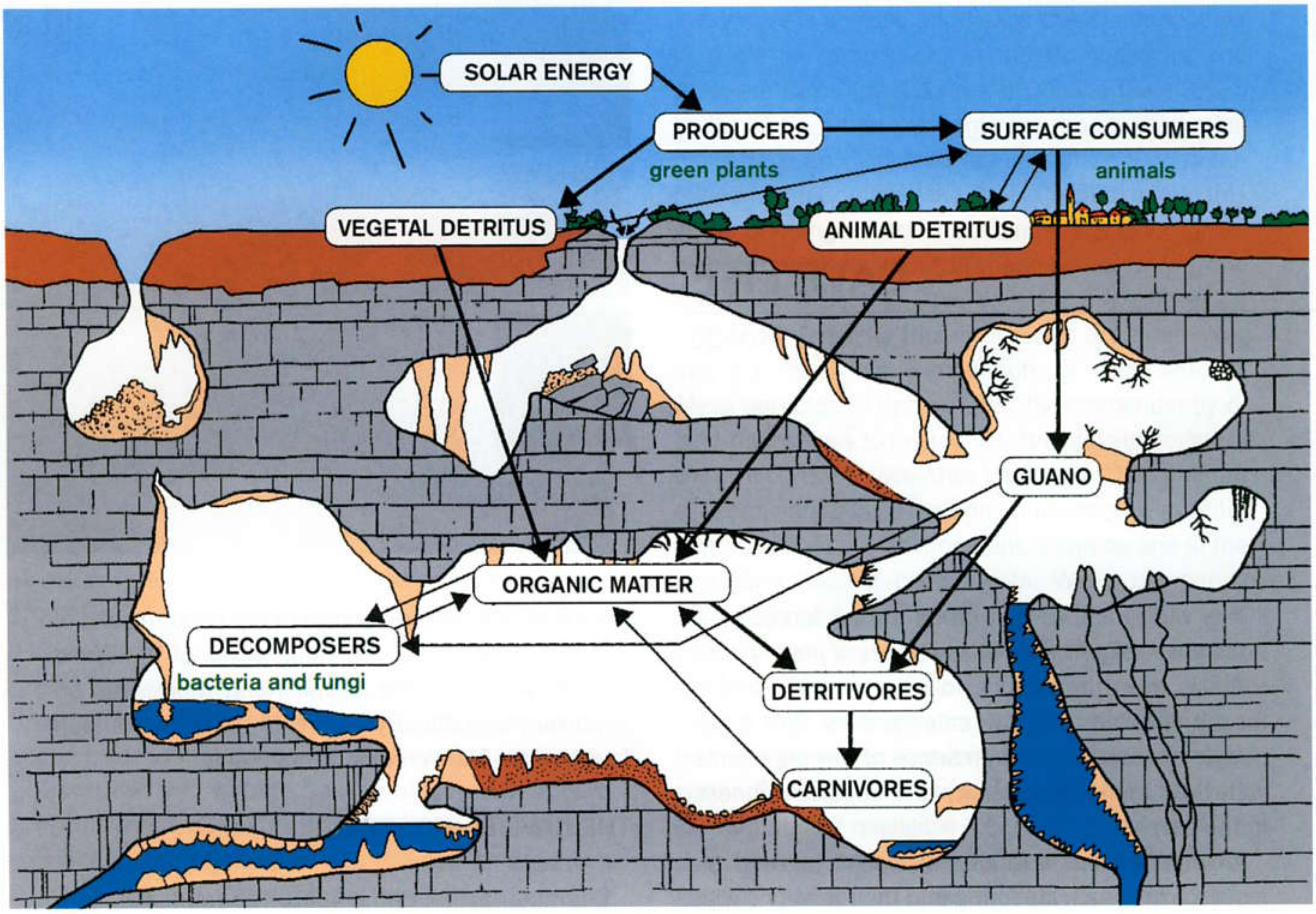
It is widely known that caves do not represent a dead environment without any traces of life and that there is even the chance to meet some animals, for example bats, frogs or salamanders. Only a few people are aware of the presence of tiny organisms with their immense diversity and species richness in the caves.

An independent scientific discipline focused on research into such life forms and their relations with the surrounding environment – ***biospeleology*** was established on the basis of this phenomenon. We can meet typical cave animals, often with bizarre shapes, in tropical and subtropical caves of the world. In Europe rich underground fauna occurs predominantly in caves of the Balkan karst mountains. Intensive biospeleological research in the last two decades has confirmed the presence of unique subterranean animals in the karst regions of Slovakia. Many of them inhabit caves of the World Natural Heritage. The Slovak Karst represents an important evolutionary centre of the subterranean fauna within the Western Carpathians.

Flying bat, Domica Cave. Photo: P. Bella

THE CAVE ECOSYSTEM

Characterization of the ***subterranean*** (cave) ecosystem is necessary if we want to understand the crucial phenomena of the distribution of living organisms in caves. Among the most important ***abiotic*** factors (agents of the "lifeless" environment) are light, temperature and air humidity. Light is a limiting factor for the occurrence of vegetation in the entrance parts of the caves. The majority of underground fauna escapes from the light to the dark, a phenomenon called ***photophobia***. However, it was observed that light does not necessarily constitute a limiting factor. For example, aquatic crustaceans of the genus *Niphargus* regularly occur in karst springs where they find richer and more accessible food, but also more natural enemies. Cave air temperature reflects the yearly average value of the external environment as a result of the latitude and altitude of the given site. The temperature range, which the animals are able to tolerate, differs with the species. Subterranean fauna is able to withstand lower temperatures (close to the freezing point) more easily than values above 20 °C. Air humidity is an important factor ruling the distribution of true cave fauna that prefers high values (95 – 100 %). Drier spaces are poorer for specialized subterranean forms. In caves with high air humidity due to percolating water, such



Food web in cave environment (after M. Chiesi et al., 2002)

as the Domica or Krásnohorská Cave, *Niphargus* specimens may be observed in water pools or even moving on the wet cave floor overcoming relatively long distances.

All living components of the ecosystem may be classified as ***biotic*** factors. ***Autotrophic*** organisms are the category associated with the presence of light (algae, mosses, lichens and higher plants). They produce organic substances as a result of photosynthesis performed in their bodies. Heterotrophic organisms are consumers of these substances and so are primarily dependent on the autotrophs. This group includes bacteria, microscopic fungi and animals. The presence of autotrophic organisms is limited to the entrance parts of the caves exposed to the light on which they are dependent. However, they are absent in the internal cave spaces and the food web is based only on the nutrients in the form of organic remnants originating in the surface karst horizons. A simplified food web dominated by ***detritophagous*** animals (those feeding on dead organic materials) and carnivorous (predator) forms is characteristic of caves.

CAVE VEGETATION

Caves, deep sinkholes, and gorges have special vegetation. The rapid changes in the environmental conditions give rise to the well-known phenomenon of ***inverse stratification*** of the flora. In the Slovak Karst the great entrance part of the Silická

Liverworts – inhabitants of the cold and wet cave entrances. Photo: P. Ľuptáčik

Macroscopic ligniperdous fungi in the Krásnohorská Cave.
Photo: P. Ľuptáčik

Algae - part of the lamp flora, Domica Cave.
Photo: P. Ľuptáčik

Mucor mucedo *- colony of the microscopic fungi covering bat guano.*
Photo: P. Ľuptáčik

ľadnica Cave, evolved by failure of the cave ceiling, is a good example of this phenomenon. Counting from the surface of the karst plateau to the end of the floor ice it is 79 m deep. The air temperature at the bottom of the monumental entrance of abyssal character fluctuates only negligibly around 0 °C. We may observe here well-marked vegetation associations. At the margin of the plateau with direct sunlight, a ***euphotic zone*** with predominantly higher, flowering plants occurs. In the twilight - ***dysphotic zone*** - we may find ferns, mosses, liverworts, lichens and algae growing on the primary soil or rocks. In the lower part of this space only ice and talus deposits are present. In the zone of full darkness of caves - the ***aphotic zone*** - vegetation is completely absent. That is why it is not correct to classify any plant as a true cave organism although some species prefer conditions close to the cave entrances. Deeper caves are inhabited by primitive microscopic fungi (moulds), light-independent bacteria and in some special cases also by green algae. They are very important as food sources for many animals. On rotten wood we may observe fruiting bodies of ligniperdous fungi. In caves the colonies of microscopic fungi such as *Mucor mucedo* may be easily recognized on the surface of the bat guano.

Growths of primitive plants around light bulbs, so-called ***lamp flora***, represent artificial communities in caves. Lamp flora is composed mainly of diatoms, blue and green algae, mosses and sometimes also of ferns. It is an undesirable and unnatural component, development of which is apparently limited by using of cold light and is removed either mechanically or chemically.

CLASSIFICATION OF THE CAVE FAUNA

Cavernicolous (rock crevice inhabiting) animals dwelling in subterranean habitats are adapted to this environment to different extents. Thus, several ecological categories were outlined that partly reflect ***adaptations*** of the particular faunal species. Of the proposed classifications, division of the subterranean fauna into four categories is widely used at present. Terrestrial animal forms entering the caves only at random, perhaps transported by water stream from the surface or fallen into abysses, are called **trogloxenes**. Animals that may be found in caves more regularly are classified as **troglophiles**. They represent a broader category involving two rather different groups. **Subtroglophiles** are associated with caves only during certain stages of their life cycle and they do not posses any specific adaptations to this kind of environment. Some dipteran flies or bats may serve as examples of animals dwelling in caves only during a certain season of the year or during some part of the day. **Eutroglophiles** are animals permanently preferring the subterranean environment and are well adapted by external body constitution and usually also by internal life functions. However, they may marginally live and reproduce also beyond the caves, as do some mites, collembolans and other arthropods. Obvious adaptations to the subterranean world are characteristic of **troglobites,** which spend their whole lives in caves or similar habitats.

The similar classification may be used for the aquatic fauna, where we may distinguish **stygoxenes**, **stygophiles** and **eustygophiles**. Organisms strictly limited to occurrence in underground water are classified as **stygobites**. The prefix of these words is derived from the Styx River, that in Greek mythology represented the river through which dead people entered the underworld. We may register such animals in the Styx of the Domica Cave or in the underground streams of the Krásnohorská and Hrušovská caves. However, these expressions are not strictly connected with the cave fauna. For example, the **phreatobites** that live in the tiny crevices among the sand particles and gravels in submerged sediments of the cave and above-ground streams also belong to the stygobites. It is not always easy to allocate animals occurring in the underground to one of the above-mentioned categories, since there are many intermediate cases. This division of the subterranean fauna suggests the necessity of protection of the specific micro-environments inhabited by this fauna.

ADAPTATIONS OF THE CAVE FAUNA

Adaptations to life in the subterranean spaces are obvious predominantly found in animals classified as troglobites. Interestingly very similar adaptations are observed in very different faunal groups. We may recognize adaptations in external body shape (morphological), internal life processes (physiological), behaviour (ethological) and heritage (genetic). The morphological adaptations are very marked and often very bizarre, especially in the warmer regions of the Earth. Reduction or complete lost of the visual apparatus is characteristic of the majority of true cave animals. They are pale or white as the consequence of the reduction or absence of pigmentation in cover body layers. In many arthropods we may observe apparently elongated antennae and legs. On these extremities an increased number of elongated sensory setae is distributed. The function of these external body changes is to strengthen sensory organs that are essential for life in complete darkness, namely sensitivity to air humidity and odour (chemical) signals. Longer legs enable the animal to move faster when searching for food, sources of which are usually poor in the cave environment. Among the most pronounced physiological changes the following are concerned: elimination of the daily rhythms in animal activities, inhibition of the metabolism and ability to starve for longer periods, and lower number of eggs laid. Ethological adaptations are connected with the mode in which the animals colonize underground habitats.

THE UNDERGROUND ENVIRONMENT AND CAVE FAUNA

Terrestrial subterranean environment

The term "cave ecosystem" was used for a long time for the parts of the natural underground spaces reachable by man. However, caves are not the only environment inhabited by the cavernicolous fauna. The terrestrial underground environments may be divided into three main groups:

1. natural caves
2. epikarst
3. artificial caves made by man

Natural caves usually represent spaces that may hide even larger animals – bats or amphibians. The presence and distribution of the animals in them is determined by various ecological factors. In many cases we may distinguish several well-defined associations of the animals occurring in caves. Cave entrances are markedly influenced by the external climate. These usually wetter and protected sites serve as refuges for some bird species (pigeons, owls, passerine birds). Some animals nest or stay close to the entrances, for example, dormice, frogs, salamanders, snails, insects and other arthropods. From the entrance to the beginning of the aphotic zone, cave walls and ceilings are inhabited by a heterogeneous community of animals defined as **parietal fauna**. They represent occasional cave animals using cave entrances only as temporary shelter mainly during summer and winter (troglophiles): dipterans, butterflies, trichopterans, spiders and opilionids. The composition of such communities is dependent on the size, orientation and altitude of the entrance, further on the structure of the entrance parts of the cave and on the seasonal changes of the above-ground climate. Internal parts are used by bat colonies that produce excrements rich in nutrients during their activity phase – ***guano***, an important food source for a wide spectrum of invertebrates. Depending on the degree of association with such micro-environment they may be classified either **guanophiles** or **guanobites**. On the piles or smaller guano accumulations we may recognize earthworms, mites, collembolans, woodlice, millipedes, beetles and dipterans. Thus, the populations of such animals are primarily associated with the presence of bats depending on the amount and the age of the guano.

Obligate cave forms of the fauna live in the deeper parts of caves in complete darkness, stable temperatures and high air humidity. We may observe them on the surface of sediments and speleothems, under rocks, on the organic remnants or on the surface of the water pools. In most cases they represent tiny animals that may penetrate into ***epikarst*** consisting of the system of interconnected micro-caverns in fragmented bedrock. It is situated in the upper zone of the karst massif under the superficial soil layers. This environment type links caves with the rest of the karstic system. It has been biologically poorly explored since it is hardly accessible to man.

In the territory of Slovakia, the third underground environment type has been poorly understood – the artificial shafts and adits of mines. The biological observations in that environment may add considerably to understanding of the distribution and evolution of cave fauna in the country.

The aquatic subterranean environment

This environment type may be classified into two main types: waters circulating in porous rock (alluvial terrains) and waters flowing in disconnected, predominantly karstic rock. Both types are inhabited by different fauna with specific adaptations to life in these environments. Animals of the first type are **phreatobites**, fascinating forms that have been insufficiently known up to now. Their bodies are considerably modified enabling them to live in the ***interstitial environment***, namely the micro-spaces between sand and gravel particles. The crustacean *Bathynella natans* is a good example of such fauna. Water circulating in fragmented, eroded rock is present predominantly in the karst regions. We recognize two hydro-geological zones within this environment type. The ***vadose zone*** includes the upper part of the karst massif with mainly vertical flow of the water. Here the fauna is well adapted to life in small crevices, it may occasionally appear in water pools, too. They are chiefly tiny animals with elongated and flattened bodies, such as planarians, nematodes, oligochaete worms, and from crustaceans cyclops and amphipods serve as good examples. We may also detect larger forms in such habitats, like amphipod crustaceans of the genus *Niphargus* the length of which can exceed 2 centimetres. The ***phreatic zone*** covers the part of the massif with mainly horizontal water flow. The zone is usually populated by a higher number of faunal species. This is the kingdom of larger crustaceans, for example, the above mentioned *Niphargus*.

DIVERSITY OF CAVE ORGANISMS

The ***biodiversity*** (species diversity of the organisms) of caves primarily depends on the abiotic factors of the environment. ***Heterogeneity*** of the given habitat is also very important since a wide spectrum of micro-habitats creates more possibilities for colonization by various forms of organisms. The size of the karst area is crucial in this respect since larger areas are normally inhabited by a higher number of species of organisms. This is also the case of the vast plateaus of the Slovak Karst. The biodiversity of caves also depends on stability of the environment. Less stable caves with rather fluctuating conditions during the year create diverse micro-habitats thus populated by faunal communities richer in species. Food accessibility is one of the principal factors regulating biodiversity of the subterranean habitats. ***Eutrophic*** spaces with sufficient supply of organic matter are rich in fauna and micro-organisms, for example, the bottoms of the entrance shafts with fallen plant remnants, or cave parts with guano deposits. However, in these parts trogloxenes, troglophiles or guanophiles prevail. ***Oligotrophic*** caves are poor in organic materials and are populated by fauna poorer in species. On the other hand, such caves host higher number of troglobitic animals compared to the preceding case.

ORIGIN, EVOLUTION AND DISTRIBUTION OF TROGLOBITES

Why and how did animals penetrate into the subterranean world? How is it possible that they were able to adapt to such a harsh environment? There are two main theories trying to answer these questions. Both consider evolution from ancestors originating in above ground habitats (soil, surface water streams). One of them regards cave forms of fauna as remains - ***relicts*** of the preceding geological periods, so-called "living fossils". For such forms the caves are the ***refuges*** against unfavourable external conditions. Based on this theory, surface fauna was forced to look for shelters deeper underground with the start of the long periods of the cold and dry Pleistocene climate roughly 2 million years ago. The second theory, on the other hand, considers active colonization of caves by fauna, a process that continues up till the present. However, not all animals are able to populate such an environment permanently. In some cases this was the way to the evolution of a higher number of related forms from one ancestor within a relatively small area, the evolutionary process called ***adaptive radiation***. This is the case of carabid beetles of the genus *Duvalius* and its subspecies in the territory of the Western Carpathians.

Colonization of the subterranean habitats by the surface fauna, either passively as the consequence of unfavourable climate or by active penetration, is accompanied by ***speciation***, that is by the evolution of new species. ***Isolation*** of the space or area is an unavoidable premise for the evolution of new species. Populations of the original species isolated in subterranean spaces for a relatively long time (tens- or hundred-thousands of years) become different from the ancestor during successive adaptations, species being the final product of this process. In many karst regions the populations of the same species are isolated from the surface populations. Many examples of the origin of independent species within one cave system are known. Such unique forms, limited in their occurrence to a relatively small area, are called ***endemics***. They represent the rarest and most vulnerable forms of life. We will concentrate on them more thoroughly in the following part involving the peculiarities of the cave life within the World Heritage sites in Slovakia.

THE PECULIARITIES OF LIFE IN CAVES OF THE WORLD HERITAGE

In this chapter the biota of the best known caves is stressed: Domica, Gombasecká, Krásnohorská and Jasovská caves, Silická ľadnica Cave, Ochtinská Aragonite Cave and the Dobšinská Ice Cave. We will also mention some peculiar animals of other caves or abysses of the Slovak Karst that are the part of the World Heritage.

In recent years a wide spectrum of **micro-organisms** were recorded in the caves of the Slovak Karst. Green algae are typical components of the lamp flora, with *Stichococcus bacillaris, Chlorella minutissima*, or species of the genus *Desmococcus* sp. Microscopic fungi are extraordinary in their diversity. They serve as the important food source for many smaller invertebrates, such as mites and collembolans. The species of the genus *Mucor* dominates among the first colonizers of bat guano. Entomopathogenic *Beauveria brongniartii* creates variable macroscopic colonies on limestone rocks and sinter fillings. *Pidoplitchkoviella terricola* isolated from isopod excrements is a very rare saprotrophic microfungal species.

The unicellular animals - **protists** (Protista) have not been explored sufficiently in the caves of the Slovakia yet, so we have almost no information on this animal group. **Planarians** (Turbellaria) of the genus *Dendrocoelum* are rather rare among the aquatic fauna, they are predators feeding on tiny invertebrates, including dead bodies. Among the small forms of **annelids** oligochaete worms (Annelida) that live in the clay sediments of the underground streams, or in decaying organic materials within the terrestrial habitats no unique forms have been observed yet. Larger annelids - earth-

Planarian worm of the genus Dendrocoelum *from the Farbený ponor Cave. Photo: J. Stankovič* worms represent permanent components of the fauna of many caves being preferably associated with the presence of wood. They are able to consume great amounts of clay sediment together with organic remains. In the Domica Cave several earthworm species have been detected, but not specialized cave forms. Remarkable traces of their activity are the casts (earthworm excrements) in many sites in the cave, especially in the river-bed of the Styx, often even on the sinter surfaces. Leaches have occasionally been registered in the underground waters, for example, the surface species *Haemopis sanguisuga* in the Domica Cave.

Molluscs (Mollusca) may be rather abundant in the caves of Slovakia. The snail *Oxychilus glaber* is an abundant inhabitant of the entrance micro-habitats. In karst springs we may meet the snail *Sadleriana pannonica* – an endemic of the Slovak and Aggtelek Karst, and Bükk Mts. in Hungary, as well as *Bythinella austriaca*. A so far undescribed species of cave snail of the genus *Hauffenia* has been reported from several karst springs of the Silická and Plešivská plateaux. On the surface of bank sediments of underground streams tiny bivalves of the genus *Pisidium* may be observed by the naked eye, they are very abundant in the river-bed of the Čierny Brook of the Silická ľadnica Cave.

Palpigrade Eukoenenia spelaea *(body length 1.5 mm).*
Photo: G. Csizsmárová and Ľ. Kováč

Snail Oxychilus glaber *(body length 14 mm), Krásnohorská Cave.*
Photo: P. Ľuptáčik

The highest species diversity of cave invertebrates is concentrated in the animal phyllum Arthropoda. Several unique animals of the World Heritage caves belong to the arachnids (Arachnida). **Palpigrades** (Palpigardi) have been registered in Slovakia in one species – *Eukoenenia spelaea* distributed in several caves, including the Domica, Gombasecká, Krásnohorská, Hrušovská and Jasovská caves. It represents an evolutionarily primitive arachnid form demonstrating typical characteristics of the obligate cave dwellers. A long and segmented flagellum on the end of the abdomen is one of the peculiar morphological features of this arachnid group. The territory of Slovakia is the northern-most region with the presence of palpigrades in the world. The mode of their reproduction and food preferences remain unknown. The other arachnids – predatory **pseudoscorpions** (Pseudoscorpionida) usually do

Pseudoscorpion Neobisium (Blothrus) slovacum *(body length 4 mm).*
Photo: Ľ. Kováč

Harvestmen Ischyropsalis manicata *often penetrating deeper into the caves. Photo: P. Ľuptáčik*

Spider Meta menardi, *inhabitant of the cave entrances. Photo: P. Ľuptáčik*

Troglobitic spider Porrhomma profundum, *Domica Cave. Photo: J. Stankovič*

Oribatid mite Pantelozetes cavaticus *(body length 0.5 mm). Photo: G. Csizsmárová and P. Ľuptáčik*

not live in caves. Troglobite *Neobisium* (*Blothrus*) *slovacum,* characterized by strongly elongated pincer pedipalps, have been observed in many abysses of the Plešivská Plateau, and in a limited number of caves on the Horný vrch and Zádielska plateaus. The species was described by J. Gulička in the 1970s. This was an important landmark in Slovak biospeleology since it represented one of the most valuable confirmations of original troglobitic fauna in the Slovak caves. From the **harvestmen** (Opiliones), *Ischyropsalis manicata* is a smaller predatory arachnid with remarkable chelicerae inhabiting, for example, the Domica Cave. Spiders (Araneae) such as *Meta menardi* are found in large numbers in cave entrances, where they catch flying insects in their webs. Some smaller forms of spiders are adapted to life in the deeper cave spaces where they look for their prey, most often collembolans, mites or insect larvae. The most peculiar of them belong to the genus *Porrhomma* of which *P. profundum* is considered troglobitic species. The species was described from the Domica Cave where it established stable populations. **Mites** represent an arachnid group with strongly diversified communities. Oribatid mites consume algae, fungi and rotten organic materials (wood, guano). *Pantelozetes cavaticus* is closely associated with caves. It was first described from the Čertova diera Cave near Domica. It is a eutroglophile mite often occurring in close vicinity to bat guano. Oribatid mite *Damaeus lengensdorfi* is a larger form with elongated legs, an inhabitant of the Domica Cave. In the same cave, the uropodid mites *Uroobovella advena* and *Cyrtolaelaps chiropterae* are among the principal constituents of the bat guano associations. Predatory mites are represented by the eutroglophile form *Parasitus loricatus*, a regular inhabitant of the Slovak caves, or rhagidiid mites of the genus *Robustocheles* registered in the Domica Cave in recent years.

Crustaceans (Crustacea) are predominantly aquatic animals. The terrestrial eutroglophile isopode *Mesoniscus graniger* (Isopoda) is an exception establishing abundant populations in the Domica and Jasovská caves as the important consumer of the bat guano. The isopode was discovered by Slovak native J. Frivaldszky in 1865 in the Baradla Cave near Aggtelek, a part of the Domica-Baradla cave system. Among aquatic crustaceans *Niphargus tatrensis* is worth mentioning. It is distributed in the majority of Slovak caves with standing or flowing waters. As a symbol of stygobitic animals it is abun-

Isopod Mesoniscus graniger. *Photo: J. Stankovič*

Stygobitic crustacean Niphargus tatrensis. *Photo: J. Stankovič*

Phreatobitic crustacean Bathynella natans *(body length 1.5 mm). Photo: I. Hudec*

dant especially in the Styx River (Domica) where the individuals are notable for their unusual size of up to 4 centimeters. Rich communities of cladocerans (Cladocera) penetrate into the Domica Cave by the flow of the Domický Brook especially during heavy rainfalls. However, in the underground waters in Slovakia no obligate cave species has been discovered yet. Of the related copepods (Copepoda), three species populating the Styx River may be classified as phreatobitic: *Acantocyclops venustus*, *Diacyclops languidoides* and *Microcyclops rubellus*. *Bathynella natans* belonging to the Bathynellae group of crustaceans is a phreatobite living in the micro-spaces of submerged sediments of the underground riverbeds. It may marginally occur in lakes such as in the Biela Hall of the Dobšinská Ice Cave.

The pale and blind **millipede** (Diplopoda) of the genus *Typhloiulus* was detected in the Domica and Gombasecká caves thus representing one of the most valuable discoveries of cave fauna in Slovakia in recent years. It is our largest troglobite with a body length of 2.6 cm and 147 pairs of leg. The millipede *Brachychaeteuma bradae* is a typical inhabitant of the Domica Cave. The Dobšinská Ice Cave is inhabited by *Allorhiscosoma sphinx*, a cavernicolous millipede endemic to the Western Carpathian caves. Millipedes are important consumers of decaying organic materials deposited in caves.

Collembolans (Collembola) are among the most abundant arthropods of the subterranean habitats. Several species in our caves exhibit a high degree of adaptation to that environment. They preferably feed on fungi covering the surface of decaying organic remains, or even the surface of the speleothems. *Hypogastrura crassaegranulata dobsinensis* is an inhabitant of the inversed entrance moss vegetation of the Dobšinská Ice Cave. It is a glacial relict surviving here from the last Pleistocene glaciation. Several troglobitic forms of Collembola may be recognized within the genera *Deuteraphorura*, *Pseudosinella*

Troglobitic millipede of the genus Typhloiulus, *Domica Cave. Photo: Ľ. Kováč*

Troglobitic collembolan Pseudosinella aggtelekiensis *(body length 2 mm). Photo: J. Stankovič* and *Arrhopalites*. *Deuteraphorura kratochvili* is a typical collembolan of the Dobšinská Ice Cave. In the caves of the Slovak Karst the species is replaced by a closely related undescribed one. *Deuteraphorura schoenviszkyi* ocurring in the Gombasecká Cave is a troglobite as well and an endemic species of the Slovak and Aggtelek Karst. *Pseudosinella aggtelekiensis* is an endemic species distributed in the same area where it is often abundant. In karst regions of the central Western Carpathians it is replaced by the closely related *P. paclti* that lives in the Dobšinská Ice Cave, too. The genus *Arrhopalites* includes several obligate cave forms in our territory. Eutroglophilous *A. pygmaeus* is a frequent species of the cave communities. On the other hand, troglobitic *A. aggtelekiensis* is distributed in a limited number of undisturbed caves where they may be rather numerous, as in the Čertova diera Cave near Domica and in Krásnohorská Cave. It is an endemic species of the Slovak Paradise, Muránska Plateau and Slovak Karst. During biospeleological research in recent years some unknown collembolan species have been discovered such as a new species of the genus *Mesaphorura* in the Krásnohorská Cave or that of *Neelides* and *Megalothorax* in the Jasovská Cave. Such discoveries confirm how limited our knowledge of such small living creatures populating subterranean habitats still is.

Collembola on surface of a water pool, Krásnohorská Cave (body length of smaller Megalothorax *sp. 0.5 mm). Photo: J. Stankovič*

Troglobitic collembolan Arrhopalites aggtelekiensis *(body length 2 mm). Photo: Ľ. Kováč*

Beetles (Coleoptera) are among the most remarkable cavernicolous arthropods. E. Csiki and E. Bokor provided the first information on the cave beetles of the Slovak Karst at the beginning of the last century. In caves the genera *Trechus, Quedius, Atheta* and *Choleva* are the most often representatives and the majority of them may be classified as troglophiles. In the Domica cave *Trechus austriacus* and *Quedius mesomelinus* create rather dense populations. The genus *Duvalius* covers the only obligate cave beetles in our country. The species of the genus are endemics of the Western Carpathian mountain ranges preferably inhabiting the superficial underground environment (deeper parts of the stony debris), in caves they are rarer. Interestingly, two different species live together in the Jasovská

Staphylinid beetle Quedius mesomelinus*, Domica Cave. Photo: P. Ľuptáčik*

Troglobitic carabid beetle of the genus Duvalius*, Krásnohorská Cave. Photo: J. Stankovič*

Cave – *D. hungaricus* and *D. bokori*. **Dipteran flies** (Diptera), **butterflies** (Lepidoptera) and **caddisflies** (Trichoptera) represent an important part of the parietal fauna with seasonal emergence in caves (subtroglophiles). Of dipterans *Triphleba antricola* is a stable cave dweller of the Jasovská Cave associated with the bat guano accumulations. The butterflies *Scoliopteryx libathrix* and *Triphosa dubitata* are part of the typical fauna of the entrance communities, being numerous especially during the winter.

Butterfly Scoliopteryx libatrix, *inhabitant of the cave entrances. Photo: P. Ľuptáčik*

Amphibians (Amphibia) are regular guests of the Domica Cave - salamanders and frogs passively flooded inside the cave during heavier rains. The alarmingly coloured *Salamandra salamandra* hibernates in numerous aggregations in the entrance passage of the Gombasecká Cave. Of mammals (Mammalia) small forms of rodents, dormice, weasels and martens are regular guests of the caves with an unusual sense for orientation in complete darkness. The martens are important predators of bats in caves. Bats are the best known and most popular cave mammals. From ancient times people regarded them as an inseparable part of caves. In conditions with little knowledge there were a lot of legends and reports about them. Nowadays we know that bats look for caves as one of the possible shelters during their resting period, either during the day in the warm months, or in the winter season during ***hibernation*** (winter resting stage). They are one of the few groups of warm-blood animals that stay during the winter in a stage of true winter sleep in which blood circulation and respiration are several times slower and body temperature drops to 10 - 1 °C. Bats usually fall into winter rest in November as do butterflies and beetles, their main food source. In caves they are rather protected against their natural enemies (martens, weasels, owls). Bats usually catch insects during flight. Orientation in the dark spaces is enabled by ***echolocation***, namely the type of orientation based on the reflection of supersound waves that are emitted in regular intervals and are subsequently received. Thus the bats are able to distinguish barriers or prey during flight in the darkness. Species of the family Rhinolophidae emit signals by nose, those of the family Vespertilionidae, on the other hand, by mouth. The reflected signals are received by the ears. The sounds are situated, depending on the particular species, within the extent of 15 - 115 kHz, so they can only partly be heard by the human ear. Echolocation signals emitted by bats are usually adapted to flight conditions and space structures that considerably impede their identification using "BAT" detectors - devices enabling analysis of the bat sounds.

Danube crested newt - Triturus dobrogicus, *Domica Cave. Photo: P. Ľuptáčik*

Common frog - Rana temporaria, *Domica Cave. Photo: P. Ľuptáčik*

Long-legged bat tick - Ixodes vespertilionis *(male), external parasite of bats. Photo: P. Ľuptáčik*

Guano pile in the Domica Cave. Photo: A. Nováková

Autumn colony of the greater horseshoe bat – Rhinolophus ferrumequinum. Photo: P. Ľuptáčik

Greater horseshoe bat in detail. Photo: P. Ľuptáčik

Considering the cave animals it is impossible to omit the surface parasites of bats that are sucking their blood – ticks, bugs, fleas and tiny wingless flies of the family Nycteribidae. Surface mammal species are the other hosts of these parasites. Bat tick *Ixodes vespertilionis* is the exception since it is unable to live outside the caves so that it is an obligate parasite of bats. Similarly to other cave animals it has strikingly elongated legs.

The Domica Cave is well-known for its bat colonies. In the cave we may observe larger guano piles and guano pots – smaller spheroidal cavities evolving on the sinters as a result of the action of acidic bat excrements. In the Domica cave system 16 bat species were registered. The most important is the Mediterranean horseshoe bat *Rhinolophus euryale* populating the cave during the whole year and establishing large colonies of up to 2,000 individuals. The cave is one of the northern-most distribution sites of this bat species in Europe. In the neighbouring Čertova diera Cave, part of the Domica system, the southern bent-wing bat *Miniopterus schreibersii* was very abundant in the past. It is typical of this species that in more extensive karst areas it inhabits only a few caves with favourable ambient conditions. It is an extraordinary social species living in colonies during the whole year round. In the above-mentioned cave it created colonies with 300 – 9,000 individuals. Thick guano deposits are the traces of their activity in the cave. However, since 1989 hibernation of this species have not been detected, the possible consequence of installation of an unsuitable gate on the cave entrance in the preceding years. The Jasovská Cave hosts a high number of bat species. It serves as the most important hibernation place for the greater horseshoe bat *Rhinolophus ferrumequinum* in Slovakia with 250 individuals. The Dobšinská Ice Cave represents one of the most important hibernation sites of the prevailingly cold adapted forest species *Myotis myotis* and *M. brandtii* in Central Europe with 422 individuals counted in 1999. In glaciated parts of the cave a population of the northern bat *Eptesicus nillsoni* dominates.

BASIC METHODS OF CAVE FAUNA RESEARCH

Cave invertebrates are most often collected directly by visual searching using pincers, brush or ***exhaustor***, the device by which we are able to suck smaller individuals into a vessel with fixation liquid. Baits (pieces of meat, cheese, fruits), usually deposited on the place for longer time, are used to attract fauna. The majority of smaller animals are

Collection of terrestrial invertebrates, Domica Cave. Photo: P. Ľuptáčik

Collection of aquatic fauna, Dobšinská Ice Cave. Photo: P. Ľuptáčik

fixed and transported in vials with ethyl-alcohol or formaldehyde, beetles in vessels with wood shavings saturated by ethylene acetate. Pitfall trapping is another collecting method – a plastic vessel with fixation liquid is dug into the softer cave sediment (loam, smaller stony debris) so that the sediment is levelled with the vessel upper margin. For collecting of tiny animal forms dwelling in bat guano or rotten wood a ***photo-eclector*** apparatus is used. The device consists of the mesh on which study material is deposited. The mesh is put over a funnel fixed into a stand, a vessel with conservation liquid is situated under the funnel. With progressive drying of the substrate the fauna tries to escape by moving down towards the mesh and falling through it into the vessel where it is subsequently fixed.

Aquatic invertebrates are collected with tweezers. Smaller forms may be collected by filtering of water through the planktonic net. The device consists of soft silk cloth put on a circular frame with a handle. The net progressively narrows down into the neck of a small plastic vial. In the vadose zone the water is filtered with such a net from water pools and percolating water. In larger lakes and underground streams the planktonic net is used in the same way as in the catching of water fauna in above-ground habitats. In such micro-habitats the density of the fauna is rather low, so collecting with the net has to be done repeatedly in different hydrological conditions during the year. It is also necessary to watch the surface of cave bottoms and walls for the aquatic fauna. Baits are used for attraction and subsequent collection of the water fauna. During collecting we should keep in mind the ethical side of the investigations and the aspect of the fauna conservation. Thus, it is highly desirable to modify methods to prevent remarkable losses in the fauna populations and to prevent disturbance of the existing equilibrium between particular components of the subterranean system.

Occasional collecting of invertebrates in a cave cannot in fact seriously threaten the subterranean communities since the cave is only a window into an immense system of crevices in the limestone bedrock. Thus, the organisms found in the cave represent just a minute fraction of what really lives in the whole karst massif. Massive death of the cave fauna may be caused by natural disturbances. For example, during heavy rains thousands of animals are flooded out of the caves where they die in the surface waters.

Explorations of bats are carried out by three basic methods. The first one is the direct counting. However this method is difficult to use in bat species or particular individuals preferring inaccessible or hardly accessible spaces or crevices for resting. The further method is identification of species using "BAT" detectors based on the characteristic supersound signals of the particular species. Marginally, as the additional method, collecting into the nets is sometimes used. The method is, however, less suitable since it can stress the bats and may apparently influence the behaviour of the investigated bat colony in the cave.

CONSERVATION OF THE CAVE BIOTA

The distribution of the subterranean organisms is in fact not limited to caves, it also covers epikarst (the system of crevices in disconnected rock under surface soil layers), submerged spaces in the phreatic zone, as well as micro-spaces between particles of softer sediments of the subterranean running waters (interstitial micro-habitats). Since the resources of the subterranean system originate on the surface from the production of the plants and animals, the conservation should also cover surface habitats directly connected with the cave systems.

Conservation of the cave biota results mainly from the fact that many species of organisms are "living fossils". They disappeared from the surface waters and terrestrial habitats millions years ago surviving in caves, underground waters and other types of subterranean habitats thus protected against the harsh weather outside. The other reason for the protection is the uniqueness, rarity and increased vulnerability of the cavernicolous fauna, especially endemic forms and troglobites. The following species deserve special protection in our caves: palpigrade *Eukoenenia spelaea*, pseudoscorpion *Neobisium slovacum*, millipede of the genus *Typhloiulus* and collembolans *Pseudosinella aggtelekiensis*, *P. paclti*, *Arrhopalites aggtelekiensis* and *A. intermedius* since they represent unique forms with very limited distribution. The vulnerability of these animals results from their low ecological flexibility and small distribution ranges. Thus, they are threatened even by local change of the ecological conditions or by pollution of the environment.

Direct destruction of the cave environment in limestone quarries is the most serious danger for the subterranean organisms. In this way, the locality of the first discovery of the subterranean carabid beetle *Duvalius bokori* (Leontína Cave near Gombasek) almost totally disappeared. Chemical pollution is the most drastic for the water fauna since water represents a medium of fast transport for pollution agents. These are mainly pesticides applied in agriculture, pollution by petrol substances during accidents on water-courses and pollution of waters by heavy metals or aggressive coloration substances used during investigations of the hydrology of the underground waters. Similarly, negative effects are observed when spent carbide or batteries are deposited in caves. Excessive organic substances originating in the cattle farming or in the rinse of chemicals during winter salting of roads may threaten water biota of the subterranean habitats. Construction of dams in the watershed causes changes in the profile of the river flows and in the accumulation of sediments. Interstitial micro-environments with unique fauna may be completely destroyed by fine clay particles originating in dams since they fill up minute spaces between sand and gravel particles. Populations of cave invertebrates may be threatened by intensive collection using pitfall traps, especially if they are left in the cave for longer periods.

Drop in populations of particular bat species is caused especially by disturbance during hibernation and nursing of the young, local vandalism, loss of habitat by closing of caves and mines or by change of the cave microclimate by the opening of new entrances. Change of the landscape surface with decrease of plant diversity and subsequent decrease of insects that serve as the food basis has negative effects upon bat populations. Moreover, bats may be threatened directly by excessive collecting for scientific purposes.

Several international Conventions can be applied to subterranean species and habitats, for example, the Rio Convention (13 June, 1992) for biodiversity protection. In Europe the Bonn Convention (23 June, 1979) for the conservation of wild migratory species is relevant to troglophilous bats. Law no. 543/2002 of the National Council of the Slovak Republic on the conservation of nature and the landscape also applies to all cave animals. Based on this law it is forbidden to interrupt protected animals in their natural development, especially to kill, injure, catch or move them. Moreover, it is forbidden to destroy and to harm their biotopes and dwellings. Many forms of the cave fauna are directly included in the list of protected animals. However, we should realize that ordering of the given species on the list of the protected fauna does not have much importance if we are not able to guarantee protection of the particular area, the whole system with its components which is populated by this fauna and on which it is essentially dependent.

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Editors: **Doc. RNDr. Jozef Jakál, DrSc.**
RNDr. Pavel Bella, PhD.

Authors: **RNDr. Pavel Bella, PhD.** – Slovak Caves Administration, Liptovský Mikuláš
RNDr. Ľudovít Gaál – Slovak Caves Administration, Liptovský Mikuláš
Mgr. Dagmar Haviarová – Slovak Caves Administration, Liptovský Mikuláš
Ing. Jozef Hlaváč – Slovak Caves Administration, Liptovský Mikuláš
Doc. RNDr. Jozef Jakál, DrSc. – Geographical Institute of SAS, Bratislava
Doc. RNDr. Ľubomír Kováč, CSc. – Faculty of Natural Sciences, P. J. Šafárik University, Košice
Ing. Marcel Lalkovič, CSc. – Faculty of Natural Sciences, M. Bel University, Banská Štiavnica
PhDr. Marián Soják, PhD. – Archeological Institute of SAS, Spišská Nová Ves
RNDr. Ján Zelinka – Slovak Caves Administration, Liptovský Mikuláš

Reviewers: RNDr. Václav Cílek, CSc., Prof. PhDr. Václav Furmánek, DrSc.,
Doc. RNDr. Zdenko Hochmuth, CSc., RNDr. Vladimír Košel, CSc.,
Doc. RNDr. Milan Lapin, CSc., RNDr. Ladislav Novotný, Ing. Mikuláš Rozložník

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Redaction: Mgr. Bohuslav Kortman
Translation: Ing. Peter Gažík, Doc. RNDr. Ľubomír Kováč, CSc.
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